

The Official Radare2 Book
1st Edition

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R2 "Book"

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Welcome to the Radare2 Book

- Github: <https://github.com/radare/radare2book>
- Gitbook: <https://www.gitbook.com/book/radare/radare2book/details>
- Online: <http://radare.gitbooks.io/radare2book/content/>
- PDF: <https://www.gitbook.com/download/pdf/book/radare/radare2book>
- Epub: <https://www.gitbook.com/download/epub/book/radare/radare2book>
- Mobi: <https://www.gitbook.com/download/mobi/book/radare/radare2book>

History

In 2006, Sergi Alvarez (aka pancake), was working as a forensic analyst. And, by license he wasn't allowed to use that private software for his personal needs, so he decided to write a small tool, an hexadecimal editor with very basic functionalities:

- be extremely portable (command line, c, small)
- open disk devices, this is using 64bit offsets
- search for a string or hexpair
- review and dump the results to disk

It was designed to recover a deleted file from an HFS+ partition.

After that, pancake decided to extend the tool to have a pluggable io to be able to attach to processes, implemented the debugger functionalities, support for multiple archs and code analysis.

The project has evolved to provide a complete framework for analyzing binaries while making use of basic UNIX concepts. Those concepts include the famous "everything is a file", "small programs that interact using stdin/stdout", and "keep it simple" paradigms.

But then the need for scripting showed up the fragility of the initial monolithic design of the tool. Making it hard to use the api. A refactoring was needed, in 2009, radare was forked into radare2, a complete refactor of radare1, in a more flexible and dynamic way, enabling a much better integration for using r2 from different programming languages.

It's been a one man project, with some eventual contributions, to a big community project around 2014. The number of users was growing fast, and the author, and main developer had to switch the role from coder to manager, in order to manage the different developers that join the project.

Instructing the users to report their issues allows us to define the new directions of the project in order to evolve. Everything is managed in the [radare2 GitHub](#) and discussed in the Telegram channel.

The project remains active at the moment of writing this book, and there are several side projects that provide a graphical user interface (Cutter), a decompiler (r2dec, radeco), Frida integration (r2frida), Yara, Unicorn, Keystone, and many other projects indexed in the r2pm (the radare2 package manager).

Overview

The Radare2 project is a set of small command-line utilities that can be used together or independently.

radare2

The core of the hexadecimal editor and debugger. radare2 allows you to open a number of input/output sources as if they were simple, plain files, including disks, network connections, kernel drivers, processes under debugging, and so on.

It implements an advanced command line interface for moving around a file, analyzing data, disassembling, binary patching, data comparison, searching, replacing, visualizing. It can be scripted with a variety of languages, including Python, Ruby, JavaScript, Lua, Perl.

rabin2

A program to extract information from executable binaries, such as ELF, PE, Java CLASS, Mach-O, plus any format supported by r2 plugins. rabin2 is used by the core to get data like exported symbols, imports, file information, cross references (xrefs), library dependencies, sections.

rasm2

A command line assembler and disassembler for multiple architectures (including Intel x86 and x86-64, MIPS, ARM, PowerPC, Java, and myriad of others).

Examples

```
$ rasm2 -a java 'nop'  
00
```

```
$ rasm2 -a x86 -d '90'  
nop
```

```
$ rasm2 -a x86 -b 32 'mov eax, 33'  
b821000000
```

```
$ echo 'push eax;nop;nop' | rasm2 -f -
509090
```

rahash2

An implementation of a block-based hash tool. From small text strings to large disks, rahash2 supports multiple algorithms, including MD4, MD5, CRC16, CRC32, SHA1, SHA256, and others. rahash2 can be used to check the integrity or track changes of big files, memory dumps, or disks.

Examples

```
$ rahash2 file
file: 0x00000000-0x00000007 sha256: 887cfbd0d44aaff69f7bdbedbd282ec96191cce9d7fa73362
98a18efc3c7a5a
```

```
$ rahash2 file -a md5
file: 0x00000000-0x00000007 md5: d1833805515fc34b46c2b9de553f599d
```

radiff2

A binary differencing utility that implements multiple algorithms. It supports byte-level or delta differencing for binary files, and code-analysis differencing to find changes in basic code blocks obtained from the radare code analysis.

rafind2

A program to find byte patterns in files.

ragg2

A frontend for r_egg. ragg2 compiles programs written in a simple high-level language into tiny binaries for x86, x86-64, and ARM.

Examples

```
$ cat hi.r
/* hello world in r_egg */
write@syscall(4); //x64 write@syscall(1);
exit@syscall(1); //x64 exit@syscall(60);

main@global(128) {
    .var0 = "hi!\n";
    write(1,.var0, 4);
    exit(0);
}
$ ragg2 -O -F hi.r
$ ./hi
hi!

$ cat hi.c
main@global(0,6) {
    write(1, "Hello0", 6);
    exit(0);
}
$ ragg2 hi.c
$ ./hi.c.bin
Hello
```

rarun2

A launcher for running programs within different environments, with different arguments, permissions, directories, and overridden default file descriptors. rarun2 is useful for:

- Crackmes
- Fuzzing
- Test suites

Sample rarun2 script

```
$ cat foo.rr2
#!/usr/bin/rarun2
program=./pp400
arg0=10
stdin=foo.txt
chdir=/tmp
#chroot=.
./foo.rr2
```

Connecting a Program to a Socket

```
$ nc -l 9999  
$ rарun2 program=/bin/ls connect=localhost:9999
```

Debugging a Program by Redirecting IO to Another Terminal

1 - open a new terminal and type 'tty' to get a terminal name:

```
$ tty ; clear ; sleep 9999999  
/dev/ttys010
```

2 - Create a new file containing the following rарun2 profile named foo.rr2:

```
#!/usr/bin/rарun2  
program=/bin/ls  
stdio=/dev/ttys010
```

3 - Launch the following radare2 command: r2 -r foo.rr2 -d /bin/ls

rax2

A minimalistic mathematical expression evaluator for the shell that is useful for making base conversions between floating point values, hexadecimal representations, hexpair strings to ASCII, octal to integer, and more. It also supports endianness settings and can be used as an interactive shell if no arguments are given.

Examples

```
$ rax2 1337  
0x539  
  
$ rax2 0x400000  
4194304  
  
$ rax2 -b 01111001  
y  
  
$ rax2 -S radare2  
72616461726532  
  
$ rax2 -s 617765736f6d65  
awesome
```


Getting radare2

You can get radare from the website, <http://radare.org>, or the GitHub repository, <https://github.com/radare/radare2>.

Binary packages are available for a number of operating systems (Ubuntu, Maemo, Gentoo, Windows, iPhone, and so on). Yet, you are highly encouraged to get the source and compile it yourself to better understand the dependencies, to make examples more accessible and of course to have the most recent version.

A new stable release is typically published every month. Nightly tarballs are sometimes available at <http://bin.rada.re/>.

The radare development repository is often more stable than the 'stable' releases. To obtain the latest version:

```
$ git clone https://github.com/radare/radare2.git
```

This will probably take a while, so take a coffee break and continue reading this book.

To update your local copy of the repository, use `git pull` anywhere in the radare2 source code tree:

```
$ git pull
```

If you have local modifications of the source, you can revert them (and lose them!) with:

```
$ git reset --hard HEAD
```

Or send me a patch:

```
$ git diff > radare-foo.patch
```

The most common way to get r2 updated and installed system wide is by using:

```
$ sys/install.sh
```

Build with meson + ninja

There is also a work-in-progress support for Meson.

Using clang and ld.gold makes the build faster:

```
CC=clang LDFLAGS=-fuse-ld=gold meson . release --buildtype=release --prefix ~/.local/stow/radare2/release  
ninja -C release  
# ninja -C release install
```

Helper Scripts

Take a look at the `sys/*` scripts, those are used to automate stuff related to syncing, building and installing r2 and its bindings.

The most important one is `sys/install.sh`. It will pull, clean, build and symstall r2 system wide.

Symstalling is the process of installing all the programs, libraries, documentation and data files using symlinks instead of copying the files.

By default it will be installed in `/usr`, but you can define a new prefix as argument.

This is useful for developers, because it permits them to just run 'make' and try changes without having to run make install again.

Cleaning Up

Cleaning up the source tree is important to avoid problems like linking to old objects files or not updating objects after an ABI change.

The following commands may help you to get your git clone up to date:

```
$ git clean -xdf  
$ git reset --hard @~10  
$ git pull
```

If you want to remove previous installations from your system, you must run the following commands:

```
$ ./configure --prefix=/usr/local  
$ make purge
```

Compilation and Portability

Currently the core of radare2 can be compiled on many systems and architectures, but the main development is done on GNU/Linux with GCC, and on MacOS X with clang. Radare is also known to compile on many different systems and architectures (including TCC and SunStudio).

People often want to use radare as a debugger for reverse engineering. Currently, the debugger layer can be used on Windows, GNU/Linux (Intel x86 and x86_64, MIPS, and ARM), OS X, FreeBSD, NetBSD, and OpenBSD (Intel x86 and x86_64)..

Compared to core, the debugger feature is more restrictive portability-wise. If the debugger has not been ported to your favorite platform, you can disable the debugger layer with the `--without-debugger` `configure` script option when compiling radare2.

Note that there are I/O plugins that use GDB, GDB, WinDbg, or Wine as back-ends, and therefore rely on presence of corresponding third-party tools (in case of remote debugging - just on the target machine).

To build on a system using `acn` and `GNU Make` (e.g. on *BSD systems):

```
$ ./configure --prefix=/usr  
$ gmake  
$ sudo gmake install
```

There is also a simple script to do this automatically:

```
$ sys/install.sh
```

Static Build

You can build radare2 statically along with all other tools with the command:

```
$ sys/static.sh
```

Docker

Radare2 repository ships a [Dockerfile](#) that you can use with Docker.

This dockerfile is also used by Remnux distribution from SANS, and is available on the docker [registryhub](#).

Cleaning Up Old Radare2 Installations

```
./configure --prefix=/old/r2/prefix/installation  
make purge
```

Compilation on Windows

Meson (MSVC)

The most native way to compile radare2 under Windows is to use msvc with meson. Before compiling, note that we also provide binaries available [here](#) or [here](#).

Prerequisites

First you need **python3** to be installed on your computer. Once this is done, you can install the meson build system using `pip3 install meson` (with Administrator privileges). Now navigate to your Python installation folder, and copy the `meson.py` from `.\Scripts` subfolder into your radare2 folder.

Meson also requires Ninja. You can download it from [here](#). Copy `ninja.exe` binary into your radare2 folder.

Compiling

To build r2 with meson, you have to follow the traditional meson way which consists in the following commands:

```
meson build  
ninja -C build
```

Alternatively you can use the `meson.py` script, but it is going to be deprecated.

```
python sys\meson.py
```

You can also generate a visual studio project:

```
python sys\meson.py --backend=vs2017 --project
```

Installing

Now that you successfully compiled radare2, you might want to gather every executables and requirements into the same place. The command below will collect everything and put it into the `dist` folder.

```
python sys\meson.py --install dist
```

You can now test your newly crafted radare2 binary easily:

```
E:\radare2>cd dist  
E:\radare2\dist>radare2.exe -v
```

Mingw32 (deprecated)

The easy way to compile things for Windows is using Mingw32. The w32 builds distributed from the radare homepage are generated from a GNU/Linux box using Mingw32 and they are tested with Wine. Also keep in mind, that Mingw-w64 isn't tested, so no guarantees here.

Be sure to setup your Mingw32 to compile with **thread model: win32**, not **posix**, and target should be **mingw32**. Before the starting of compilation you need to setup git first, for a proper automatic fetching of capstone:

```
git config --global core.autocrlf true  
git config --global core.filemode false
```

The following is an example of compiling with MinGW32 (you need to have installed **zip** for Windows):

```
CC=i486-mingw32-gcc ./configure  
make  
make w32dist  
zip -r w32-build.zip w32-build
```

This generates a native, 32-bit console application for Windows. The 'i486-mingw32-gcc' compiler is the one I have in my box, you will probably need to change this.

To simplify the building under Windows/Mingw32 there is a script in radare2 sources: `sys\mingw32.bat`. Simply run it from the cmd.exe (or ConEmu/cmd.exe). It assumes that you have Mingw32 installed in `C:\Mingw` and Git in `C:\Program Files (x86)\Git`. If you want to use another installations, just set `MINGW_PATH` and `GIT_PATH` variables correspondingly:

```
set MINGW_PATH=D:\Mingw32  
set "GIT_PATH=E:\Program and Stuff\Git"  
sys\mingw32.bat
```

Please, note, that this script should be run from radare2 directory.

There is a script that automates process of detecting the crosscompiler toolchain configuration, and builds a zip file containing r2 programs and libraries that can be deployed on Windows or Wine:

```
sys/mingw32.sh
```

Cygwin (deprecated)

Cygwin is another possibility; however, issues related to Cygwin libraries can make debugging difficult. But using binary compiled for Cygwin will allow you to use Unicode in the Windows console, and to have 16 million colors.

Note, Cygwin build require exactly the opposite git configuration, so setup git first, for a proper automatic fetching of capstone:

```
git config --global core.autocrlf false
```

Please, be sure to build radare2 from the same environment you're going to use r2 in. If you are going to use r2 in MinGW32 shell or cmd.exe — you should build r2 in the MinGW32 environment. And if you are going to use r2 in Cygwin — you have to build r2 from the Cygwin shell. Since Cygwin is more UNIX-compatible than MinGW, the radare2 supports more colors and Unicode symbols if build using the former one.

Mingw-W64 (deprecated)

- Download the MSYS2 distribution from the official site: <http://msys2.github.io/>
- Setup the proxy (if needed):

```
export http_proxy=<user>:<pass>@zz-wwwproxy-90-v:8080
export https_proxy=$http_proxy
export ftp_proxy=$http_proxy
export rsync_proxy=$http_proxy
export rsync_proxy=$http_proxy
export no_proxy="localhost,127.0.0.1,localaddress"
```

- Update packages:

```
pacman --needed -Sy bash pacman pacman-mirrors msys2-runtime mingw-w64-x86_64-toolchai
```

- Close MSYS2, run it again from Start menu and update the rest with

```
pacman -Su
```

- Install the building essentials:

```
pacman -S git make zip gcc patch
```

- Compile the radare2:

```
./configure --with-ostype=windows ; make ; make w32dist
```

Bindings

To build radare2 bindings, you will need to install [Vala \(valac\)](#) for Windows

Then download [valabind](#) and build it:

```
git clone https://github.com/radare/valabind
cd valabind
make
make install
```

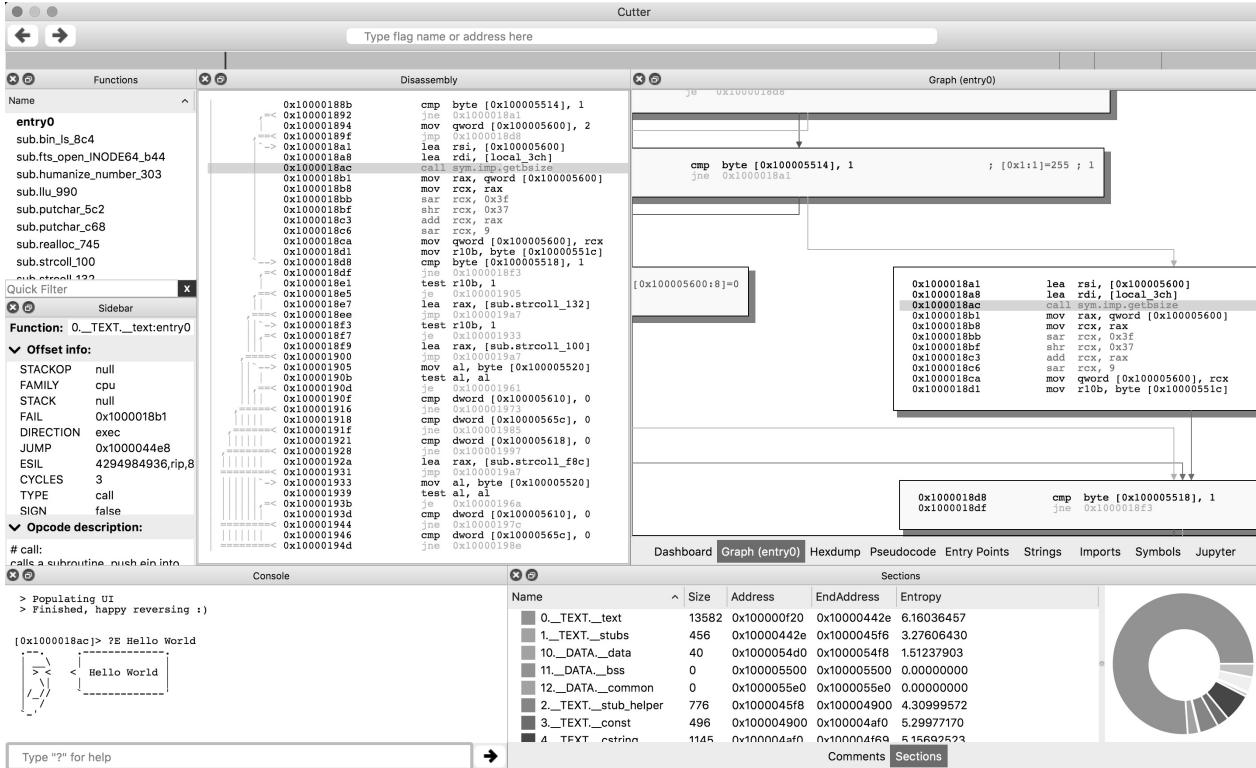
After you installed valabind, you can build radare2-bindings, for example for Python and Perl:

```
git clone https://github.com/radare/radare2-bindings
cd radare2-bindings
./configure --enable=python,perl
make
make install
```

User Interfaces

Radare2 has seen many different user interfaces being developed over the years.

The main and official Graphical User Interface (GUI) for radare2 is called [Cutter](#).



Basic Radare2 Usage

The learning curve is usually somewhat steep at the beginning. Although after an hour of using it you should easily understand how most things work, and how to combine various tools radare offers. You are encouraged to read the rest of this book to understand how some non-trivial things work, and to ultimately improve your skills.

Navigation, inspection and modification of a loaded binary file is performed using three simple actions: seek (to position), print (buffer), and alternate (write, append).

The 'seek' command is abbreviated as `s` and accepts an expression as its argument. The expression can be something like `10`, `+0x25`, or `[0x100+ptr_table]`. If you are working with block-based files, you may prefer to set the block size to a required value with `b` command, and seek forward or backwards with positions aligned to it. Use `s++` and `s--` commands to navigate this way.

If radare2 opens an executable file, by default it will open the file in VA mode and the sections will be mapped to their virtual addresses. In VA mode, seeking is based on the virtual address and the starting position is set to the entry point of the executable. Using `-n` option you can suppress this default behavior and ask radare2 to open the file in non-VA mode for you. In non-VA mode, seeking is based on the offset from the beginning of the file.

The 'print' command is abbreviated as `p` and has a number of submodes — the second letter specifying a desired print mode. Frequent variants include `px` to print in hexadecimal, and `pd` for disassembling.

To be allowed to write files, specify the `-w` option to radare2 when opening a file. The `w` command can be used to write strings, hexpairs (`x` subcommand), or even assembly opcodes (`a` subcommand). Examples:

```
> w hello world      ; string
> wx 90 90 90 90    ; hexpairs
> wa jmp 0x8048140   ; assemble
> wf inline.bin      ; write contents of file
```

Appending a `?` to a command will show its help message, for example, `p? ?`. Appending `*` will show commands starting with the given string, e.g. `p?*`.

To enter visual mode, press `v<enter>`. Use `q` to quit visual mode and return to the prompt.

In visual mode you can use HJKL keys to navigate (left, down, up, and right, respectively). You can use these keys in cursor mode toggled by `c` key. To select a byte range in cursor mode, hold down `SHIFT` key, and press navigation keys HJKL to mark your selection.

While in visual mode, you can also overwrite bytes by pressing `i`. You can press `TAB` to switch between the hex (middle) and string (right) columns. Pressing `q` inside the hex panel returns you to visual mode. By pressing `p` or `P` you can scroll different visual mode representations. There is a second most important visual mode - curses-like panels interface, accessible with `v!` command.

Command-line Options

The radare core accepts many flags from command line.

An excerpt from usage help message:

```
$ radare2 -h
Usage: r2 [-ACdfLMnNqStuvwzX] [-P patch] [-p prj] [-a arch] [-b bits] [-i file]
          [-s addr] [-B baddr] [-m maddr] [-c cmd] [-e k=v] file|pid|-|--|=

--           run radare2 without opening any file
-           same as 'r2 malloc://512'
=           read file from stdin (use -i and -c to run cmds)
-=          perform !=! command to run all commands remotely
-0          print \x00 after init and every command
-2          close stderr file descriptor (silent warning messages)
-a [arch]    set asm.arch
-A          run 'aaa' command to analyze all referenced code
-b [bits]    set asm.bits
-B [baddr]   set base address for PIE binaries
-c 'cmd...' execute radare command
-C          file is host:port (alias for -c+=http://%s/cmd/)
-d          debug the executable 'file' or running process 'pid'
-D [backend] enable debug mode (e cfg.debug=true)
-e k=v      evaluate config var
-f          block size = file size
-F [binplug] force to use that rbin plugin
-h, -hh     show help message, -hh for long
-H ([var])  display variable
-i [file]   run script file
-I [file]   run script file before the file is opened
-k [OS/kern] set asm.os (linux, macos, w32, netbsd, ...)
-l [lib]    load plugin file
-L          list supported IO plugins
-m [addr]   map file at given address (loadaddr)
-M          do not demangle symbol names
-n, -nn    do not load RBin info (-nn only load bin structures)
-N          do not load user settings and scripts
-q          quiet mode (no prompt) and quit after -i
-Q          quiet mode (no prompt) and quit faster (quickLeak=true)
-p [prj]    use project, list if no arg, load if no file
-P [file]   apply rapatch file and quit
-r [rarun2] specify rarun2 profile to load (same as -e dbg.profile=x)
-R [rr2rule] specify custom rarun2 directive
-s [addr]   initial seek
-S          start r2 in sandbox mode
-t          load rabin2 info in thread
-u          set bin.filter=false to get raw sym/sec/cls names
-v, -V     show radare2 version (-V show lib versions)
-w          open file in write mode
-x          open without exec-flag (asm.emu will not work), See io.exec
-X          same as -e bin.usestr=false (useful for dyldcache)
-z, -zz    do not load strings or load them even in raw
```

Common usage patterns

Open a file in write mode without parsing the file format headers.

```
$ r2 -nw file
```

Quickly get into an r2 shell without opening any file.

```
$ r2 -
```

Specify which sub-binary you want to select when opening a fatbin file:

```
$ r2 -a ppc -b 32 ls.fat
```

Run a script before showing interactive command-line prompt:

```
$ r2 -i patch.r2 target.bin
```

Execute a command and quit without entering the interactive mode:

```
$ r2 -qc ij hi.bin > imports.json
```

Set the configuration variable:

```
$ r2 -e scr.color=false blah.bin
```

Debug a program:

```
$ r2 -d ls
```

Use an existing project file:

```
$ r2 -p test
```

Command Format

A general format for radare2 commands is as follows:

```
[ . ][times][cmd][~grep][[@[@iter]addr!size][|>pipe] ;
```

People who use Vim daily and are familiar with its commands will find themselves at home. You will see this format used throughout the book. Commands are identified by a single case-sensitive character [a-zA-Z].

To repeatedly execute a command, prefix the command with a number:

```
px      # run px  
3px    # run px 3 times
```

The `!` prefix is used to execute a command in shell context. If you want to use the cmd callback from the I/O plugin you must prefix with `=!`.

Note that a single exclamation mark will run the command and print the output through the RCons API. This means that the execution will be blocking and not interactive. Use double exclamation marks -- `!!` -- to run a standard system call.

All the socket, filesystem and execution APIs can be restricted with the `cfg.sandbox` configuration variable.

A few examples:

```
ds                      ; call the debugger's 'step' command  
px 200 @ esp           ; show 200 hex bytes at esp  
pc > file.c            ; dump buffer as a C byte array to file.c  
wx 90 @@ sym.*          ; write a nop on every symbol  
pd 2000 | grep eax     ; grep opcodes that use the 'eax' register  
px 20 ; pd 3 ; px 40    ; multiple commands in a single line
```

The standard UNIX pipe `|` is also available in the radare2 shell. You can use it to filter the output of an r2 command with any shell program that reads from stdin, such as `grep`, `less`, `wc`. If you do not want to spawn anything, or you can't, or the target system does not have the basic UNIX tools you need (Windows or embedded users), you can also use the built-in grep (`~`).

See `?~?` for help.

The `~` character enables internal grep-like function used to filter output of any command:

```
pd 20~call ; disassemble 20 instructions and grep output for 'call'
```

Additionally, you can grep either for columns or for rows:

```
pd 20~call:0 ; get first row  
pd 20~call:1 ; get second row  
pd 20~call[0] ; get first column  
pd 20~call[1] ; get second column
```

Or even combine them:

```
pd 20~call:0[0] ; grep the first column of the first row matching 'call'
```

This internal grep function is a key feature for scripting radare2, because it can be used to iterate over a list of offsets or data generated by disassembler, ranges, or any other command. Refer to the [loops](#) section (iterators) for more information.

The `@` character is used to specify a temporary offset at which the command to its left will be executed. The original seek position in a file is then restored.

For example, `pd 5 @ 0x100000fce` to disassemble 5 instructions at address 0x100000fce.

Most of the commands offer autocomplete support using `<TAB>` key, for example `s eek` or `f lags` commands. It offers autocomplete using all possible values, taking flag names in this case. Note that it is possible to see the history of the commands using the `!~...` command - it offers a visual mode to scroll through the radare2 command history.

To extend the autocomplete support to handle more commands or enable autocomplete to your own commands defined in core, I/O plugins you must use the `!!!` command.

Expressions

Expressions are mathematical representations of 64-bit numerical values. They can be displayed in different formats, be compared or used with all commands accepting numeric arguments. Expressions can use traditional arithmetic operations, as well as binary and boolean ones. To evaluate mathematical expressions prepend them with command `? :`

Supported arithmetic operations are:

- + : addition
 - - : subtraction
 - * : multiplication
 - / : division
 - % : modulus
 - > : shift right
 - < : shift left

[0x00000000]> ?vi 1+2+3
6

To use of logical OR should quote the whole command to avoid executing the | pipe:

```
[0x00000000]> "? 1 | 2"
hex      0x3
octal    03
unit     3
segment 0000:0003
int32   3
string   "\x03"
binary   0b000000011
fvalue: 2.0
float:  0.000000f
double: 0.000000
trits   0t10
```

Numbers can be displayed in several formats:

```
0x033  : hexadecimal can be displayed
3334   : decimal
sym.fo : resolve flag offset
10K    : KBytes 10*1024
10M    : MBytes 10*1024*1024
```

You can also use variables and seek positions to build complex expressions.

Use the `?$?` command to list all the available commands or read the refcard chapter of this book.

```
$$  here (the current virtual seek)
$1  opcode length
$s  file size
$j  jump address (e.g. jmp 0x10, jz 0x10 => 0x10)
$f  jump fail address (e.g. jz 0x10 => next instruction)
$m  opcode memory reference (e.g. mov eax,[0x10] => 0x10)
$b  block size
```

Some more examples:

```
[0x4A13B8C0]> ? $m + $1
140293837812900 0x7f98b45df4a4 03771426427372244 130658.0G 8b45d000:04a4 1402938378129
00 10100100 140293837812900.0 -0.000000
```

```
[0x4A13B8C0]> pd 1 @ +$1
0x4A13B8C2  call 0x4a13c000
```


Basic Debugger Session

To debug a program, start radare with the `-d` option. Note that you can attach to a running process by specifying its PID, or you can start a new program by specifying its name and parameters:

```
$ pidof mc
32220
$ r2 -d 32220
$ r2 -d /bin/ls
$ r2 -a arm -b 16 -d gdb://192.168.1.43:9090
...
```

In the second case, the debugger will fork and load the debuggee `ls` program in memory.

It will pause its execution early in `ld.so` dynamic linker. As a result, you will not yet see the entrypoint or any shared libraries at this point.

You can override this behavior by setting another name for an entry breakpoint. To do this, add a radare command `e dbg.bep=entry` or `e dbg.bep=main` to your startup script, usually it is `~/.config/radare2/radare2rc`.

Another way to continue until a specific address is by using the `dcu` command. Which means: "debug continue until" taking the address of the place to stop at. For example:

```
dcu main
```

Be warned that certain malware or other tricky programs can actually execute code before `main()` and thus you'll be unable to control them. (Like the program constructor or the tls initializers)

Below is a list of most common commands used with debugger:

```
> d?          ; get help on debugger commands
> ds 3        ; step 3 times
> db 0x8048920 ; setup a breakpoint
> db -0x8048920 ; remove a breakpoint
> dc          ; continue process execution
> dcs         ; continue until syscall
> dd          ; manipulate file descriptors
> dm          ; show process maps
> dmp A S rwx ; change permissions of page at A and size S
> dr eax=33    ; set register value. eax = 33
```

There is another option for debugging in radare, which may be easier: using visual mode.

That way you will neither need to remember many commands nor to keep program state in your mind.

To enter visual debugger mode use `vpp` :

```
[0xb7f0c8c0]> vpp
```

The initial view after entering visual mode is a hexdump view of current target program counter (e.g., EIP for x86). Pressing `p` will allow you to cycle through the rest of visual mode views. You can press `p` and `P` to rotate through the most commonly used print modes. Use F7 or `s` to step into and F8 or `S` to step over current instruction. With the `c` key you can toggle the cursor mode to mark a byte range selection (for example, to later overwrite them with `nop`). You can set breakpoints with `F2` key.

In visual mode you can enter regular radare commands by prepending them with `:`. For example, to dump a one block of memory contents at ESI:

```
<Press ':'>
x @ esi
```

To get help on visual mode, press `?`. To scroll help screen, use arrows. To exit help view, press `q`.

A frequently used command is `dr`, to read or write values of target's general purpose registers. For more compact registers value representation you might use `dr=` command. You can also manipulate the hardware and extended/floating point registers.

Contributing

Radare2 Book

If you want to contribute to the Radare2 book, you can do it at the [Github repository](#). Suggested contributions include:

- Crackme writeups
- CTF writeups
- Documentation on how to use Radare2
- Documentation on developing for Radare2
- Conference presentations/workshops using Radare2
- Missing content from the Radare1 book updated to Radare2

Please get permission to port any content you do not own/did not create before you put it in the Radare2 book.

See <https://github.com/radare/radare2/blob/master/DEVELOPERS.md> for general help on contributing to radare2.

Configuration

The core reads `~/.config/radare2/radare2rc` while starting. You can add `e` commands to this file to tune radare2 configuration to your taste.

To prevent radare2 from parsing this file at the start, pass it `-N` option.

All the configuration of radare2 is done with the `eval` commands. A typical startup configuration file looks like this:

```
$ cat ~/.radare2rc
e scr.color = true
e dbg.bep = loader
```

Configuration can also be changed with `-e` command-line option. This way you can adjust configuration from the command line, keeping the `.radare2rc` file intact. For example, to start with empty configuration and then adjust `scr.color` and `asm.syntax` the following line may be used:

```
$ radare2 -N -e scr.color=true -e asm.syntax=intel -d /bin/ls
```

Internally, the configuration is stored in a hash table. The variables are grouped in namespaces: `cfg.`, `file.`, `dbg.`, `scr.` and so on.

To get a list of all configuration variables just type `e` in the command line prompt. To limit output to a selected namespace, pass it with an ending dot to `e.`. For example, `e file.` will display all variables defined inside the "file" namespace.

To get help about `e` command type `e?`:

```
Usage: e[?] [var[=value]]
e?                  show this help
e?asm.bytes        show description
e??                 list config vars with description
e                  list config vars
e-                 reset config vars
e*                 dump config vars in r commands
e!a                invert the boolean value of 'a' var
er [key]            set config key as readonly. no way back
ec [k] [color]      set color for given key (prompt, offset, ...)
e a                get value of var 'a'
e a=b              set var 'a' the 'b' value
env [k=v]           get/set environment variable
```

A simpler alternative to `e` command is accessible from the visual mode. Type `ve` to enter it, use arrows (up, down, left, right) to navigate the configuration, and `q` to exit it. The start screen for the visual configuration edit looks like this:

```
[EvalSpace]

> anal
asm
scr
asm
bin
cfg
diff
dir
dbg
cmd
fs
hex
http
graph
hud
scr
search
io
```

For configuration values that can take one of several values, you can use the `=?` operator to get a list of valid values:

```
[0x00000000]> e scr.nkey = ?
scr.nkey = fun, hit, flag
```

Colors

Console access is wrapped in API that permits to show the output of any command as ANSI, W32 Console or HTML formats. This allows radare's core to run inside environments with limited displaying capabilities, like kernels or embedded devices. It is still possible to receive data from it in your favorite format.

To enable colors support by default, add a corresponding configuration option to the `.radare2` configuration file:

```
$ echo 'e scr.color=1' >> ~/.radare2rc
```

Note that enabling colors is not a boolean option. Instead, it is a number because there are different color depth levels. This is:

- 0: black and white
- 1: 16 basic ANSI colors
- 2: 256 scale colors
- 3: 24bit true color

The reason for having such user-defined options is because there's no standard or portable way for the terminal programs to query the console to determine the best configuration, same goes for charset encodings, so r2 allows you to choose that by hand.

Usually, serial consoles may work with 0 or 1, while xterms may support up to 3. RCons will try to find the closest color scheme for your theme when you choose a different them with the `eco` command.

It is possible to configure the color of almost any element of disassembly output. For *NIX terminals, r2 accepts color specification in RGB format. To change the console color palette use `ec` command.

Type `ec` to get a list of all currently used colors. Type `ecs` to show a color palette to pick colors from:

```
[0x00000000]> ecs
  black
  red
  white
  green
  magenta
  yellow
  cyan
  blue
  __ gray

Greyscale:
  rgb:000  rgb:111  rgb:222  rgb:333  rgb:444  rgb:555
  rgb:666  rgb:777  rgb:888  rgb:999  rgb:aaa  rgb:bbb
  rgb:ccc  rgb:ddd  rgb:eee  rgb:fff

RGB:
  rgb:000  rgb:030  rgb:060  rgb:090  rgb:0c0  rgb:0f0
  rgb:003  rgb:033  rgb:063  rgb:093  rgb:0c3  rgb:0f3
  rgb:006  rgb:036  rgb:066  rgb:096  rgb:0c6  rgb:0f6
  rgb:009  rgb:039  rgb:069  rgb:099  rgb:0c9  rgb:0f9
  rgb:00c  rgb:03c  rgb:06c  rgb:09c  rgb:0cc  rgb:0fc
  rgb:0ff  rgb:03f  rgb:06f  rgb:09f  rgb:0cf  rgb:0ff
  rgb:300  rgb:330  rgb:360  rgb:390  rgb:3c0  rgb:3f0
  rgb:303  rgb:333  rgb:363  rgb:393  rgb:3c3  rgb:3f3
  rgb:306  rgb:336  rgb:366  rgb:396  rgb:3c6  rgb:3f6
  rgb:309  rgb:339  rgb:369  rgb:399  rgb:3c9  rgb:3f9
  rgb:30c  rgb:33c  rgb:36c  rgb:39c  rgb:3cc  rgb:3fc
  rgb:30f  rgb:33f  rgb:36f  rgb:39f  rgb:3cf  rgb:3ff
  rgb:600  rgb:630  rgb:660  rgb:690  rgb:6c0  rgb:6f0
  rgb:603  rgb:633  rgb:663  rgb:693  rgb:6c3  rgb:6f3
  rgb:606  rgb:636  rgb:666  rgb:696  rgb:6c6  rgb:6f6
  rgb:609  rgb:639  rgb:669  rgb:699  rgb:6c9  rgb:6f9
  rgb:60c  rgb:63c  rgb:66c  rgb:69c  rgb:6cc  rgb:6fc
  rgb:60f  rgb:63f  rgb:66f  rgb:69f  rgb:6cf  rgb:6ff
  rgb:900  rgb:930  rgb:960  rgb:990  rgb:9c0  rgb:9f0
  rgb:903  rgb:933  rgb:963  rgb:993  rgb:9c3  rgb:9f3
  rgb:906  rgb:936  rgb:966  rgb:996  rgb:9c6  rgb:9f6
  rgb:909  rgb:939  rgb:969  rgb:999  rgb:9c9  rgb:9f9
  rgb:90c  rgb:93c  rgb:96c  rgb:99c  rgb:9cc  rgb:9fc
  rgb:90f  rgb:93f  rgb:96f  rgb:99f  rgb:9cf  rgb:9ff
  rgb:c00  rgb:c30  rgb:c60  rgb:c90  rgb:cc0  rgb:cf0
  rgb:c03  rgb:c33  rgb:c63  rgb:c93  rgb:cc3  rgb:cf3
  rgb:c06  rgb:c36  rgb:c66  rgb:c96  rgb:cc6  rgb:cf6
  rgb:c09  rgb:c39  rgb:c69  rgb:c99  rgb:cc9  rgb:cf9
  rgb:c0c  rgb:c3c  rgb:c6c  rgb:c9c  rgb:ccc  rgb:cfc
  rgb:c0f  rgb:c3f  rgb:c6f  rgb:c9f  rgb:ccf  rgb:cff
  rgb:f00  rgb:f30  rgb:f60  rgb:f90  rgb:fc0  rgb:ff0
  rgb:f03  rgb:f33  rgb:f63  rgb:f93  rgb:fc3  rgb:ff3
  rgb:f06  rgb:f36  rgb:f66  rgb:f96  rgb:fc6  rgb:ff6
  rgb:f09  rgb:f39  rgb:f69  rgb:f99  rgb:fc9  rgb:ff9
  rgb:f0c  rgb:f3c  rgb:f6c  rgb:f9c  rgb:fcc  rgb:ffc
  rgb:f0f  rgb:f3f  rgb:f6f  rgb:f9f  rgb:fcf  rgb:fff

[0x00000000]>
```

Themes

You can create your own color theme, but radare2 have its own predefined ones. Use the `eco` command to list or select them.

In visual mode use the `R` key to randomize colors or choose the next theme in the list.

Configuration Variables

Below is a list of the most frequently used configuration variables. You can get a complete list by issuing `e` command without arguments. For example, to see all variables defined in the "cfg" namespace, issue `e cfg.` (mind the ending dot). You can get help on any eval configuration variable by using `e? cfg.`

The `e??` command to get help on all the evaluable configuration variables of radare2. As long as the output of this command is pretty large you can combine it with the internal grep `~` to filter for what you are looking for:

```
[0x100001200]> e??~color
graph.gv.graph: Graphviz global style attributes. (bgcolor=white)
graph.gv.node: Graphviz node style. (color=gray, style=filled shape=box)
scr.color: Enable colors (0: none, 1: ansi, 2: 256 colors, 3: truecolor)
scr.color.args: Colorize arguments and variables of functions
scr.color.bytes: Colorize bytes that represent the opcodes of the instruction
scr.color.grep: Enable colors when using ~grep
scr.color.ops: Colorize numbers and registers in opcodes
scr.pipecolor: Enable colors when using pipes
scr.rainbow: Shows rainbow colors depending of address
scr.randpal: Random color palette or just get the next one from 'eco'
```

The Visual mode has an eval browser that is accessible through the `vbe` command.

asm.arch

Defines the target CPU architecture used for disassembling (`pd`, `pD` commands) and code analysis (`a` command). You can find the list of possible values by looking at the result of `e asm.arch=?` or `rasm2 -L`. It is quite simple to add new architectures for disassembling and analyzing code. There is an interface for that. For x86, it is used to attach a number of third-party disassembler engines, including GNU binutils, Udis86 and a few handmade ones.

asm.bits

Determines width in bits of registers for the current architecture. Supported values: 8, 16, 32, 64. Note that not all target architectures support all combinations for `asm.bits`.

asm.syntax

Changes syntax flavor for disassembler between Intel and AT&T. At the moment, this setting affects Udis86 disassembler for Intel 32/Intel 64 targets only. Supported values are `intel` and `att`.

asm.pseudo

A boolean value to choose a string disassembly engine. "False" indicates a native one, defined by the current architecture, "true" activates a pseudocode strings format; for example, it will show `eax=ebx` instead of a `mov eax, ebx`.

asm.os

Selects a target operating system of currently loaded binary. Usually, OS is automatically detected by `rabin -rI`. Yet, `asm.os` can be used to switch to a different syscall table employed by another OS.

asm.flags

If defined to "true", disassembler view will have flags column.

asm.lines.call

If set to "true", draw lines at the left of the disassemble output (`pd`, `pD` commands) to graphically represent control flow changes (jumps and calls) that are targeted inside current block. Also, see `asm.linesout`.

asm.linesout

When defined as "true", the disassembly view will also draw control flow lines that go outside of the block.

asm.linestyle

A boolean value which changes the direction of control flow analysis. If set to "false", it is done from top to bottom of a block; otherwise, it goes from bottom to top. The "false" setting seems to be a better choice for improved readability and is the default one.

asm.offset

Boolean value which controls the visibility of offsets for individual disassembled instructions.

asm.trace

A boolean value that controls displaying of tracing information (sequence number and counter) at the left of each opcode. It is used to assist with programs trace analysis.

asm.bytes

A boolean value used to show or hide displaying of raw bytes of instructions.

cfg.bigendian

Change endianness. "true" means big-endian, "false" is for little-endian. "file.id" and "file.flag" both to be true.

cfg.newtab

If this variable is enabled, help messages will be displayed along with command names in tab completion for commands.

scr.color

This variable specifies the mode for colorized screen output: "false" (or 0) means no colors, "true" (or 1) means 16-colors mode, 2 means 256-colors mode, 3 means 16 million-colors mode. If your favorite theme looks weird, try to bump this up.

scr.seek

This variable accepts a full-featured expression or a pointer/flag (eg. eip). If set, radare will set seek position to its value on startup.

cfg.fortunes

Enables or disables "fortune" messages displayed at each radare start.

cfg.fortunes.type

Fortunes are classified by type. This variable determines which types are allowed for displaying when `cfg.fortunes` is `true`, so they can be fine-tuned on what's appropriate for the intended audience. Current types are `tips`, `fun`, `nsfw`, `creepy`.

Files

Use `r2 -H` to list all the environment variables that matter to know where it will be looking for files. Those paths depend on the way (and operating system) you have built r2 for.

```
R2_PREFIX=/usr
MAGICPATH=/usr/share/radare2/2.8.0-git/magic
PREFIX=/usr
INCDIR=/usr/include/libr
LIBDIR=/usr/lib64
LIBEXT=so
RCONFIGHOME=/home/user/.config/radare2
RDATAHOME=/home/user/.local/share/radare2
RCACHEHOME=/home/user/.cache/radare2
LIBR_PLUGINS=/usr/lib/radare2/2.8.0-git
USER_PLUGINS=/home/user/.local/share/radare2/plugins
USER_ZIGNS=/home/user/.local/share/radare2/zigns
```

RC Files

RC files are r2 scripts that are loaded at startup time. Those files must be in 3 different places:

System

radare2 will try to load the `/usr/share/radare2/radare2rc` file first

Your Home

Each user in the system can have its own r2 scripts to run on startup to select the color scheme, and other custom options by having r2 commands in there.

- `~/.radare2rc`
- `~/.config/radare2/radare2rc`
- `~/.config/radare2/radare2rc.d/`

Target file

If you want to run a script everytime you open a file, just create a file with the same name of the file but appending `.r2` to it.

Basic Commands

Most command names in radare are derived from action names. They should be easy to remember, as they are short. Actually, all commands are single letters. Subcommands or related commands are specified using the second character of the command name. For example, `/ foo` is a command to search plain string, while `/x 90 90` is used to look for hexadecimal pairs.

The general format for a valid command (as explained in the 'Command Format' chapter) looks like this:

```
[ .][times][cmd][~grep][@[@iter]addr!size][|>pipe] ; ...
```

For example,

```
> 3s +1024 ; seeks three times 1024 from the current seek
```

If a command starts with `=!`, the rest of the string is passed to currently loaded IO plugin (a debugger, for example). Most plugins provide help messages with `=!?` or `=!help`.

```
$ r2 -d /bin/ls  
> =!help ; handled by the IO plugin
```

If a command starts with `!`, `posix_system()` is called to pass the command to your shell. Check `!?` for more options and usage examples.

```
> !ls ; run `ls` in the shell
```

The meaning of arguments (iter, addr, size) depends on the specific command. As a rule of thumb, most commands take a number as an argument to specify the number of bytes to work with, instead of the currently defined block size. Some commands accept math expressions or strings.

```
> px 0x17 ; show 0x17 bytes in hexs at current seek  
> s base+0x33 ; seeks to flag 'base' plus 0x33  
> / lib ; search for 'lib' string.
```

The `@` sign is used to specify a temporary offset location or a seek position at which the command is executed, instead of current seek position. This is quite useful as you don't have to seek around all the time.

```
> p8 10 @ 0x4010 ; show 10 bytes at offset 0x4010  
> f patata @ 0x10 ; set 'patata' flag at offset 0x10
```

Using `@@` you can execute a single command on a list of flags matching the glob. You can think of this as a foreach operation:

```
> s 0  
> / lib ; search 'lib' string  
> p8 20 @@ hit0_* ; show 20 hexpairs at each search hit
```

The `>` operation is used to redirect the output of a command into a file (overwriting it if it already exists).

```
> pr > dump.bin ; dump 'raw' bytes of current block to file named 'dump.bin'  
> f > flags.txt ; dump flag list to 'flags.txt'
```

The `|` operation (pipe) is similar to what you are used to expecting from it in a *NIX shell: an output of one command as input to another.

```
[0x4A13B8C0]> f | grep section | grep text  
0x0805f3b0 512 section._text  
0x080d24b0 512 section._text_end
```

You can pass several commands in a single line by separating them with a semicolon `;`:

```
> px ; dr
```

Seeking

To move around the file we are inspecting we will need to change the offset we are using the `s` command.

The argument is a math expression that can contain flag names, parenthesis, addition, subtraction, multiplication of immediates or contents of memory using brackets.

Some example commands:

```
[0x00000000]> s 0x10
[0x00000010]> s+4
[0x00000014]> s-
[0x00000010]> s+
[0x00000014]>
```

Observe how the prompt offset changes. The first line move the current offset to the address 0x10.

The second does a relative seek 4 bytes forward.

And finally, the last 2 commands are undoing, and redoing the last seek operations.

Instead of using just numbers, we can use complex expressions, or basic arithmetic operations to represent the address to seek.

To do this, check the `?$?` Help message which describes the internal variables that can be used in the expressions. For example. This is the same as doing `s+4`

```
[0x00000000]> s $$+4
```

From the debugger (or when emulating) we can also use the register names as references. They are loaded as flags with the `.dr*` command, which happens under the hood.

```
[0x00000000]> s rsp+0x40
```

Here's the full help of the `s` command. We will explain in more detail below.

```
[0x00000000]> s?
Usage: s[+-] [addr]
s          print current address
s 0x320    seek to this address
s-         undo seek
s+         redo seek
s*         list undo seek history
s++        seek blocksize bytes forward
s--        seek blocksize bytes backward
s+ 512    seek 512 bytes forward
s- 512    seek 512 bytes backward
sg/sG     seek begin (sg) or end (sG) of section or file
s.hexoff  Seek honoring a base from core->offset
sa [[+-]a] [asz] seekasz (or bsize) aligned to addr
sn/sp     seek next/prev scr.nkey
s/ DATA   search for next occurrence of 'DATA'
s/x 9091  search for next occurrence of \x90\x91
sb        seek aligned to bb start
so [num]   seek to N next opcode(s)
sf        seek to next function (f->addr+f->size)
sc str    seek to comment matching given string
sr pc    seek to register

> 3s++      ; 3 times block-seeking
> s 10+0x80 ; seek at 0x80+10
```

If you want to inspect the result of a math expression, you can evaluate it using the `?` command. Simply pass the expression as an argument. The result can be displayed in hexadecimal, decimal, octal or binary formats.

```
> ? 0x100+200
0x1C8 ; 456d ; 7100 ; 1100 1000
```

There's also subcommands of `?` that display in one specific format (base 10, base 16 ,...). See `?v` and `?vi`.

In the visual mode, you can press `u` (undo) or `u` (redo) inside the seek history to return back to previous or forward to the next location.

Open file

As a test file, let's use a simple `hello_world.c` compiled in Linux ELF format. After we compile it let's open it with radare2:

```
$ r2 hello_world
```

Now we have the command prompt:

```
[0x00400410]>
```

And it is time to go deeper.

Seeking at any position

All seeking commands that take an address as a command parameter can use any numeral base such as hex, octal, binary or decimal.

Seek to an address 0x0. An alternative command is simply `0x0`

```
[0x00400410]> s 0x0  
[0x00000000]>
```

Print current address

```
[0x00000000]> s  
0x0  
[0x00000000]>
```

There is an alternate way to print current position: `?v $$`.

Seek N positions forward, space is optional

```
[0x00000000]> s+ 128  
[0x00000080]>
```

Undo last two seeks to return to the initial address

```
[0x00000080]> s-  
[0x00000000]> s-  
[0x00400410]>
```

We are back at `0x00400410`.

There's also a command to show the seek history:

```
[0x00400410]> s*
f undo_3 @ 0x400410
f undo_2 @ 0x40041a
f undo_1 @ 0x400410
f undo_0 @ 0x400411
# Current undo/redo position.
f redo_0 @ 0x4005b4
```

Block Size

The block size determines how many bytes radare2 commands will process when not given an explicit size argument. You can temporarily change the block size by specifying a numeric argument to the print commands. For example `px 20`.

```
[0xB7F9D810]> b?  
|Usage: b[f] [arg] Get/Set block size  
| b      display current block size  
| b 33    set block size to 33  
| b+3   increase blocksize by 3  
| b-16   decrease blocksize by 16  
| b eip+4 numeric argument can be an expression  
| bf foo  set block size to flag size  
| bm 1M   set max block size
```

The `b` command is used to change the block size:

```
[0x0000000000]> b 0x100 ; block size = 0x100  
[0x0000000000]> b +16    ; ... = 0x110  
[0x0000000000]> b -32    ; ... = 0xf0
```

The `bf` command is used to change the block size to value specified by a flag. For example, in symbols, the block size of the flag represents the size of the function.

```
[0x0000000000]> bf sym.main ; block size = sizeof(sym.main)  
[0x0000000000]> pd @ sym.main ; disassemble sym.main  
...
```

You can combine two operations in a single one (`pdf`):

```
[0x0000000000]> pdf @ sym.main
```

Sections

The concept of sections is tied to the information extracted from the binary. We can display this information by using the `i` command.

Displaying information about sections:

```
[0x000005310]> iS
[Sections]
00 0x0000000000      0 0x0000000000      0  -----
01 0x00000238      28 0x00000238      28 -r-- .interp
02 0x00000254      32 0x00000254      32 -r-- .note.ABI_tag
03 0x00000278     176 0x00000278     176 -r-- .gnu.hash
04 0x00000328    3000 0x00000328    3000 -r-- .dynsym
05 0x00000ee0    1412 0x00000ee0    1412 -r-- .dynstr
06 0x00001464     250 0x00001464     250 -r-- .gnu.version
07 0x00001560     112 0x00001560     112 -r-- .gnu.version_r
08 0x000015d0    4944 0x000015d0    4944 -r-- .rela.dyn
09 0x00002920    2448 0x00002920    2448 -r-- .rela.plt
10 0x000032b0      23 0x000032b0      23 -r-x .init
...
...
```

As you may know, binaries use to have sections and maps. The sections define the contents of a portion of the file that can be mapped in memory (or not). What is mapped is defined by the segments.

Before the IO refactoring done by condret, the `S` command was used to manage what we now call maps. Currently the `S` command is supposed to be deprecated because `iS` and `om` should be enough.

Firmware images, bootloaders and binary files usually place various sections of a binary at different addresses in memory. To represent this behavior, radare offers the `s` command. Use `s?` to get the help message. But we would recommend you to better check `om` and `is` and try to avoid `s` as much as possible as long as it will be deprecated soon. To list all created sections use `s` (or `Sj` to get the json format). The `s=` will show the region bars in ascii-art.

You can create a new section with a line like this:

```
s [off] [va] [sz] [vsz] [name] [mrwx]
```

For example:

```
[0x00404888]> S 0x00000100 0x00400000 0x0001ae08 0001ae08 test rwx
```

It is possible to remove a section definition using the `s-` command. Pass the section id to it as an argument:

```
[0xB7EE8810]> S-4
```

Mapping Files

Radare I/O subsystem allows you to map contents of files into the same I/O space used to contain loaded binary. New contents can be placed at random offsets.

The `o` command permits the user to open a file, this is mapped at offset 0 unless it have a known binary header and then the maps are created in virtual addresses.

Sometimes, we want to rebase a binary, or maybe we want to load or map the file in a different address.

When launching `r2`, the base address can be changed with the `-B` flag. But you must notice the difference when opening files with unknown headers, like bootloaders, so we need to map them using the `-m` flag (or specifying it as argument to the `o` command).

Being able to open files and map portions of them at random places in memory specifying attributes like permissions and name. Is the perfect basic tooling to reproduce an environment like a core file, a debug session, by also loading and mapping all the libraries the binary depends.

Opening files (and mapping them) is done using the `o` (open) command. Let's read the help:

```
[0x00000000]> o?
|usage: o [com- ] [file] ([offset])
| o                      list opened files
| o-1                    close file descriptor 1
| o-!*                  close all opened files
| o--                   close all files, analysis, binfiles, flags, same as !r2 --
| o [file]                open [file] file in read-only
| o+ [file]                open file in read-write mode
| o [file] 0x4000 rwx     map file at 0x4000
| oa[-] [A] [B] [filename] Specify arch and bits for given file
| oq                     list all open files
| o*                     list opened files in r2 commands
| o. [len]                open a malloc://[len] copying the bytes from current offse
t
| o=                     list opened files (ascii-art bars)
| ob[?] [lbdos] [...]    list opened binary files backed by fd
| oc [file]                open core file, like relaunching r2
| of [file]                open file and map it at addr 0 as read-only
| oi[-|idx]               alias for o, but using index instead of fd
| oj[?]                  list opened files in JSON format
| oL                     list all IO plugins registered
| om[?]                  create, list, remove IO maps
| on [file] 0x4000         map raw file at 0x4000 (no r_bin involved)
| oo[?]                  reopen current file (kill+fork in debugger)
| oo+                    reopen current file in read-write
| ood[r] [args]            reopen in debugger mode (with args)
| oo[bnm] [...]           see oo? for help
| op [fd]                 prioritize given fd (see also ob)
| ox fd fdx               exchange the desc of fd and fdx and keep the mapping
```

Prepare a simple layout:

```
$ rabin2 -l /bin/ls
[Linked libraries]
libselinux.so.1
librt.so.1
libacl.so.1
libc.so.6

4 libraries
```

Map a file:

```
[0x00001190]> o /bin/zsh 0x499999
```

List mapped files:

```
[0x00000000]> o
- 6 /bin/ls @ 0x0 ; r
- 10 /lib/ld-linux.so.2 @ 0x100000000 ; r
- 14 /bin/zsh @ 0x499999 ; r
```

Print hexadecimal values from /bin/zsh:

```
[0x00000000]> px @ 0x499999
```

Unmap files using the `o-` command. Pass required file descriptor to it as an argument:

```
[0x00000000]> o-14
```

Print Modes

One of the key features of radare2 is displaying information in many formats. The goal is to offer a selection of displaying choices to best interpret binary data.

Binary data can be represented as integers, shorts, longs, floats, timestamps, hexpair strings, or more complex formats like C structures, disassembly listings, decompilation listing, be a result of an external processing...

Below is a list of available print modes listed by `p?` :

```
[0x000005310]> p?
|Usage: p[=68abcdFfiImrstuxz] [arg|len] [@addr]
| p-[?][jh] [mode]          bar|json|histogram blocks (mode: e?search.in)
| p=[?][bep] [N] [len] [b] show entropy/printable chars/chars bars
| p2 [len]                  8x8 2bpp-tiles
| p3 [file]                 print stereogram (3D)
| p6[de] [len]               base64 decode/encode
| p8[?][j] [len]             8bit hexpair list of bytes
| pa[edD] [arg]              pa:assemble pa[dD]:disasm or pae: esil from hexpairs
| pA[n_ops]                  show n_ops address and type
| p[b|B|xb] [len] ([skip]) bindump N bits skipping M
| pb[?] [n]                  bitstream of N bits
| pB[?] [n]                  bitstream of N bytes
| pc[?][p] [len]             output C (or python) format
| pC[d] [rows]               print disassembly in columns (see hex.cols and pdi)
| pd[?] [sz] [a] [b]         disassemble N opcodes (pd) or N bytes (pD)
| pf[?][.nam] [fmt]          print formatted data (pf.name, pf.name $<expr>)
| ph[?][=|hash] ([len])     calculate hash for a block
| pj[?] [len]                print as indented JSON
| p[iI][df] [len]            print N ops/bytes (f=func) (see pi? and pdi)
| p[kK] [len]                print key in randomart (K is for mosaic)
| pm[?] [magic]              print libmagic data (see pm? and /m?)
| pq[?][iz] [len]            print QR code with the first Nbytes of the current block
| pr[?][glx] [len]           print N raw bytes (in lines or hexblocks, 'g'unzip)
| ps[?][pwz] [len]           print pascal/wide/zero-terminated strings
| pt[?][dn] [len]            print different timestamps
| pu[?][w] [len]             print N url encoded bytes (w=wide)
| pv[?][jh] [mode]           show variable/pointer/value in memory
| pwd                       display current working directory
| px[?][owq] [len]           hexdump of N bytes (o=octal, w=32bit, q=64bit)
| pz[?] [len]                print zoom view (see pz? for help)
[0x000005310]>
```

Tip: when using json output, you can append the `~{}` to the command to get a pretty-printed version of the output:

```
[0x00000000]> oj
[{"raised":false,"fd":563280,"uri":"malloc://512","from":0,"writable":true,"size":512,
"overlaps":false}]
[0x00000000]> oj~{}
[
  {
    "raised": false,
    "fd": 563280,
    "uri": "malloc://512",
    "from": 0,
    "writable": true,
    "size": 512,
    "overlaps": false
  }
]
```

For more on the magical powers of `~` see the help in `?@?`, and the "Command Format" chapter earlier in the book.

Hexadecimal View

`px` gives a user-friendly output showing 16 pairs of numbers per row with offsets and raw representations:

```
[0x00404888]> px
- offset - 0 1 2 3 4 5 6 7 8 9 A B C D E F 0123456789ABCDEF
0x00404888 31ed 4989 d15e 4889 e248 83e4 f050 5449 1.I..^H..H...PTI
0x00404898 c7c0 4024 4100 48c7 c1b0 2341 0048 c7c7 ..@$A.H...#A.H..
0x004048a8 d028 4000 e83f dcff ffff 6690 662e 0f1f .(@...?....f.f...
```

Show Hexadecimal Words Dump (32 bits)

```
[0x00404888]> pwx
0x00404888 0x8949ed31 0x89485ed1 0xe48348e2 0x495450f0 1.I..^H..H...PTI
0x00404898 0x2440c0c7 0xc7480041 0x4123b0c1 0xc7c74800 ..@$A.H...#A.H..
0x004048a8 0x004028d0 0xffffdc3fe8 0x9066f4ff 0x1f0f2e66 .(@...?....f.f...

[0x00404888]> e cfg.bigEndian
false

[0x00404888]> e cfg.bigEndian = true

[0x00404888]> pwx
0x00404888 0x31ed4989 0xd15e4889 0xe24883e4 0xf0505449 1.I..^H..H...PTI
0x00404898 0xc7c04024 0x410048c7 0xc1b02341 0x0048c7c7 ..@$A.H...#A.H..
0x004048a8 0xd0284000 0xe83fdcfc 0xffff46690 0x662e0f1f .(@...?....f.f...
```

8 bits Hexpair List of Bytes

```
[0x00404888]> p8 16
31ed4989d15e4889e24883e4f0505449
```

Show Hexadecimal Quad-words Dump (64 bits)

```
[0x08049A80]> pxq
0x00001390 0x65625f6b63617473 0x646e6962006e6967 stack_begin.bind
0x000013a0 0x616d6f6474786574 0x7469727766006e69 textdomain.fwrit
0x000013b0 0x6b636f6c6e755f65 0x6d63727473006465 e_unlocked.strcm
...
```

Date/Time Formats

Currently supported timestamp output modes are:

[0x00404888]> pt? |Usage: pt[dn?] | pt print unix time (32 bit cfg.big_endian) | ptd print dos time (32 bit cfg.big_endian) | ptn print ntfs time (64 bit !cfg.big_endian) | pt? show help message

For example, you can 'view' the current buffer as timestamps in the ntfs time:

[0x08048000]> e cfg.bigendian = false [0x08048000]> pt 4 29:04:32948 23:12:36 +0000
[0x08048000]> e cfg.bigendian = true [0x08048000]> pt 4 20:05:13001 09:29:21 +0000

As you can see, the endianness affects the result. Once you have printed a timestamp, you can grep output, for example, by year value:

[0x08048000]> pt ~1974 | wc -l 15 [0x08048000]> pt ~2022 27:04:2022 16:15:43 +0000

The default date format can be configured using the `cfg.datefmt` variable. Formatting rules for it follow the well known strftime(3) format. Check the manpage for more details, but those are the more importants:

%a The abbreviated name of the day of the week according to the current locale. %A The full name of the day of the week according to the current locale. %d The day of the month as a decimal number (range 01 to 31). %D Equivalent to %m/%d/%y. (Yecch—for Americans only). %H The hour as a decimal number using a 24-hour clock (range 00 to 23). %I The hour as a decimal number using a 12-hour clock (range 01 to 12). %m The month as a decimal number (range 01 to 12). %M The minute as a decimal number (range 00 to 59). %p Either "AM" or "PM" according to the given time value. %s The number of seconds since the Epoch, 1970-01-01 00:00:00 +0000 (UTC). (%TZ) %S The second as a decimal number (range 00 to 60). (The range is up to 60 to allow for occasional leap seconds.) %T The time in 24-hour notation (%H:%M:%S). (%U) %y The year as a decimal number without a century

(range 00 to 99). %Y The year as a decimal number including the century. %z The +hhmm or -hhmm numeric timezone (that is, the hour and minute offset from UTC). (SU) %Z The timezone name or abbreviation.

Basic Types

There are print modes available for all basic types. If you are interested in a more complex structure, type `pf??` for format characters and `pf???` for examples:

```
[0x00499999]> pf?? |pf: pf[.k[.f[=v]]|[v]][[n]][0|cnt][fmt] [a0 a1 ...] | Format: | b byte (unsigned)
| B resolve enum bitfield (see t?) | c char (signed byte) | d 0x%08x hexadecimal value (4 bytes) (see %%i and %%x) | D disassemble one opcode | e temporally swap endian | E resolve enum name (see t?) | f float value (4 bytes) | F double value (8 bytes) | i %%i signed integer value (4 bytes) (see %%d and %%x) | n next char specifies size of signed value (1, 2, 4 or 8 byte(s)) | N next char specifies size of unsigned value (1, 2, 4 or 8 byte(s)) | o 0x%08o octal value (4 byte) | p pointer reference (2, 4 or 8 bytes) | q quadword (8 bytes) | r CPU register | pf r (eax)plop | s 32bit pointer to string (4 bytes) | S 64bit pointer to string (8 bytes) | t UNIX timestamp (4 bytes) | T show Ten first bytes of buffer | u uleb128 (variable length) | w word (2 bytes unsigned short in hex) | x 0x%08x hex value and flag (fd @ addr) (see %%d and %%i) | X show formatted hexpairs | z \0 terminated string | Z \0 terminated wide string | ? data structure | pf ? (struct_name)example_name | * next char is pointer (honors asm.bits) | + toggle show flags for each offset | : skip 4 bytes | . skip 1 byte
```

Use triple-question to get some examples using print format strings.

```
[0x00499999]> pf??? |pf: pf[.k[.f[=v]]|[v]][[n]][0|cnt][fmt] [a0 a1 ...] | Examples: | pf 3xi foo bar 3-array of struct, each with named fields: 'foo' as hex, and 'bar' as int | pf B (BitFldType)arg_name bitfield type | pf E (EnumType)arg_name enum type | pf.obj xxdz prev next size name Define the obj format as xxdz | pf obj=xxdz prev next size name Same as above | pf iwq foo bar troll Print the iwq format with foo, bar, troll as the respective names for the fields | pf 0iwq foo bar troll Same as above, but considered as a union (all fields at offset 0) | pf.plop ? (troll)mystruct Use structure troll previously defined | pf 10xiz pointer length string Print a size 10 array of the xiz struct with its field names | pf {integer}? (bifc) Print integer times the following format (bifc) | pf [4]w[7]i Print an array of 4 words and then an array of 7 integers | pf ic...?i foo bar "(pf xw yo foo)troll" yo Print nested anonymous structures | pfn2 print signed short (2 bytes) value. Use N insted of n for printing unsigned values
```

Some examples are below:

```
[0x4A13B8C0]> pf i 0x00404888 = 837634441
```

```
...
[0x4A13B8C0]> pf
0x00404888 = 837634432.000000
```

High-level Languages Views

Valid print code formats for human-readable languages are:

- pc C
- pc* print 'wx' r2 commands
- pch C half-words (2 byte)
- pcw C words (4 byte)
- pcd C dwords (8 byte)
- pca GAS .byte blob
- pcA .bytes with instructions in comments
- pcs string
- pcS shellscript that reconstructs the bin
- pcj json
- pcJ javascript
- pcp python

If we need to create a .c file containing a binary blob, use the pc command, that creates this output. The default size, is like in many other commands: the block size. Which can be changed with the b command.

But we can just temporarily override this block size by expressing it as argument.

```
[0xB7F8E810]> pc 32
#define _BUFFER_SIZE 32
unsigned char buffer[_BUFFER_SIZE] = {
0x89, 0xe0, 0xe8, 0x49, 0x02, 0x00, 0x00, 0x89, 0xc7, 0xe8, 0xe2, 0xff, 0xff, 0xff, 0x
81, 0xc3, 0xd6, 0xa7, 0x01, 0x00, 0x8b, 0x83, 0x00, 0xff, 0xff, 0xff, 0x5a, 0x8d, 0x24
, 0x84, 0x29, 0xc2 };
```

That cstring can used in many programming languages, not just C.

```
[0x7fcfd6a891630]> pcs
"\x48\x89\xe7\xe8\x68\x39\x00\x00\x49\x89\xc4\x8b\x05\xef\x16\x22\x00\x5a\x48\x8d\x24\
\xc4\x29\xc2\x52\x48\x89\xd6\x49\x89\xe5\x48\x83\xe4\xf0\x48\x8b\x3d\x06\x1a
```

Strings

Strings are probably one of the most important entry points when starting to reverse engineer a program because they usually reference information about functions' actions (asserts, debug or info messages...) Therefore radare supports various string formats:

```
[0x00000000]> ps?
|Usage: ps[zpw] [N]Print String
| ps   print string
| pss  print string in screen (wrap width)
| psi  print string inside curseek
| psb  print strings in current block
| psx  show string with escaped chars
| psz  print zero terminated string
| psp  print pascal string
| psu  print utf16 unicode (json)
| psw  print 16bit wide string
| psW  print 32bit wide string
| psj  print string in JSON format
```

Most strings are zero-terminated. Here is an example by using the debugger to continue the execution of a program until it executes the 'open' syscall. When we recover the control over the process, we get the arguments passed to the syscall, pointed by %ebx. In the case of the 'open' call, it is a zero terminated string which we can inspect using `psz`.

```
[0x4A13B8C0]> dcs open
0x4a14fc24 syscall(5) open ( 0x4a151c91 0x00000000 0x00000000 ) = 0xffffffffda
[0x4A13B8C0]> dr
    eax 0xffffffffda    esi 0xffffffff    eip 0x4a14fc24
    ebx 0x4a151c91    edi 0x4a151be1    oeax 0x00000005
    ecx 0x00000000    esp 0xbfbbedb1c    eflags 0x200246
    edx 0x00000000    ebp 0xbfbbedbb0    cPaZstIdor0 (PZI)
[0x4A13B8C0]>
[0x4A13B8C0]> psz @ 0x4a151c91
/etc/ld.so.cache
```

Print Memory Contents

It is also possible to print various packed data types using the `pf` command:

```
[0xB7F08810]> pf xxS @ rsp
0x7fff0d29da30 = 0x00000001
0x7fff0d29da34 = 0x00000000
0x7fff0d29da38 = 0x7fff0d29da38 -> 0xd29f7ee /bin/ls
```

This can be used to look at the arguments passed to a function. To achieve this, simply pass a 'format memory string' as an argument to `pf`, and temporally change the current seek position/offset using `@`. It is also possible to define arrays of structures with `pf`. To do this, prefix the format string with a numeric value. You can also define a name for each field of the structure by appending them as a space-separated arguments list.

```
[0x4A13B8C0]> pf 2*xw pointer type @ esp
0x00404888 [0] {
    pointer :
    (*0xffffffff8949ed31)      type : 0x00404888 = 0x8949ed31
        0x00404890 = 0x48e2
}
0x00404892 [1] {
    (*0x50f0e483)      pointer : 0x00404892 = 0x50f0e483
        type : 0x0040489a = 0x2440
}
```

A practical example for using `pf` on a binary of a GStreamer plugin:

```
$ radare ~/.gststreamer-0.10/plugins/libgstflumms.so
[0x000028A0]> seek sym.gst_plugin_desc
[0x000185E0]> pf iissxsssss major minor name desc _init version \
    license source package origin
    major : 0x000185e0 = 0
    minor : 0x000185e4 = 10
    name : 0x000185e8 = 0x000185e8 flumms
    desc : 0x000185ec = 0x000185ec Fluendo MMS source
    _init : 0x000185f0 = 0x00002940
    version : 0x000185f4 = 0x000185f4 0.10.15.1
    license : 0x000185f8 = 0x000185f8 unknown
    source : 0x000185fc = 0x000185fc gst-fluendo-mms
    package : 0x00018600 = 0x00018600 Fluendo MMS source
    origin : 0x00018604 = 0x00018604 http://www.fluendo.com
```

Disassembly

The `pd` command is used to disassemble code. It accepts a numeric value to specify how many instructions should be disassembled. The `pD` command is similar but instead of a number of instructions, it decompiles a given number of bytes.

- `d` : disassembly N opcodes count of opcodes
- `D` : asm.arch disassembler bsize bytes

```
[0x00404888]> pd 1
;-- entry0:
0x00404888 31ed xor ebp, ebp
```

Selecting Target Architecture

The architecture flavor for disassembler is defined by the `asm.arch` eval variable. You can use `e asm.arch=??` to list all available architectures.

```
[0x000005310]> e asm.arch=???
_dAe _8_16      6502      LGPL3    6502/NES/C64/Tamagotchi/T-1000 CPU
_dAe _8          8051     PD       8051 Intel CPU
_dA_  _16_32     arc      GPL3    Argonaut RISC Core
a____ _16_32_64 arm.as   LGPL3    as ARM Assembler (use ARM_AS environment)
adAe _16_32_64 arm      BSD      Capstone ARM disassembler
_dA_  _16_32_64 arm.gnu  GPL3    Acorn RISC Machine CPU
_d__   _16_32     arm.winedbg LGPL2   WineDBG's ARM disassembler
adAe _8_16      avr      GPL     AVR Atmel
adAe _16_32_64 bf       LGPL3   Brainfuck
_dA_  _32        chip8   LGPL3   Chip8 disassembler
_dA_  _16        cr16    LGPL3   cr16 disassembly plugin
_dA_  _32        cris    GPL3    Axis Communications 32-bit embedded processor
adA_  _32_64    dalvik  LGPL3   AndroidVM Dalvik
ad__   _16        dcpu16  PD      Mojang's DCPU-16
_dA_  _32_64    ebc     LGPL3   EFI Bytecode
adAe _16        gb      LGPL3   GameBoy(TM) (z80-like)
_dAe _16        h8300   LGPL3   H8/300 disassembly plugin
_dAe _32        hexagon  LGPL3   Qualcomm Hexagon (QDSP6) V6
_d__   _32        hppa    GPL3   HP PA-RISC
_dAe _0         i4004   LGPL3   Intel 4004 microprocessor
_dA_  _8         i8080   BSD     Intel 8080 CPU
adA_  _32        java    Apache  Java bytecode
_d__   _32        lanai   GPL3   LANAI
...
...
```

Configuring the Disassembler

There are multiple options which can be used to configure the output of disassembler. All these options are described in `e? asm.`

```
[0x000005310]> e? asm.  
asm.anal: Analyze code and refs while disassembling (see anal.strings)  
asm.arch: Set the arch to be used by asm  
asm.assembler: Set the plugin name to use when assembling  
asm.bbline: Show empty line after every basic block  
asm.bits: Word size in bits at assembler  
asm.bytes: Display the bytes of each instruction  
asm.bytespace: Separate hexadecimal bytes with a whitespace  
asm.calls: Show callee function related info as comments in disasm  
asm.capitalize: Use camelcase at disassembly  
asm.cmt.col: Column to align comments  
asm.cmt.flgrefs: Show comment flags associated to branch reference  
asm.cmt.fold: Fold comments, toggle with Vz  
...  
...
```

Currently there are 136 `asm.` configuration variables so we do not list them all

Disassembly Syntax

The `asm.syntax` variable is used to change the flavor of the assembly syntax used by a disassembler engine. To switch between Intel and AT&T representations:

```
e asm.syntax = intel  
e asm.syntax = att
```

You can also check `asm.pseudo`, which is an experimental pseudocode view, and `asm.esil` which outputs [ESIL](#) ('Evaluable Strings Intermediate Language'). ESIL's goal is to have a human-readable representation of every opcode semantics. Such representations can be evaluated (interpreted) to emulate effects of individual instructions.

Flags

Flags are conceptually similar to bookmarks. They associate a name with a given offset in a file. Flags can be grouped into 'flag spaces'. A flag space is a namespace for flags, grouping together flags of similar characteristics or type. Examples for flag spaces: sections, registers, symbols.

To create a flag:

```
[0x4A13B8C0]> f flag_name @ offset
```

You can remove a flag by appending the `-` character to command. Most commands accept `-` as argument-prefix as an indication to delete something.

```
[0x4A13B8C0]> f-flag_name
```

To switch between or create new flagspaces use the `fs` command:

```
[0x000005310]> fs?
|Usage: fs [*] [+][flagspace|addr] # Manage flagspaces
| fs          display flagspaces
| fs*         display flagspaces as r2 commands
| fsj         display flagspaces in JSON
| fs *        select all flagspaces
| fs flagspace select flagspace or create if it doesn't exist
| fs-flagspace remove flagspace
| fs-*        remove all flagspaces
| fs+foo      push previous flagspace and set
| fs-         pop to the previous flagspace
| fs-.        remove the current flagspace
| fsq         list flagspaces in quiet mode
| fsm [addr]  move flags at given address to the current flagspace
| fss         display flagspaces stack
| fss*        display flagspaces stack in r2 commands
| fssj        display flagspaces stack in JSON
| fsr newname  rename selected flagspace
[0x000005310]> fs
0 439 * strings
1 17 * symbols
2 54 * sections
3 20 * segments
4 115 * relocs
5 109 * imports
[0x000005310]>
```

Here there are some command examples:

```
[0x4A13B8C0]> fs symbols ; select only flags in symbols flagspace
[0x4A13B8C0]> f           ; list only flags in symbols flagspace
[0x4A13B8C0]> fs *        ; select all flagspaces
[0x4A13B8C0]> f myflag   ; create a new flag called 'myflag'
[0x4A13B8C0]> f-myflag  ; delete the flag called 'myflag'
```

You can rename flags with `fr`.

Local flags

Every flag name should be unique for addressing reasons. But it is quite a common need to have the flags, for example inside the functions, with simple and ubiquitous names like `loop` or `return`. For this purpose you can use so called "local" flags, which are tied to the function where they reside. It is possible to add them using `f.` command:

```
[0x00003a04]> pd 10
| 0x00003a04      48c705c9cc21. mov qword [0x002206d8], 0xffffffffffffffffffff ;
[0x2206d8:8]=0
| 0x00003a0f      c60522cc2100. mov byte [0x00220638], 0          ; [0x220638:1]=0
| 0x00003a16      83f802      cmp eax, 2
| .-< 0x00003a19  0f84880d0000 je 0x47a7
| | 0x00003a1f      83f803      cmp eax, 3
| .-< 0x00003a22  740e      je 0x3a32
| || 0x00003a24      83e801      sub eax, 1
| .-< 0x00003a27  0f84ed080000 je 0x431a
|||| 0x00003a2d      e8fef8ffff call sym.imp.abort      ; void abort(void)
|||| ; CODE XREF from main (0x3a22)
||`-> 0x00003a32      be07000000 mov esi, 7

[0x00003a04]> f. localflag @ 0x3a32
[0x00003a04]> f.
0x00003a32 localflag  [main + 210]
[0x00003a04]> pd 10
| 0x00003a04      48c705c9cc21. mov qword [0x002206d8], 0xffffffffffffffffffff ;
[0x2206d8:8]=0
| 0x00003a0f      c60522cc2100. mov byte [0x00220638], 0          ; [0x220638:1]=0
| 0x00003a16      83f802      cmp eax, 2
| .-< 0x00003a19  0f84880d0000 je 0x47a7
| | 0x00003a1f      83f803      cmp eax, 3
| .-< 0x00003a22  740e      je 0x3a32      ; main.localflag
| || 0x00003a24      83e801      sub eax, 1
| .-< 0x00003a27  0f84ed080000 je 0x431a
|||| 0x00003a2d      e8fef8ffff call sym.imp.abort      ; void abort(void)
|||| ; CODE XREF from main (0x3a22)
||`-> .localflag:
|||| ; CODE XREF from main (0x3a22)
||`-> 0x00003a32      be07000000 mov esi, 7

[0x00003a04]>
```

Writing Data

Radare can manipulate a loaded binary file in many ways. You can resize the file, move and copy/paste bytes, insert new bytes (shifting data to the end of the block or file), or simply overwrite bytes. New data may be given as a wide-string, assembler instructions, or the data may be read in from another file.

Resize the file using the `r` command. It accepts a numeric argument. A positive value sets a new size for the file. A negative one will truncate the file to the current seek position minus N bytes.

```
r 1024      ; resize the file to 1024 bytes
r -10 @ 33  ; strip 10 bytes at offset 33
```

Write bytes using the `w` command. It accepts multiple input formats like inline assembly, endian-friendly dwords, files, hexpair files, wide strings:

```
[0x00404888]> w?
| usage: w[x] [str] [<file>] [<<EOF>>] [@addr]
| w[1248][+-][n]      increment/decrement byte,word..
| w foobar            write string 'foobar'
| w0 [len]             write 'len' bytes with value 0x00
| w6[de] base64/hex   write base64 [d]ecoded or [e]ncoded string
| wa[?] push ebp      write opcode, separated by ';'
| waf file            assemble file and write bytes
| wao[?] op            modify opcode (conditional jump, nop, etc)
| wA[?] r 0            alter/modify opcode at current seek (wA?)
| wb 010203            fill current block with cyclic hexpairs
| wB[-]0xVALUE         set or unset bits with given value
| wc                  list all write changes
| wc[?][ir*?]
| wd [off] [n]          duplicate N bytes from offset to here
| we[?] [nNsX] [arg]    extend write operations (insert vs replace)
| wf -|file            write contents of file at current offset
| wh r2                whereis/which shell command
| wm f0ff              set cyclick binary write mask hexpair
| wo[?] hex            write in block with operation. 'wo?' fmi
| wp[?] -|file         apply radare patch file. See wp? fmi
| wr 10                write 10 random bytes
| ws pstring           write 1 byte for length and then the string
| wt[f][?] file [sz]   write to file (from current seek, blocksize)
| wts host:port [sz]   send data to remote host:port via tcp://
| ww foobar            write wide string
| wx[?][fs] 9090        write two intel nops (from wxfile or wxseek)
| wv[?] eip+34          write 32-64 bit value
| wz string            write zero terminated string (like w + \x00)
```

Some examples:

```
[0x0000000000]> wx 123456 @ 0x8048300
[0x0000000000]> wv 0x8048123 @ 0x8049100
[0x0000000000]> wa jmp 0x8048320
```

Write Over

The `wo` command (write over) has many subcommands, each combines the existing data with the new data using an operator. The command is applied to the current block. Supported operators include XOR, ADD, SUB...

```
[0x4A13B8C0]> wo?
|Usage: wo[asmdxoAr124] [hexpairs] @ addr[:bsize]
|Example:
| wox 0x90 ; xor cur block with 0x90
| wox 90 ; xor cur block with 0x90
| wox 0x0203 ; xor cur block with 0203
| woa 02 03 ; add [0203][0203][...] to curblk
| woe 02 03
|Supported operations:
| wow == write looped value (alias for 'wb')
| woa += addition
| wos -= subtraction
| wom *= multiply
| wod /= divide
| wox ^= xor
| woo |= or
| woA &= and
| woR random bytes (alias for 'wr $b')
| wor >>= shift right
| wol <<= shift left
| wo2 2= 2 byte endian swap
| wo4 4= 4 byte endian swap
```

It is possible to implement cipher-algorithms using radare core primitives and `wo`. A sample session performing `xor(90) + add(01, 02)`:

```
[0x7fcd6a891630]> px
- offset -      0 1 2 3 4 5 6 7 8 9  A B  C D  E F
0x7fcd6a891630 4889 e7e8 6839 0000 4989 c48b 05ef 1622
0x7fcd6a891640 005a 488d 24c4 29c2 5248 89d6 4989 e548
0x7fcd6a891650 83e4 f048 8b3d 061a 2200 498d 4cd5 1049
0x7fcd6a891660 8d55 0831 ede8 06e2 0000 488d 15cf e600
[0x7fcd6a891630]> wox 90
[0x7fcd6a891630]> px
- offset -      0 1 2 3 4 5 6 7 8 9  A B  C D  E F
0x7fcd6a891630 d819 7778 d919 541b 90ca d81d c2d8 1946
0x7fcd6a891640 1374 60d8 b290 d91d 1dc5 98a1 9090 d81d
0x7fcd6a891650 90dc 197c 9f8f 1490 d81d 95d9 9f8f 1490
0x7fcd6a891660 13d7 9491 9f8f 1490 13ff 9491 9f8f 1490
[0x7fcd6a891630]> woa 01 02
[0x7fcd6a891630]> px
- offset -      0 1 2 3 4 5 6 7 8 9  A B  C D  E F
0x7fcd6a891630 d91b 787a 91cc d91f 1476 61da 1ec7 99a3
0x7fcd6a891640 91de 1a7e d91f 96db 14d9 9593 1401 9593
0x7fcd6a891650 c4da 1a6d e89a d959 9192 9159 1cb1 d959
0x7fcd6a891660 9192 79cb 81da 1652 81da 1456 a252 7c77
```

Write

Zoom

The zoom is a print mode that allows you to get a global view of the whole file or a memory map on a single screen. In this mode, each byte represents `file_size/block_size` bytes of the file. Use the `pz` command, or just use `z` in the visual mode to toggle the zoom mode.

The cursor can be used to scroll faster through the zoom out view. Pressing `z` again will zoom-in at the cursor position.

```
[0x004048c5]> pz?
|Usage: pz [len] print zoomed blocks (filesize/N)
| e zoom.maxsz  max size of block
| e zoom.from   start address
| e zoom.to     end address
| e zoom.byte   specify how to calculate each byte
| pzp          number of printable chars
| pzf          count of flags in block
| pzs          strings in range
| pz0          number of bytes with value '0'
| pzF          number of bytes with value 0xFF
| pze          calculate entropy and expand to 0-255 range
| pzh          head (first byte value); This is the default mode
```

Let's see some examples:

```
[0x08049790]> e zoom.byte=h
[0x08049790]> pz // or default pzh
0x00000000 7f00 0000 e200 0000 146e 6f74 0300 0000
0x00000010 0000 0000 0068 2102 00ff 2024 e8f0 007a
0x00000020 8c00 18c2 ffff 0080 4421 41c4 1500 5dff
0x00000030 ff10 0018 0fc8 031a 000c 8484 e970 8648
0x00000040 d68b 3148 348b 03a0 8b0f c200 5d25 7074
0x00000050 7500 00e1 ffe8 58fe 4dc4 00e0 dbc8 b885

[0x08049790]> e zoom.byte=p
[0x08049790]> pz // or pzp
0x00000000 2f47 0609 070a 0917 1e9e a4bd 2a1b 2c27
0x00000010 322d 5671 8788 8182 5679 7568 82a2 7d89
0x00000020 8173 7f7b 727a 9588 a07b 5c7d 8daf 836d
0x00000030 b167 6192 a67d 8aa2 6246 856e 8c9b 999f
0x00000040 a774 96c3 b1a4 6c8e a07c 6a8f 8983 6a62
0x00000050 7d66 625f 7ea4 7ea6 b4b6 8b57 a19f 71a2

[0x08049790]> eval zoom.byte = flags
[0x08049790]> pz // or pzf
0x00406e65 48d0 80f9 360f 8745 ffff ffeb ae66 0f1f
0x00406e75 4400 0083 f801 0f85 3fff ffff 410f b600
0x00406e85 3c78 0f87 6301 0000 0fb6 c8ff 24cd 0026
0x00406e95 4100 660f 1f84 0000 0000 0084 c074 043c
0x00406ea5 3a75 18b8 0500 0000 83f8 060f 95c0 e9cd
0x00406eb5 feff ff0f 1f84 0000 0000 0041 8801 4983
0x00406ec5 c001 4983 c201 4983 c101 e9ec feff ff0f

[0x08049790]> e zoom.byte=F
[0x08049790]> p0 // or pzF
0x00000000 0000 0000 0000 0000 0000 0000 0000 0000
0x00000010 0000 2b5c 5757 3a14 331f 1b23 0315 1d18
0x00000020 222a 2330 2b31 2e2a 1714 200d 1512 383d
0x00000030 1e1a 181b 0a10 1a21 2a36 281e 1d1c 0e11
0x00000040 1b2a 2f22 2229 181e 231e 181c 1913 262b
0x00000050 2b30 4741 422f 382a 1e22 0f17 0f10 3913
```

You can limit zooming to a range of bytes instead of the whole bytespace. Change `zoom.from` and `zoom.to` eval variables:

```
[0x00003a04]> e? zoom.  
zoom.byte: Zoom callback to calculate each byte (See pz? for help)  
zoom.from: Zoom start address  
zoom.in: Specify boundaries for zoom  
zoom.maxsz: Zoom max size of block  
zoom.to: Zoom end address  
[0x00003a04]> e zoom.  
zoom.byte = h  
zoom.from = 0  
zoom.in = io.map  
zoom.maxsz = 512  
zoom.to = 0
```

Yank/Paste

Radare2 have an internal clipboard to save and write portions of memory loaded from the current io layer.

This clipboard can be manipulated with the `y` command.

The two basic operations are

- copy (yank)
- paste

The yank operation will read N bytes (specified by the argument) into the clipboard. We can later use the `yy` command to paste what we read before into a file.

You can yank/paste bytes in visual mode selecting them with the cursor mode (`Vc`) and then using the `y` and `Y` key bindings which are aliases for `y` and `yy` commands of the command-line interface.

```
[0x00000000]> y?
|Usage: y[ptxy] [len] [[@]addr] # See wd? for memcpy, same as 'yf'.
| y           show yank buffer information (srcoff len bytes)
| y 16        copy 16 bytes into clipboard
| y 16 0x200   copy 16 bytes into clipboard from 0x200
| y 16 @ 0x200 copy 16 bytes into clipboard from 0x200
| yz [len]     copy string (from current block) into clipboard
| yp          print contents of clipboard
| yx          print contents of clipboard in hexadecimal
| ys          print contents of clipboard as string
| yt 64 0x200  copy 64 bytes from current seek to 0x200
| ytf file    dump the clipboard to given file
| yf 64 0x200  copy 64 bytes from 0x200 from file
| yfa file copy copy all bytes from file (opens w/ io)
| yy 0x3344    paste clipboard
```

Sample session:

```
[0x00000000]> s 0x100      ; seek at 0x100
[0x00000100]> y 100        ; yanks 100 bytes from here
[0x00000200]> s 0x200      ; seek 0x200
[0x00000200]> yy           ; pastes 100 bytes
```

You can perform a yank and paste in a single line by just using the `yt` command (yank-to). The syntax is as follows:

```
[0x4A13B8C0]> x
  offset 0 1 2 3 4 5 6 7 8 9 A B 0123456789AB
0xA13B8C0, 89e0 e839 0700 0089 c7e8 e2ff ...9.....
0xA13B8CC, ffff 81c3 eea6 0100 8b83 08ff .....
0xA13B8D8, ffff 5a8d 2484 29c2 ..Z.$.).
```

```
[0x4A13B8C0]> yt 8 0xA13B8CC @ 0xA13B8C0
```

```
[0x4A13B8C0]> x
  offset 0 1 2 3 4 5 6 7 8 9 A B 0123456789AB
0xA13B8C0, 89e0 e839 0700 0089 c7e8 e2ff ...9.....
0xA13B8CC, 89e0 e839 0700 0089 8b83 08ff ...9.....
0xA13B8D8, ffff 5a8d 2484 29c2 ..Z.$.).
```

Comparing Bytes

For most generic reverse engineering tasks like finding the differences between two binary files, which bytes has changed, find differences in the graphs of the code analysis results, and other diffing operations you can just use radiff2:

```
$ radiff2 -h
```

Inside r2, the functionalities exposed by radiff2 are available in the c command.

c (short for "compare") allows you to compare arrays of bytes from different sources. The command accepts input in a number of formats and then compares it against values found at current seek position.

```
[0x00404888]> c?
|Usage: c[?dfx] [argument] # Compare
| c [string]      Compare a plain with escaped chars string
| c* [string]     Same as above, but printing r2 commands
| c4 [value]      Compare a doubleword from a math expression
| c8 [value]      Compare a quadword from a math expression
| cat [file]      Show contents of file (see pwd, ls)
| cc [at]         Compares in two hexdump columns of block size
| ccc [at]        Same as above, but only showing different lines
| ccd [at]        Compares in two disasm columns of block size
| cf [file]       Compare contents of file at current seek
| cg[?] [o] [file] Graphdiff current file and [file]
| cu[?] [addr] @at Compare memory hexdumps of $$ and dst in unified diff
| cud [addr] @at Unified diff disasm from $$ and given address
| cv[1248] [hexpairs] @at Compare 1,2,4,8-byte value
| cv[1248] [addr] @at   Compare 1,2,4,8-byte address contents
| cw[?] [us?] [...] Compare memory watchers
| cx [hexpair]    Compare hexpair string (use '.' as nibble wildcard)
| cx* [hexpair]   Compare hexpair string (output r2 commands)
| cX [addr]       Like 'cc' but using hexdiff output
| cd [dir]        chdir
| cl|cls|clear   Clear screen, (clear0 to goto 0, 0 only)
```

To compare memory contents at current seek position against given string of values, use
 cx :

```
[0x08048000]> p8 4  
7f 45 4c 46  
  
[0x08048000]> cx 7f 45 90 46  
Compare 3/4 equal bytes  
0x00000002 (byte=03) 90 ' ' -> 4c 'L'  
[0x08048000]>
```

Another subcommand of `c` command is `cc` which stands for "compare code". To compare a byte sequence with a sequence in memory:

```
[0x4A13B8C0]> cc 0x39e8e089 @ 0x4A13B8C0
```

To compare contents of two functions specified by their names:

```
[0x08049A80]> cc sym.main2 @ sym.main
```

`c8` compares a quadword from the current seek (in the example below, 0x00000000) against a math expression:

```
[0x00000000]> c8 4  
  
Compare 1/8 equal bytes (0%)  
0x00000000 (byte=01) 7f ' ' -> 04 ' '  
0x00000001 (byte=02) 45 'E' -> 00 ' '  
0x00000002 (byte=03) 4c 'L' -> 00 ' '
```

The number parameter can, of course, be math expressions which use flag names and anything allowed in an expression:

```
[0x00000000]> cx 7f469046  
  
Compare 2/4 equal bytes  
0x00000001 (byte=02) 45 'E' -> 46 'F'  
0x00000002 (byte=03) 4c 'L' -> 90 ' '
```

You can use the compare command to find differences between a current block and a file previously dumped to a disk:

```
r2 /bin/true  
[0x08049A80]> s 0  
[0x08048000]> cf /bin/true  
Compare 512/512 equal bytes
```


SDB

SDB stands for String DataBase. It's a simple key-value database that only operates with strings created by pancake. It is used in many parts of r2 to have a disk and in-memory database which is small and fast to manage using it as a hashtable on steroids.

SDB is a simple string key/value database based on djb's cdb disk storage and supports JSON and arrays introspection.

There's also the sdbtypes: a vala library that implements several data structures on top of an sdb or a memcache instance.

SDB supports:

- namespaces (multiple sdb paths)
- atomic database sync (never corrupted)
- bindings for vala, luvit, newlisp and nodejs
- commandline frontend for sdb databases
- memcache client and server with sdb backend
- arrays support (syntax sugar)
- json parser/getter

Usage example

Let's create a database!

```
$ sdb d hello=world
$ sdb d hello
world
```

Using arrays:

```
$ sdb - '[]list=1,2' '[0]list' '[0]list=foo' '[]list' '[+1]list=bar'
1
foo
2
foo
fuck
2
```

Let's play with json:

```
$ sdb d g='{"foo":1,"bar":{"cow":3}}'  
$ sdb d g?bar.cow  
3  
$ sdb - user='{"id":123}' user?id=99 user?id  
99
```

Using the command line without any disk database:

```
$ sdb - foo=bar foo a=3 +a -a  
bar  
4  
3  
  
$ sdb -  
foo=bar  
foo  
bar  
a=3  
+a  
4  
-a  
3
```

Remove the database

```
$ rm -f d
```

So what ?

So, you can now do this inside your radare2 sessions!

Let's take a simple binary, and check what is already *sdbized*.

```
$ cat test.c  
int main(){  
    puts("Hello world\n");  
}  
$ gcc test.c -o test
```

```
$ r2 -A ./test
[0x08048320]> k **
bin
anal
syscall
debug
```

```
[0x08048320]> k bin/***
fd.6
[0x08048320]> k bin/fd.6/*
archs=0:0:x86:32
```

The file corresponding to the sixth file descriptor is a x86_32 binary.

```
[0x08048320]> k anal/meta/*
meta.s.0x80484d0=12,SGVsbG8gd29ybGQ=
[...]
[0x08048320]> ?b64- SGVsbG8gd29ybGQ=
Hello world
```

Strings are stored encoded in base64.

More Examples

List namespaces

```
k **
```

List sub-namespaces

```
k anal/**
```

List keys

```
k *
k anal/*
```

Set a key

```
k foo=bar
```

Get the value of a key

```
k foo
```

List all syscalls

```
k syscall/*~^0x
```

List all comments

```
k anal/meta/*~.C.
```

Show a comment at given offset:

```
k %anal/meta/[1]meta.C.0x100005000
```

Visual Mode

The visual mode is a more user-friendly interface alternative to radare2's command-line prompt. It uses HJKL or arrow keys to move around data and code, has a cursor mode for selecting bytes, and offers numerous key bindings to simplify debugger use. To enter visual mode, use `v` command. To exit from it back to command line, press `q`.

```
[0x000404890 16% 120 /bin/ls]> pd $r @ entry0
/ (fcn) entry0: 42
| ;-- entry0:
| 0x000404890 31ed xor ebp, ebp
| 0x000404892 4989d1 mov r9, rdx
| 0x000404895 5e pop rsi
| 0x000404896 4889e2 mov rdx, rsp
| 0x000404899 4883c4f0 and rsp, 0xffffffffffff
| 0x00040489d 50 push rax
| 0x00040489e 54 push rsp
| 0x00040489f 49c7c0d1e41. mov r8, 0x411ed0
| 0x0004048a6 48c7c1601e41. mov rcx, 0x411e60
| 0x0004048ad 48c7c7c02840. mov rdi, main ; "AWAWAUAUTUH..S..H..
| 0x0004048b4 e837dcffff call sym.imp._libc_start_main ;[1]
| sym.imp._libc_start_main(unk, unk, unk)
\ 0x0004048b9 f4 hlt
0x0004048ba 660f1f440000 nop word [rax + rax]

/ (fcn) Fcn.004048cb: 41
; CALL XREF from 0x00040493d (fcn.0040493d)
| 0x0004048c0 b8 a56100 mov eax, 0x61a5ff ; "hstrtab" @ 0x6
| 0x0004048c5 55 push rbp
| 0x0004048c6 482df8a56100 sub rax, 0x61a5ff
| 0x0004048cc 4883f80e cmp rax, 0xe
| 0x0004048d0 4889e5 mov rbp, rsp
```

```
0x000404890 16% 368 /bin/ls> x @ entry0
offset - 0 1 2 3 4 5 6 7 8 9 A B C D E F 0123456789ABCDEF
ix000404890 31ed 4989 d15e 4889 e248 83e4 f050 5449 1.I..^H..H...PTI
ix0004048a0 c7c0 d01e 4100 48c7 c160 1e41 0048 c7c7 ....A.H.^A.H.
ix0004048b0 c028 4000 e837 dc1f fff4 660f 1f44 0000 .@(....f.D...
ix0004048c0 b8 t a561 0055 482d f8a5 6100 4883 f80e ..a.UH..a.H...
ix0004048d0 4889 e577 025d c3b5 0000 0000 4885 c074 H..w.J.....H.t
ix0004048e0 f45d bff8 a561 00f e00f 1f80 0000 0000 .J...a.....
ix0004048f0 b8f8 a561 0055 482d f8a5 6100 48c1 f803 ...a.UH..a.H...
ix000404900 4889 e548 89c2 48c1 ea3f 4801 d048 d1f8 H..M..H..?H..H..
ix000404910 7502 5dc3 baa0 0000 0048 85d2 74f4 5d48 u.].....H.t]H
ix000404920 89c6 bff8 a561 00f e20f 1f80 0000 0000 .....a.....
ix000404930 803d 215d 2100 0075 1155 4889 e5e8 7eff :=!]..u.UH...-
ix000404940 ffff 5dc6 050e 5d21 0001 f3c3 0f40 0000 ...]!....@.
ix000404950 4883 3da8 5421 0000 741e b800 0000 0048 H.=.T!..t....H
ix000404960 85c0 7414 55bf 009e 6100 4889 e5ff d05d ..t.U..a.H...]
ix000404970 e97b ffff 0f 1f00 e973 ffff 0f 1f00 .{.....s.....
ix000404980 488b 0731 d248 f7f6 4889 doc3 0f1f 4000 H..1.H.H....@.
ix000404990 31c0 48b8 1648 3917 7406 f3c3 0f1f 4000 1.H..H9.t....@.
ix0004049a0 488b 4608 4839 4708 0f94 c0c3 0f1f 4000 H.F..H9G....@.
ix0004049b0 8b05 8266 2100 85c0 7506 893d 7866 2100 ...f!..u.=xf!.
ix0004049c0 f3c3 6666 6666 662e 0f1f 8400 0000 0000 .....ffff.....
ix0004049d0 e91b d8 f1 66 662e 0f1f 8400 0000 0000 .....ff.....
```

```
[0x000404890 16% 120 /bin/ls]> pc @ entry0
#define _BUFFER_SIZE 120
unsigned char buffer[120] = {
0x31, 0xed, 0x49, 0x89, 0xd1, 0x5e, 0x48, 0x89, 0xe2, 0x48, 0x83,
0xe4, 0xf0, 0x50, 0x54, 0x49, 0xc7, 0xc0, 0xd0, 0x1e, 0x41, 0x00,
0x48, 0xc7, 0xc1, 0x60, 0x1e, 0x41, 0x00, 0x48, 0xc7, 0xc0,
0x28, 0x40, 0x00, 0x88, 0x37, 0xdc, 0xff, 0xf4, 0x66, 0x0f,
0x1f, 0x44, 0x00, 0x00, 0xb8, 0xff, 0xa5, 0x61, 0x00, 0x55, 0x48,
0x2d, 0xf8, 0x5, 0x61, 0x00, 0x48, 0x83, 0xf8, 0x0e, 0x48, 0x89,
0x5, 0x77, 0x02, 0x5d, 0xc3, 0xb8, 0x00, 0x00, 0x00, 0x00, 0x48,
0x85, 0xc0, 0x74, 0xf4, 0x5d, 0xb8, 0xf8, 0xa5, 0x61, 0x00, 0xff,
0xe0, 0x0f, 0x1f, 0x80, 0x00, 0x00, 0x00, 0xb8, 0xf8, 0xa5,
0x61, 0x00, 0x55, 0x48, 0x2d, 0xf8, 0xa5, 0x61, 0x00, 0x48, 0x1c,
0xf8, 0x03, 0x48, 0x89, 0xe5, 0x48, 0x89, 0xc2, 0x48, 0x1c},
```

```
[0x000404890 16% 115 /bin/ls]> f tmp;sr s.. @ entry0
offset - 0 1 2 3 4 5 6 7 8 9 A B C D E F 0123456789ABCDEF
0x00000000 7f45 4c46 0201 0100 0000 0000 0000 0000 .ELF.....
0x00000010 0200 3e00 0100 0000 9048 4000 0000 0000 ..>....H@...
0x00000020 4000 0000 0000 0000 0000 0000 0000 0000 @.....
0x00000030 0000 0000 4000 3800 0900 4000 1c00 1b00 ...@.B...@....
r15 0x00000000 r14 0x00000000 r13 0x00000000
r12 0x00000000 rbp 0x00000000 rbx 0x00000000
r11 0x00000000 r10 0x00000000 r9 0x00000000
r8 0x00000000 rax 0x00000000 rcx 0x00000000
rdx 0x00000000 rsi 0x00000000 rdi 0x00000000
orax 0x00000000 rip 0x00000000 rflags =
rsp 0x00000000
```

```
/ (fcn) entry0: 42
| ;-- entry0:
| 0x000404890 31ed xor ebp, ebp
| 0x000404892 4989d1 mov r9, rdx
| 0x000404895 5e pop rsi
| 0x000404896 4889e2 mov rdx, rsp
| 0x000404899 4883c4f0 and rsp, 0xffffffffffff
| 0x00040489d 50 push rax
| 0x00040489e 54 push rsp
| 0x00040489f 49c7c0d1e41. mov r8, 0x411ed0
```

print modes aka Panels

The Visual mode uses "print modes" which are basically different panel that you can rotate. By default those are:

⌚ **Hexdump panel** → **Disassembly panel** → **Debugger panel** → **Hexadecimal words dump panel** → **Hex-less hexdump panel** → **Op analysis color map panel** → **Annotated hexdump panel** ⌚.

Notice that the top of the panel contains the command which is used, for example for the disassembly panel:

```
[0x000404890 16% 120 /bin/ls]> pd $r @ entry0
```

Getting Help

To see help on all key bindings defined for visual mode, press `? :`

```
Visual mode help:
?      show this help
??     show the user-friendly hud
%      in cursor mode finds matching pair, or toggle autoblocksz
@      redraw screen every 1s (multi-user view)
^      seek to the beginning of the function
!      enter into the visual panels mode
_      enter the flag/comment/functions/.. hud (same as VF_)
=      set cmd.vprompt (top row)
|      set cmd.cprompt (right column)
.      seek to program counter
\      toggle visual split mode
"      toggle the column mode (uses pC..)
/      in cursor mode search in current block
:cmd   run radare command
;[-]cmt add/remove comment
0      seek to beginning of current function
[1-9]   follow jmp/call identified by shortcut (like ;[1])
,file   add a link to the text file
/*+-[] change block size, [] = resize hex.cols
</>    seek aligned to block size (seek cursor in cursor mode)
a/A    (a)ssemble code, visual (A)ssembler
b      browse symbols, flags, configurations, classes, ...
B      toggle breakpoint
c/C    toggle (c)ursor and (C)ołors
d[f?] define function, data, code, ..
D      enter visual diff mode (set diff.from/to
e      edit eval configuration variables
f/F    set/unset or browse flags. f- to unset, F to browse, ..
gG    go seek to begin and end of file (0-$)
hjkl   move around (or HJKL) (left-down-up-right)
i      insert hex or string (in hexdump) use tab to toggle
mK/'K mark/go to Key (any key)
M      walk the mounted filesystems
n/N    seek next/prev function/flag/hit (scr.nkey)
o      go/seek to given offset
O      toggle asm.pseudo and asm.esil
p/P    rotate print modes (hex, disasm, debug, words, buf)
q      back to radare shell
r      refresh screen / in cursor mode browse comments
R      randomize color palette (ecr)
ss    step / step over
t      browse types
T      enter textlog chat console (TT)
uu    undo/redo seek
v      visual function/vars code analysis menu
V      (V)iew graph using cmd.graph (agv?)
```

```
WW      seek cursor to next/prev word
XX      show xrefs/refs of current function from/to data/code
YY      copy and paste selection
z       fold/unfold comments in disassembly
Z       toggle zoom mode
Enter   follow address of jump/call
Function Keys: (See 'e key.'), defaults to:
F2      toggle breakpoint
F4      run to cursor
F7      single step
F8      step over
F9      continue
```

Visual Disassembly

Navigation

Move within the Disassembly using `arrows` or `hjk1`. Use `o` to seek directly to a flag or an offset, type it when requested by the prompt: `[offset]>`. Follow a jump or a call using the number of your keyboard `[0-9]` and the number on the right in disassembly to follow a call or a jump. In this example typing `1` on the keyboard would follow the call to `sym.imp.__libc_start_main` and therefore, seek at the offset of this symbol.

```
0x00404894      e857dcffff      call sym.imp.__libc_start_main ;[1]
```

Seek back to the previous location using `u`, `u` will allow you to redo the seek.

d as define

`d` can be used to change the type of data of the current block, several basic types/structures are available as well as more advanced one using `pf` template:

```
d → ...
0x004048f7      48c1e83f      shr rax, 0x3f
d → b
0x004048f7 .byte 0x48
d → B
0x004048f7 .word 0xc148
d → d
0x004048f7 hex length=165 delta=0
0x004048f7  48c1 e83f 4801 c648 d1fe 7415 b800 0000
...
```

To improve code readability you can change how radare2 presents numerical values in disassembly, by default most of disassembly display numerical value as hexadecimal. Sometimes you would like to view it as a decimal, binary or even custom defined constant. To change value format you can use `d` following by `i` then choose what base to work in, this is the equivalent to `ahi`:

```

d → i → ...
0x004048f7    48c1e83f      shr rax, 0x3f
d → i → 10
0x004048f7    48c1e83f      shr rax, 63
d → i → 2
0x004048f7    48c1e83f      shr rax, '?'

```

Usage of the Cursor for Inserting/Patching...

Remember that, to be able to actually edit files loaded in radare2, you have to start it with the `-w` option. Otherwise a file is opened in read-only mode.

Pressing lowercase `c` toggles the cursor mode. When this mode is active, the currently selected byte (or byte range) is highlighted.

```
[0x00404890 16% 330 (0x6:-1=1)]> pd $r @ entry0+6 # 0x404896
/ (fcn) entry0 42
|     ;-- entry0:
|     0x00404890 31ed      xor ebp, ebp
|     0x00404892 4989d1      mov r9, rdx
|     0x00404895 5e          pop rsi
|     0x00404896 * 4889e2      mov rdx, rsp
|     0x00404899 4883e4f0      and rsp, 0xfffffffffffffff0
|     0x0040489d 50          push rax
|     0x0040489e 54          push rsp
|     0x0040489f 49c7c0d01e41  mov r8, 0x411ed0
|     0x004048a6 48c7c1601e41  mov rcx, 0x411e60
|     0x004048ad 48c7c7c02840  mov rdi, main           ; "AWAVAUATUH..S..H...." @ 0x4028c0
|     0x004048b4 e837dcffff  call sym.imp.__libc_start_main ;[1]
|             sym.imp.__libc_start_main(unk, unk)
|     0x004048b9 f4          hlt
\     0x004048ba 660f1f440000  nop word [rax + rax]
```

The cursor is used to select a range of bytes or simply to point to a byte. You can use the cursor to create a named flag at specific location. To do so, seek to the required position, then press `f` and enter a name for a flag. If the file was opened in write mode using the `-w` flag or the `o+` command, you can also use the cursor to overwrite a selected range with new values. To do so, select a range of bytes (with HJKL and SHIFT key pressed), then press `i` and enter the hexpair values for the new data. The data will be repeated as needed to fill the range selected. For example:

```
<select 10 bytes in visual mode using SHIFT+HJKL>
<press 'i' and then enter '12 34'>
```

The 10 bytes you have selected will be changed to "12 34 12 34 12 ...".

The Visual Assembler is a feature that provides a live-preview while you type in new instructions to patch into the disassembly. To use it, seek or place the cursor at the wanted location and hit the 'A' key. To provide multiple instructions, separate them with semicolons,

`;`

XREF

When radare2 has discovered a XREF during the analysis, it will show you the information in the Visual Disassembly using `XREF` tag:

```
; DATA XREF from 0x00402e0e (unk)
str.David_MacKenzie:
```

To see where this string is called, press `x`, if you want to jump to the location where the data is used then press the corresponding number [0-9] on your keyboard. (This functionality is similar to `axt`)

`x` corresponds to the reverse operation aka `axf`.

Function Argument display

To enable this view use this config var `e dbg.funcarg = true`

```
[0x5621e0accd83 190 /bin/ls]> ?0;f tmp;s..
- offset - 0 1 2 3 4 5 6 7 8 9 A B C D E F 0123456789ABCDEF
0x7ffcf13a0e0 20a1 13fd fc7f 0000 0240 264a ba7f 0000 .....@&J....
0x7ffcf13a0f0 90e4 20e1 2156 0000 60e2 20e1 2156 0000 ... .!V..` .!V..
0x7ffcf13a100 0000 0000 0000 0000 10e0 20e1 2156 0000 ..... .!V..
0x7ffcf13a110 0000 0000 0000 0000 0000 0000 0000 0000 ..... .
rax 0x5621e120f850 = r_ax rbx 0x7ffcf13a248e->anal rcx 0x7ffcf139f64
rdx 0x00000000 (fcn) r8 0x00000081 r9 0x7fba4a5c9a20
r10 0xfffffffffffffec8 r11a 0x00000000 name; r12 0x5621e0ace600
r13 0x7ffcf13a240 use { r14 0x00000000 r15 0x00000000
rsi 0x5621e0ae0261 rrdi 0x5621e0ae0247 rsp 0x7ffcf13a0e0
rbp 0x00000001 rip 0x5621e0accd8a item = rflags 1I_t (core->flags, pc)
orax 0xfffffffffffffff if (item) {
arg [0] -domainname: 0x5621e0ae0247 --> "coreutils" item->name;
arg [1] -dirname: 0x5621e0ae0261 --> "/usr/share/locale"
0x5621e0accd83 488d3dbd3401. lea rdi, [0x5621e0ae0247] ; "
;-- rip:
0x5621e0accd8a = r_e881faffff_func_2 call sym.imp.bindtextdomain ;[1]
0x5621e0accd8f g_str 488d3db13401. lea rdi, [0x5621e0ae0247] ; ; "
0x5621e0accd96 { e835faffff call sym.imp.textdomain ;[2]
0x5621e0accd9b cons_p 488d3dae8100. lea rdi, [0x5621e0ad4f50]
0x5621e0accda2 c7054cb42100. mov dword obj.exit_failure, 2
0x5621e0accdac cons_p e89f1a0100
0x5621e0accdb1 48b800000000. movabs rax, 0x8000000000000000
0x5621e0accdbb t_empty c7054bc32100. mov dword [0x5621e0ce9110], 0
0x5621e0accdc5 argc c605ecc32100. mov byte [0x5621e0ce91b8], 1
0x5621e0accdcc list_f 4889059dc421. mov qword [0x5621e0ce9270], rax
0x5621e0accdd3 8b0507b42100 set eax, dword obj.ls_modeoptions
0x5621e0accdd9 48c7059cc421. mov qword [0x5621e0ce9280], 0
0x5621e0accde4 48c70589c421. mov qword [0x5621e0ce9278], 0xff
0x5621e0accdef c605e2c32100. move byte [0x5621e0ce91d8], 0 _RE_
0x5621e0accd6 83f802 format_va cmp eax, 2, arg->fmt, onst2ck, ai
,=< 0x5621e0accd9 0f844f0c0000 je 0x5621e0acda4e ;[4]
| 0x5621e0accdff 83f803 cmp eax, 3 ; 3
,==< 0x5621e0acce02 740e je 0x5621e0acce12 ;[5]
|| 0x5621e0acce04 (fcn) 83e801 sub eax, 1
---- 0x5621e0acce07 0f844f0c0000 je 0x5621e0accd601 ;[6]
```

Add a comment

To add a comment press `; .`

Type other commands

Quickly type commands using `: .`

Search

`/ : allows highlighting of strings in the current display.` `:cmd` `allows you to use one of the "/?" commands that perform more specialized searches.`

The Huds

The "UserFriendly HUD"

The "UserFriendly HUD" can be accessed using the `??` key-combination. This HUD acts as an interactive Cheat Sheet that one can use to more easily find and execute commands. This HUD is particularly useful for new-comers. For experienced users, the other Huds which are more activity-specific may be more useful.

The "flag/comment/functions/.. HUD"

This HUD can be displayed using the `_` key, it shows a list of all the flags defined and lets you jump to them. Using the keyboard you can quickly filter the list down to a flag that contains a specific pattern.

Tweaking the Disassembly

The disassembly's look-and-feel is controlled using the "asm.*" configuration keys, which can be changed using the `e` command. All configuration keys can also be edited through the Visual Configuration Editor.

Visual Configuration Editor

This HUD can be accessed using the `e` key in visual mode. The editor allows you to easily examine and change radare2's configuration. For example, if you want to change something about the disassembly display, select `asm` from the list, navigate to the item you wish to modify it, then select it by hitting `Enter`. If the item is a boolean variable, it will toggle, otherwise you will be prompted to provide a new value.

```
[EvalSpace]

    anal
> asm
  bin
  cfg
  cmd
  dbg
  diff
  dir
  esil
  file
  fs
  graph
  hex
  http
  hud
  io
  key
  magic
  pdb
  rap
  rop
  scr
  search
  stack
  time
  zoom

Sel:asm.arch

/ (fcn) entry0 42
|     ;-- entry0:
|     0x00404890  31ed          xor ebp, ebp
|     0x00404892  4989d1        mov r9, rdx
|     0x00404895  5e             pop rsi
|     0x00404896  4889e2        mov rdx, rsp
|     0x00404899  4883e4f0      and rsp, 0xfffffffffffffff0
```

Example switch to pseudo disassembly:

```
[EvalSpace < Variables: asm.arch]
```

```
asm.functions = true
asm.indent = false
asm.lbytes = true
asm.lines = true
asm.linescall = false
asm.linesout = true
asm.linesright = false
asm.linesstyle = false
asm.lineswide = false
asm.linewidth = 7
asm.maxrefs = 5
asm.middle = false
asm.nbytes = 6
asm.offset = true
asm.os = linux
asm.parser = x86.pseudo
> asm.pseudo = false
asm.reloff = false
asm.section = false
asm.segoff = false
asm.size = false
asm.stackptr = false
asm.syntax = intel
asm.tabs = 0
asm.trace = false
asm.tracespace = false
asm.ucase = false
asm.vars = true
asm.varsub = true
asm.varxs = false
asm.xrefs = true
```

Selected: asm.pseudo (Enable pseudo syntax)

```
/ (fcn) entry0 42
|   ;-- entry0:
|   0x00404890  31ed      xor    ebp, ebp
|   0x00404892  4989d1    mov    r9, rdx
|   0x00404895  5e        pop    rsi
|   0x00404896  4889e2    mov    rdx, rsp
|   0x00404899  4883e4f0  and    rsp, 0xfffffffffffffff0
```

```
[EvalSpace < Variables: asm.arch]

asm.functions = true
asm.indent = false
asm.lbytes = true
asm.lines = true
asm.linescall = false
asm.linesout = true
asm.linesright = false
asm.linesstyle = false
asm.lineswide = false
asm.lineWidth = 7
asm.maxrefs = 5
asm.middle = false
asm.nbytes = 6
asm.offset = true
asm.os = linux
asm.parser = x86.pseudo
> asm.pseudo = true
asm.reloff = false
asm.section = false
asm.segoff = false
asm.size = false
asm.stackptr = false
asm.syntax = intel
asm.tabs = 0
asm.trace = false
asm.tracespace = false
asm.ucase = false
asm.vars = true
asm.varsub = true
asm.varxs = false
asm.xrefs = true

Selected: asm.pseudo (Enable pseudo syntax)

/ (fcn) entry0 42
|     ;-- entry0:
|     0x00404890  31ed          ebp = 0
|     0x00404892  4989d1        r9 = rdx
|     0x00404895  5e             pop rsi
|     0x00404896  4889e2        rdx = rsp
|     0x00404899  4883e4f0      rsp &= 0xfffffffffffffff0
```

Following are some example of eval variable related to disassembly.

Examples

asm.arch: Change Architecture && asm.bits: Word size in bits at assembler

You can view the list of all arch using `e asm.arch=?`

```
e asm.arch = dalvik
0x000404870      31ed4989      cmp-long v237, v73, v137
0x000404874      d15e4889      rsub-int v14, v5, 0x8948
0x000404878      e24883e4      ushr-int/lit8 v72, v131, 0xe4
0x00040487c      f0505449c7c0  +invoke-object-init-range {}, method+18772 ;[0]
0x000404882      90244100      add-int v36, v65, v0
```

```
e asm.bits = 16
0000:4870      31ed          xor bp, bp
0000:4872      49             dec cx
0000:4873      89d1          mov cx, dx
0000:4875      5e             pop si
0000:4876      48             dec ax
0000:4877      89e2          mov dx, sp
```

This latest operation can also be done using `&` in Visual mode.

asm.pseudo: Enable pseudo syntax

```
e asm.pseudo = true
0x000404870      31ed          ebp = 0
0x000404872      4989d1        r9 = rdx
0x000404875      5e             pop rsi
0x000404876      4889e2        rdx = rsp
0x000404879      4883e4f0    rsp &= 0xfffffffffffffff0
```

asm.syntax: Select assembly syntax (intel, att, masm...)

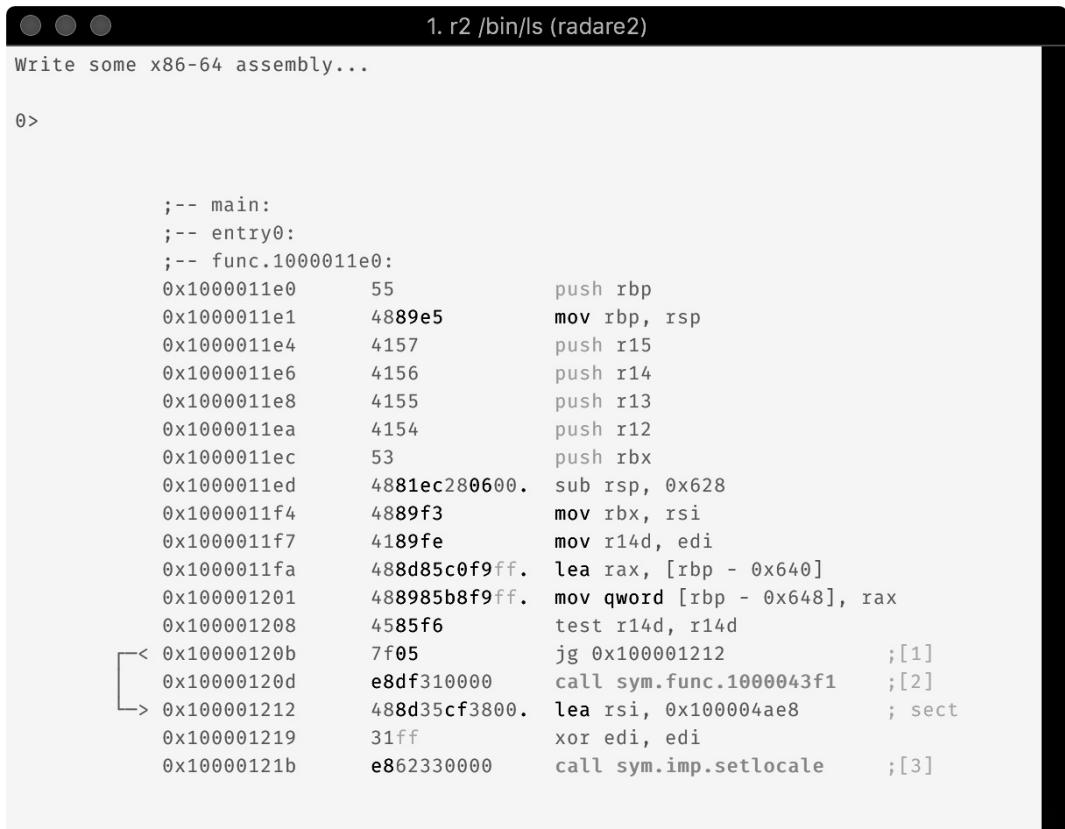
```
e asm.syntax = att
0x000404870      31ed          xor %ebp, %ebp
0x000404872      4989d1        mov %rdx, %r9
0x000404875      5e             pop %rsi
0x000404876      4889e2        mov %rsp, %rdx
0x000404879      4883e4f0    and $0xfffffffffffffff0, %rsp
```

asm.describe: Show opcode description

```
e asm.describe = true
0x00404870 xor ebp, ebp      ; logical exclusive or
0x00404872 mov r9, rdx       ; moves data from src to dst
0x00404875 pop rsi          ; pops last element of stack and stores the result in argument
0x00404876 mov rdx, rsp       ; moves data from src to dst
0x00404879 and rsp, -0xf    ; binary and operation between src and dst, stores result on dst
```

Visual Assembler

You can use Visual Mode to assemble code using `A`. For example let's replace the `push` by a `jmp`:



The screenshot shows the radare2 interface with the title "1. r2 /bin/ls (radare2)". The assembly code is displayed in the main window:

```
Write some x86-64 assembly...

0>

;-- main:
;-- entry0:
;-- func.1000011e0:
0x1000011e0      55          push rbp
0x1000011e1      4889e5      mov rbp, rsp
0x1000011e4      4157        push r15
0x1000011e6      4156        push r14
0x1000011e8      4155        push r13
0x1000011ea      4154        push r12
0x1000011ec      53          push rbx
0x1000011ed      4881ec280600. sub rsp, 0x628
0x1000011f4      4889f3      mov rbx, rsi
0x1000011f7      4189fe      mov r14d, edi
0x1000011fa      488d85c0f9ff. lea rax, [rbp - 0x640]
0x100001201      488985b8f9ff. mov qword [rbp - 0x648], rax
0x100001208      4585f6      test r14d, r14d
0x10000120b      7f05        jg 0x100001212      ;[1]
0x10000120d      e8df310000  call sym.func.1000043f1  ;[2]
0x100001212      488d35cf3800. lea rsi, 0x100004ae8  ; sect
0x100001219      31ff        xor edi, edi
0x10000121b      e862330000  call sym.imp.setlocale ;[3]
```

Arrows indicate control flow between instructions at addresses 0x10000120b, 0x10000120d, and 0x100001212.

Notice the preview of the disassembly and arrows:

The screenshot shows the radare2 assembly editor interface. The title bar says "1. r2 /bin/ls (radare2)". Below it, a status bar says "Write some x86-64 assembly...". The main area displays assembly code:

```
2> jmp 0x1000011ec
* eb0a

    <-- main:
    <-- entry0:
    <-- func.1000011e0:
    < 0x1000011e0      eb0a        jmp 0x1000011ec          ;[1]
    0x1000011e2      89e5        mov ebp, esp
    0x1000011e4      4157        push r15
    0x1000011e6      4156        push r14
    0x1000011e8      4155        push r13
    0x1000011ea      4154        push r12
    > 0x1000011ec      53          push rbx
    0x1000011ed      4881ec280600. sub rsp, 0x628
    0x1000011f4      4889f3        mov rbx, rsi
    0x1000011f7      4189fe        mov r14d, edi
    0x1000011fa      488d85c0f9ff. lea rax, [rbp - 0x640]
    0x100001201      488985b8f9ff. mov qword [rbp - 0x648], rax
    0x100001208      4585f6        test r14d, r14d
    < 0x10000120b      7f05        jg 0x100001212         ;[2]
    0x10000120d      e8df310000  call sym.func.1000043f1 ;[3]
    > 0x100001212      488d35cf3800. lea rsi, 0x100004ae8 ; sect
    0x100001219      31ff        xor edi, edi
    0x10000121b      e862330000  call sym.imp.setlocale ;[4]
```

You need to open the file in writing mode (`r2 -w` or `oo+`) in order to patch the file. You can also use the cache mode: `e io.cache = true` and `wc?`.

Remember that patching files in debug mode only patch the memory not the file.

Visual Configuration Editor

`ve` or `e` in visual mode allows you to edit radare2 configuration visually. For example, if you want to change the assembly display just select `asm` in the list and choose your assembly display flavor.

```
[EvalSpace]

anal
> asm
bin
cfg
cmd
dbg
diff
dir
esil
file
fs
graph
hex
http
hud
io
key
magic
pdb
rap
rop
scr
search
stack
time
zoom

Sel:asm.arch

/ (fcn) entry0 42
|      ;-- entry0:
|      0x00404890  31ed      xor ebp, ebp
|      0x00404892  4989d1    mov r9, rdx
|      0x00404895  5e        pop rsi
|      0x00404896  4889e2    mov rdx, rsp
|      0x00404899  4883e4f0  and rsp, 0xfffffffffffff0
```

Example switch to pseudo disassembly:

```
[EvalSpace < Variables: asm.arch]
```

```
asm.functions = true
asm.indent = false
asm.lbytes = true
asm.lines = true
asm.linescall = false
asm.linesout = true
asm.linesright = false
asm.linesstyle = false
asm.lineswide = false
asm.linewidth = 7
asm.maxrefs = 5
asm.middle = false
asm.nbytes = 6
asm.offset = true
asm.os = linux
asm.parser = x86.pseudo
> asm.pseudo = false
asm.reloff = false
asm.section = false
asm.segoff = false
asm.size = false
asm.stackptr = false
asm.syntax = intel
asm.tabs = 0
asm.trace = false
asm.tracespace = false
asm.ucase = false
asm.vars = true
asm.varsub = true
asm.varxs = false
asm.xrefs = true
```

Selected: asm.pseudo (Enable pseudo syntax)

```
/ (fcn) entry0 42
|   ;-- entry0:
|   0x00404890  31ed      xor    ebp, ebp
|   0x00404892  4989d1    mov    r9, rdx
|   0x00404895  5e        pop    rsi
|   0x00404896  4889e2    mov    rdx, rsp
|   0x00404899  4883e4f0  and    rsp, 0xfffffffffffffff0
```

```
[EvalSpace < Variables: asm.arch]
```

```
asm.functions = true
asm.indent = false
asm.lbytes = true
asm.lines = true
asm.linescall = false
asm.linesout = true
asm.linesright = false
asm.linesstyle = false
asm.lineswide = false
asm.lineWidth = 7
asm.maxrefs = 5
asm.middle = false
asm.nbytes = 6
asm.offset = true
asm.os = linux
asm.parser = x86.pseudo
> asm.pseudo = true
asm.reloff = false
asm.section = false
asm.segoff = false
asm.size = false
asm.stackptr = false
asm.syntax = intel
asm.tabs = 0
asm.trace = false
asm.tracespace = false
asm.ucase = false
asm.vars = true
asm.varsub = true
asm.varxs = false
asm.xrefs = true
```

Selected: asm.pseudo (Enable pseudo syntax)

```
/ (fcn) entry0 42
|      ;-- entry0:
|      0x00404890  31ed          ebp = 0
|      0x00404892  4989d1        r9 = rdx
|      0x00404895  5e             pop rsi
|      0x00404896  4889e2        rdx = rsp
|      0x00404899  4883e4f0      rsp &= 0xfffffffffffff0
```

Visual Panels

Concept

Visual Panels is characterized by the following core functionalities:

1. Split Screen
2. Display multiple screens such as Symbols, Registers, Stack, as well as customized panels
3. Menu will cover all those commonly used commands for you so that you don't have to memorize any of them

CUI met some useful GUI as the menu, that is Visual Panels.

Overview

The screenshot shows the Visual Panels interface with four main panes:

- Graph**: Shows a call graph with nodes representing functions like `main`, `strdup`, `obstack_malloc`, etc. Nodes are color-coded (blue for functions, grey for symbols).
- Disassembly**: Displays assembly code for various functions. It includes comments from the C code above the assembly, assembly mnemonics, and memory addresses.
- Symbols**: Shows a tree view of symbols, including global variables and function pointers. It highlights the current symbol being examined.
- Registers**: Shows the state of CPU registers at the current instruction. It includes register names, values, and flags.

Commands

```

| Panels commands:
| ?      show this help
| !      run r2048 game
| .      seek to PC or entrypoint
| :      run r2 command in prompt
| _      start the hud input mode
| |      split the current panel vertically
| -      split the current panel horizontally
| *      show pseudo code/r2dec in the current panel
| [1-9]  follow jmp/call identified by shortcut (like ;[1])
| b      browse symbols, flags, configurations, classes, etc
| c      toggle cursor
| C      toggle color
| d      define in the current address. Same as Vd
| D      show disassembly in the current panel
| e      change title and command of current panel
| g      show graph in the current panel
| hjkl  move around (left-down-up-right)
| HL    resize panels horizontally
| JK    scroll panels vertically by page
| i      insert hex
| m      move to the menu
| M      open new custom frame
| nN    create new panel with given command
| r      toggle jmphints/leahints
| o      go/seek to given offset
| pP    seek to next or previous scr.nkey
| q      quit, back to visual mode
| ss    step in / step over
| uU    undo / redo seek
| V      go to the graph mode
| w      change the current layout of the panels
| X      close current panel

```

Basic Usage

Use `tab` to move around the panels until you get to the targeted panel. Then, use `hjkl`, just like in vim, to scroll the panel you are currently on. Use `s` and `S` to step over/in, and all the panels should be updated dynamically while you are debugging. Either in the Registers or Stack panels, you can edit the values by inserting hex. This will be explained later. While hitting `tab` can help you moving between panels, it is highly recommended to use `m` to open the menu. As usual, you can use `hjkl` to move around the menu and will find tons of useful stuff there.

Split Screen

`|` is for the vertical and `-` is for the horizontal split. You can delete any panel by pressing `x`.

Edit Values

Either in the Register or Stack panel, you can edit the values. Use `c` to activate cursor mode and you can move the cursor by pressing `hjk1`, as usual. Then, hit `i`, just like the insert mode of vim, to insert a value.

Searching for Bytes

The radare2 search engine is based on work done by esteve, plus multiple features implemented on top of it. It supports multiple keyword searches, binary masks, and hexadecimal values. It automatically creates flags for search hit locations ease future referencing.

Search is initiated by `/` command.

```
[0x00000000]> /?
|Usage: /[!bf] [arg]Search stuff (see 'e??search' for options)
|Use io.va for searching in non virtual addressing spaces
| / foo\x00          search for string 'foo\0'
| /j foo\x00          search for string 'foo\0' (json output)
| /! ff              search for first occurrence not matching, command modifier
| /!x 00              inverse hexa search (find first byte != 0x00)
| /+ /bin/sh         construct the string with chunks
| //                repeat last search
| /a jmp eax        assemble opcode and search its bytes
| /A jmp             find analyzed instructions of this type (/A? for help)
| /b                search backwards, command modifier, followed by other command
d
| /B                search recognized RBin headers
| /c jmp [esp]       search for asm code matching the given string
| /ce rsp,rbp        search for esil expressions matching
| /C[ar]            search for crypto materials
| /d 101112          search for a deltified sequence of bytes
| /e /E.F/i          match regular expression
| /E esil-expr      offset matching given esil expressions %=% here
| /f                search forwards, command modifier, followed by other command
| /F file [off] [sz] search contents of file with offset and size
| /g[g] [from]       find all graph paths A to B (/gg follow jumps, see search.co
unt and
anal.depth)
| /h[t] [hash] [len] find block matching this hash. See ph
| /i foo             search for string 'foo' ignoring case
| /m magicfile       search for matching magic file (use blocksize)
| /M                search for known filesystems and mount them automatically
| /o [n]             show offset of n instructions backward
| /O [n]             same as /o, but with a different fallback if anal cannot be
used
| /p patternsize     search for pattern of given size
| /P patternsize     search similar blocks
| /r[erwx][?] sym.printf analyze opcode reference an offset (/re for esil)
| /R [grepopcode]    search for matching ROP gadgets, semicolon-separated
| /s                search for all syscalls in a region (EXPERIMENTAL)
| /v[1248] value     look for an `cfg.bigendian` 32bit value
| /V[1248] min max   look for an `cfg.bigendian` 32bit value in range
| /w foo             search for wide string 'f\00\00\00'
| /wi foo            search for wide string ignoring case 'f\00\00\00'
| /x ff..33          search for hex string ignoring some nibbles
| /x ff0033          search for hex string
| /x ff43:ffd0       search for hexpair with mask
| /z min max         search for strings of given size
```

Because everything is treated as a file in radare2, it does not matter whether you search in a socket, a remote device, in process memory, or a file.

Basic Search

A basic search for a plain text string in a file would be something like:

```
$ r2 -q -c "/ lib" /bin/ls
Searching 3 bytes from 0x00400000 to 0x0041ae08: 6c 69 62
hits: 9
0x00400239 hit0_0 "lib64/ld-linux-x86-64.so.2"
0x00400f19 hit0_1 "libselinux.so.1"
0x00400fae hit0_2 "librt.so.1"
0x00400fc7 hit0_3 "libacl.so.1"
0x00401004 hit0_4 "libc.so.6"
0x004013ce hit0_5 "libc_start_main"
0x00416542 hit0_6 "libs/"
0x00417160 hit0_7 "lib/xstrtol.c"
0x00417578 hit0_8 "lib"
```

As can be seen from the output above, radare2 generates a "hit" flag for every entry found. You can then use the `ps` command to see the strings stored at the offsets marked by the flags in this group, and they will have names of the form `hit0_<index>`:

```
[0x00404888]> / ls
...
[0x00404888]> ps @ hit0_0
lseek
```

You can search for wide-char strings (e.g., unicode letters) using the `/w` command:

```
[0x0000000000]> /w Hello
0 results found.
```

To perform a case-insensitive search for strings use `/i`:

```
[0x0040488f]> /i Stallman
Searching 8 bytes from 0x00400238 to 0x0040488f: 53 74 61 6c 6c 6d 61 6e
[# ]hits: 004138 < 0x0040488f hits = 0
```

It is possible to specify hexadecimal escape sequences in the search string by prepending them with "\x":

```
[0x0000000000]> / \xFELF
```

But, if you are searching for a string of hexadecimal values, you're probably better off using the `/x` command:

```
[0x00000000]> /x 7F454C46
```

Once the search is done, the results are stored in the `searches` flag space.

```
[0x00000000]> fs
0    0 . strings
1    0 . symbols
2    6 . searches

[0x00000000]> f
0x000000135 512 hit0_0
0x00000b71 512 hit0_1
0x00000bad 512 hit0_2
0x00000bdd 512 hit0_3
0x00000bfb 512 hit0_4
0x00000f2a 512 hit0_5
```

To remove "hit" flags after you do not need them anymore, use the `f- hit*` command.

Often, during long search sessions, you will need to launch the latest search more than once. You can use the `//` command to repeat the last search.

```
[0x00000f2a]> //      ; repeat last search
```

Configuring Search Options

The radare2 search engine can be configured through several configuration variables, modifiable with the `e` command.

```
e cmd.hit = x      ; radare2 command to execute on every search hit
e search.distance = 0 ; search string distance
e search.in = [foo]   ; pecify search boundarie. Supported values are listed under e s
search.in=??
e search.align = 4    ; only show search results aligned by specified boundary.
e search.from = 0     ; start address
e search.to = 0       ; end address
e search.asmstr = 0    ; search for string instead of assembly
e search.flags = true ; if enabled, create flags on hits
```

The `search.align` variable is used to limit valid search hits to certain alignment. For example, with `e search.align=4` you will see only hits found at 4-bytes aligned offsets.

The `search.flags` boolean variable instructs the search engine to flag hits so that they can be referenced later. If a currently running search is interrupted with `ctrl-c` keyboard sequence, current search position is flagged with `search_stop`.

Pattern Matching Search

The `/p` command allows you to apply repeated pattern searches on IO backend storage. It is possible to identify repeated byte sequences without explicitly specifying them. The only command's parameter sets minimum detectable pattern length. Here is an example:

```
[0x00000000]> /p 10
```

This command output will show different patterns found and how many times each of them is encountered.

Search Automation

The `cmd.hit` configuration variable is used to define a radare2 command to be executed when a matching entry is found by the search engine. If you want to run several commands, separate them with `;`. Alternatively, you can arrange them in a separate script, and then invoke it as a whole with `. script-file-name` command. For example:

```
[0x00404888]> e cmd.hit = p8 8
[0x00404888]> / lib
Searching 3 bytes from 0x00400000 to 0x0041ae08: 6c 69 62
hits: 9
0x00400239 hit4_0 "lib64/ld-linux-x86-64.so.2"
31ed4989d15e4889
0x00400f19 hit4_1 "libselinux.so.1"
31ed4989d15e4889
0x00400fae hit4_2 "librt.so.1"
31ed4989d15e4889
0x00400fc7 hit4_3 "libacl.so.1"
31ed4989d15e4889
0x00401004 hit4_4 "libc.so.6"
31ed4989d15e4889
0x004013ce hit4_5 "libc_start_main"
31ed4989d15e4889
0x00416542 hit4_6 "libs/"
31ed4989d15e4889
0x00417160 hit4_7 "lib/xstrtol.c"
31ed4989d15e4889
0x00417578 hit4_8 "lib"
31ed4989d15e4889
```

Searching Backwards

Sometimes you want to find a keyword backwards. This is, before the current offset, to do this you can seek back and search forward by adding some search.from/to restrictions, or use the `/b` command.

```
[0x100001200]> / nop
0x100004b15 hit0_0 .STUwabcdefghijklmnoprstuvwxyzbin/ls.
0x100004f50 hit0_1 .STUwabcdefghijklmnoprstuvwxyz1] [file .
[0x100001200]> /b nop
[0x100001200]> s 0x100004f50p
[0x100004f50]> /b nop
0x100004b15 hit2_0 .STUwabcdefghijklmnoprstuvwxyzbin/ls.
[0x100004f50]>
```

Note that `/b` is doing the same as `/`, but backward, so what if we want to use `/x` backward? We can use `/bx`, and the same goes for other search subcommands:

```
[0x100001200]> /x 90
0x100001a23 hit1_0 90
0x10000248f hit1_1 90
0x1000027b2 hit1_2 90
0x100002b2e hit1_3 90
0x1000032b8 hit1_4 90
0x100003454 hit1_5 90
0x100003468 hit1_6 90
0x10000355b hit1_7 90
0x100003647 hit1_8 90
0x1000037ac hit1_9 90
0x10000389c hit1_10 90
0x100003c5c hit1_11 90

[0x100001200]> /bx 90
[0x100001200]> s 0x10000355b
[0x10000355b]> /bx 90
0x100003468 hit3_0 90
0x100003454 hit3_1 90
0x1000032b8 hit3_2 90
0x100002b2e hit3_3 90
0x1000027b2 hit3_4 90
0x10000248f hit3_5 90
0x100001a23 hit3_6 90
[0x10000355b]>
```


Assembler Search

If you want to search for a certain assembler opcodes, you can either use `/c` or `/a` commands.

The command `/c jmp [esp]` searches for the specified category of assembly mnemonic:

```
[0x00404888]> /c jmp qword [rdx]
f hit_0 @ 0x0040e50d    # 2: jmp qword [rdx]
f hit_1 @ 0x00418dbb    # 2: jmp qword [rdx]
f hit_2 @ 0x00418fcf    # 3: jmp qword [rdx]
f hit_3 @ 0x004196ab    # 6: jmp qword [rdx]
f hit_4 @ 0x00419bf3    # 3: jmp qword [rdx]
f hit_5 @ 0x00419c1b    # 3: jmp qword [rdx]
f hit_6 @ 0x00419c43    # 3: jmp qword [rdx]
```

The command `/a jmp eax` assembles a string to machine code, and then searches for the resulting bytes:

```
[0x00404888]> /a jmp eax
hits: 1
0x004048e7 hit3_0 ffe00f1f8000000000b8
```

Searching for AES Keys

Thanks to Victor Muñoz, radare2 now has support of the algorithm he developed, capable of finding expanded AES keys with `/ca` command. It searches from current seek position up to the `search.distance` limit, or until end of file is reached. You can interrupt current search by pressing `ctrl-c`. For example, to look for AES keys in physical memory of your system:

```
$ sudo r2 /dev/mem  
[0x00000000]> /Ca  
0 AES keys found
```

Disassembling

Disassembling in radare is just a way to represent an array of bytes. It is handled as a special print mode within `p` command.

In the old times, when the radare core was smaller, the disassembler was handled by an external rsc file. That is, radare first dumped current block into a file, and then simply called `objdump` configured to disassemble for Intel, ARM or other supported architectures.

It was a working and unix friendly solution, but it was inefficient as it repeated the same expensive actions over and over, because there were no caches. As a result, scrolling was terribly slow.

So there was a need to create a generic disassembler library to support multiple plugins for different architectures. We can list the current loaded plugins with

```
$ rasm2 -L
```

Or from inside radare2:

```
> e asm.arch=??
```

This was many years before capstone appeared. So r2 was using udis86 and olly disassemblers, many gnu (from binutils).

Nowadays, the disassembler support is one of the basic features of radare. It now has many options, endianness, including target architecture flavor and disassembler variants, among other things.

To see the disassembly, use the `pd` command. It accepts a numeric argument to specify how many opcodes of current block you want to see. Most of the commands in radare consider the current block size as the default limit for data input. If you want to disassemble more bytes, set a new block size using the `b` command.

```
[0x0000000000]> b 100      ; set block size to 100
[0x0000000000]> pd        ; disassemble 100 bytes
[0x0000000000]> pd 3      ; disassemble 3 opcodes
[0x0000000000]> pd 30     ; disassemble 30 bytes
```

The `pd` command works like `pd` but accepts the number of input bytes as its argument, instead of the number of opcodes.

The "pseudo" syntax may be somewhat easier for a human to understand than the default assembler notations. But it can become annoying if you read lots of code. To play with it:

```
[0x00405e1c]> e asm.pseudo = true
[0x00405e1c]> pd 3
; JMP XREF from 0x00405dfa (fcn.00404531)
0x00405e1c 488b9424a80. rdx = [rsp+0x2a8]
0x00405e24 64483314252. rdx ^= [fs:0x28]
0x00405e2d 4889d8        rax = rbx

[0x00405e1c]> e asm.syntax = intel
[0x00405e1c]> pd 3
; JMP XREF from 0x00405dfa (fcn.00404531)
0x00405e1c 488b9424a80. mov rdx, [rsp+0x2a8]
0x00405e24 64483314252. xor rdx, [fs:0x28]
0x00405e2d 4889d8        mov rax, rbx

[0x00405e1c]> e asm.syntax=att
[0x00405e1c]> pd 3
; JMP XREF from 0x00405dfa (fcn.00404531)
0x00405e1c 488b9424a80. mov 0x2a8(%rsp), %rdx
0x00405e24 64483314252. xor %fs:0x28, %rdx
0x00405e2d 4889d8        mov %rbx, %rax
```

Adding Metadata to Disassembly

The typical work involved in reversing binary files makes powerful annotation capabilities essential. Radare offers multiple ways to store and retrieve such metadata.

By following common basic UNIX principles, it is easy to write a small utility in a scripting language which uses `objdump`, `otool` or any other existing utility to obtain information from a binary and to import it into radare. For example, take a look at `idc2r.py` shipped with [radare2ida](#). To use it, invoke it as `idc2r.py file.idc > file.r2`. It reads an IDC file exported from an IDA Pro database and produces an r2 script containing the same comments, names of functions and other data. You can import the resulting 'file.r2' by using the dot `.` command of radare:

```
[0x00000000]> . file.r2
```

The `.` command is used to interpret Radare commands from external sources, including files and program output. For example, to omit generation of an intermediate file and import the script directly you can use this combination:

```
[0x00000000]> .!idc2r.py < file.idc
```

Please keep in mind that importing IDA Pro metadata from IDC dump is deprecated mechanism and might not work in the future. The recommended way to do it - use [python-idb-based](#) `ida2r2.py` which opens IDB files directly without IDA Pro installed.

The `c` command is used to manage comments and data conversions. You can define a range of program's bytes to be interpreted as either code, binary data or string. It is also possible to execute external code at every specified flag location in order to fetch some metadata, such as a comment, from an external file or database.

There are many different metadata manipulation commands, here is the glimpse of all of them:

```
[0x00404cc0]> C?
|Usage: C[-LCvsdfm*?][*?][...] # Metadata management
| C                         list meta info in human friendly form
| C*                        list meta info in r2 commands
| C[Chsdmf]                  list comments/hidden/strings/data/magic/formatted in hu
man friendly form
| C[Chsdmf]*                list comments/hidden/strings/data/magic/formatted in r2
commands
| C- [len] [[@]addr]         delete metadata at given address range
| CL[-][*] [file:line] [addr] show or add 'code line' information (bininfo)
| CS[-][space]               manage meta-spaces to filter comments, etc..
| CC[?] [-] [comment-text] [@addr] add/remove comment
| CC.[addr]                  show comment in current address
| CC! [@addr]                 edit comment with $EDITOR
| CCA[-at][at] [text] [@addr] add/remove comment at given address
| CCU [comment-text] [@addr] add unique comment
| Cv[bsr][?]                add comments to args
| Cs[?] [-] [size] [@addr]   add string
| Cz[@addr]                  add string (see Cs?)
| Ch[-] [size] [@addr]      hide data
| Cd[-] [size] [repeat] [@addr] hexdump data array (Cd 4 10 == dword [10])
| Cf[?][-] [sz] [0|cnt][fmt] [a0 a1...] [@addr] format memory (see pf?)
| CF[sz] [fcn-sign...] [@addr] function signature
| Cm[-] [sz] [fmt...] [@addr] magic parse (see pm?)
```

Simply to add the comment to a particular line/address you can use `ca` command:

```
[0x00000000]> CCA 0x00000002 this guy seems legit
[0x00000000]> pd 2
0x00000000 0000      add [rax], al
;      this guy seems legit
0x00000002 0000      add [rax], al
```

The `c?` family of commands lets you mark a range as one of several kinds of types. Three basic types are: code (disassembly is done using `asm.arch`), data (an array of data elements) or string. Use the `cs` command to define a string, use the `cd` command for defining an array of data elements, and use the `cf` command to define more complex data structures like structs.

Annotating data types is most easily done in visual mode, using the "d" key, short for "data type change". First, use the cursor to select a range of bytes (press `c` key to toggle cursor mode and use `HJKL` keys to expand selection), then press 'd' to get a menu of possible actions/types. For example, to mark the range as a string, use the 's' option from the menu. You can achieve the same result from the shell using the `cs` command:

```
[0x00000000]> f string_foo @ 0x800
[0x00000000]> Cs 10 @ string_foo
```

The `cf` command is used to define a memory format string (the same syntax used by the `pf` command). Here's an example:

```
[0x7fd9f13ae630]> Cf 16 2xi foo bar
[0x7fd9f13ae630]> pd
;-- rip:
0x7fd9f13ae630 format 2xi foo bar {
0x7fd9f13ae630 [0] {
    foo : 0x7fd9f13ae630 = 0xe8e78948
    bar : 0x7fd9f13ae634 = 14696
}
0x7fd9f13ae638 [1] {
    foo : 0x7fd9f13ae638 = 0x8bc48949
    bar : 0x7fd9f13ae63c = 571928325
}
} 16
0x7fd9f13ae633      e868390000  call 0x7fd9f13b1fa0
0x7fd9f13ae638      4989c4      mov r12, rax
```

The `[sz]` argument to `cf` is used to define how many bytes the struct should take up in the disassembly, and is completely independent from the size of the data structure defined by the format string. This may seem confusing, but has several uses. For example, you may want to see the formatted structure displayed in the disassembly, but still have those locations be visible as offsets and with raw bytes. Sometimes, you find large structures, but only identified a few fields, or only interested in specific fields. Then, you can tell r2 to display only those fields, using the format string and using 'skip' fields, and also have the disassembly continue after the entire structure, by giving it full size using the `sz` argument.

Using `cf`, it's easy to define complex structures with simple oneliners. See `pf?` for more information. Remember that all these `c` commands can also be accessed from the visual mode by pressing the `d` (data conversion) key. Note that unlike `t` commands `cf` doesn't change analysis results. It is only a visual boon.

Sometimes just adding a single line of comments is not enough, in this case radare2 allows you to create a link for a particular text file. You can use it with `cc` command or by pressing `,` key in the visual mode. This will open an `$EDITOR` to create a new file, or if filename does exist, just will create a link. It will be shown in the disassembly comments:

```
[0x000003af7 11% 290 /bin/ls]> pd $r @ main+55 # 0x3af7
|0x000003af7  call sym.imp.setlocale      ;[1] ; ,(locale-help.txt) ; char *setlocale
(int category, const char *locale)
|0x000003afc  lea rsi, str.usr_share_locale ; 0x179cc ; "/usr/share/locale"
|0x000003b03  lea rdi, [0x000179b2]        ; "coreutils"
|0x000003b0a  call sym.imp.bindtextdomain ;[2] ; char *bindtextdomain(char *domainname,
                           char *dirname)
```

Note `,(locale-help.txt)` appeared in the comments, if we press `,` again in the visual mode, it will open the file. Using this mechanism we can create a long descriptions of some particular places in disassembly, link datasheets or related articles.

ESIL

ESIL stands for 'Evaluable Strings Intermediate Language'. It aims to describe a [Forth](#))-like representation for every target CPU opcode semantics. ESIL representations can be evaluated (interpreted) in order to emulate individual instructions. Each command of an ESIL expression is separated by a comma. Its virtual machine can be described as this:

```
while ((word=haveCommand())) {
    if (word.isOperator()) {
        esilOperators[word](esil);
    } else {
        esil.push (word);
    }
    nextCommand();
}
```

As we can see ESIL uses a stack-based interpreter similar to what is commonly used for calculators. You have two categories of inputs: values and operators. A value simply gets pushed on the stack, an operator then pops values (its arguments if you will) off the stack, performs its operation and pushes its results (if any) back on. We can think of ESIL as a post-fix notation of the operations we want to do.

So let's see an example:

```
4, esp, -=, ebp, esp, =[4]
```

Can you guess what this is? If we take this post-fix notation and transform it back to in-fix we get

```
esp -= 4
4bytes(dword) [esp] = ebp
```

We can see that this corresponds to the x86 instruction `push ebp` ! Isn't that cool? The aim is to be able to express most of the common operations performed by CPUs, like binary arithmetic operations, memory loads and stores, processing syscalls. This way if we can transform the instructions to ESIL we can see what a program does while it is running even for the most cryptic architectures you definitely don't have a device to debug on for.

Use ESIL

Using visual mode is great to inspect the esil evaluations.

There are 2 environment variables that are important for watching what a program does:

```
[0x00000000]> e asm.emu = true
[0x00000000]> e asm.emustr = true    # for version 2.2 and earlier
[0x00000000]> e asm.emu.str = true   # for version 2.3 and earlier
```

`asm.emu` tells r2 if you want ESIL information to be displayed. If it is set to true you will see comments appear to the right of your disassembly that tell you how the contents of registers and memory addresses are changed by the current instruction. For example if you have an instruction that subtracts a value from a register it tells you what the value was before and what it becomes after. This is super useful so you don't have to sit there yourself and track which value goes where.

One problem with this is that it is a lot of information to take in at once and sometimes you simply don't need it. r2 has a nice compromise for this. That is what the `asm.emu.str` variable is for (`asm.emustr` on 2.2 and earlier). Instead of this super verbose output with every register value, this only adds really useful information to the output, e.g., strings that are found at addresses a program uses or whether a jump is likely to be taken or not.

The third important variable is `asm.esil`. This switches your disassembly to no longer show you the actual disassembled instructions, but instead now shows you corresponding ESIL expressions that describe what the instruction does. So if you want to take a look at how instructions are expressed in ESIL simply set "asm.esil" to true.

```
[0x00000000]> e asm.esil = true
```

In visual mode you can also toggle this by simply typing `o`.

ESIL Commands

- "ae" : Evaluate ESIL expression.

```
[0x00000000]> "ae 1,1,+"  
0x2  
[0x00000000]>
```

- "aes" : ESIL Step.

```
[0x00000000]> aes
[0x00000000]>10aes
```

- "aeso" : ESIL Step Over.

```
[0x00000000]> aeso
[0x00000000]>10aes0
```

- "aesu" : ESIL Step Until.

```
[0x00001000]> aesu 0x1035
ADDR BREAK
[0x00001019]>
```

- "ar" : Show/modify ESIL registry

```
[0x00001ec7]> ar r_00 = 0x1035
[0x00001ec7]> ar r_00
0x00001035
[0x00001019]>
```

ESIL Instruction Set

Here is the complete instruction set used by the ESIL VM:

ESIL Opcode	Operands	Name	Operation	example
TRAP	src	Trap	Trap signal	
\$	src	Syscall	syscall	
\$\$	src	Instruction address	Get address of current instruction stack=instruction address	
==	src,dst	Compare	stack = (dst == src); update_eflags(dst - src)	
<	src,dst	Smaller (signed comparison)	stack = (dst < src); update_eflags(dst - src)	[0x0000000]> "ae 1,5,<" 0x0 [0x00000000]> "ae 5,5" 0x0"

<code><=</code>	src,dst	Smaller or Equal (signed comparison)	stack = (dst <= src) ; update_eflags(dst - src)	[0x00000000]> "ae 1,5,<" 0x0 [0x00000000]> "ae 5,5" 0x1"
<code>></code>	src,dst	Bigger (signed comparison)	stack = (dst > src) ; update_eflags(dst - src)	[0x00000000]> "ae 1,5,>" 0x1 [0x00000000]> "ae 5,5,>" 0x0
<code>>=</code>	src,dst	Bigger or Equal (signed comparison)	stack = (dst >= src) ; update_eflags(dst - src)	[0x00000000]> "ae 1,5,>=" 0x1 [0x00000000]> "ae 5,5,>=" 0x1
<code><<</code>	src,dst	Shift Left	stack = dst << src	[0x00000000]> "ae 1,1,<<" 0x2 [0x00000000]> "ae 2,1,<<" 0x4
<code>>></code>	src,dst	Shift Right	stack = dst >> src	[0x00000000]> "ae 1,4,>>" 0x2 [0x00000000]> "ae 2,4,>>" 0x1
<code><<<</code>	src,dst	Rotate Left	stack=dst ROL src	[0x00000000]> "ae 31,1,<<<" 0x80000000 [0x00000000]> "ae 32,1,<<<" 0x1
<code>>>></code>	src,dst	Rotate Right	stack=dst ROR src	[0x00000000]> "ae 1,1,>>>" 0x80000000 [0x00000000]> "ae 32,1,>>>" 0x1
				[0x00000000]> "ae 1,1,&" 0x1 [0x00000000]> "ae 1,0,&" 0x0

&	src,dst	AND	stack = dst & src	[0x00000000]> 0,1,&" 0x0 [0x00000000]> 0,0,&" 0x0	"ae
	src,dst	OR	stack = dst src	[0x00000000]> 1,1, " 0x1 [0x00000000]> 1,0, " 0x1 [0x00000000]> 0,1, " 0x1 [0x00000000]> 0,0, " 0x0	"ae
^	src,dst	XOR	stack = dst ^ src	[0x00000000]> 1,1,^" 0x0 [0x00000000]> 1,0,^" 0x1 [0x00000000]> 0,1,^" 0x1 [0x00000000]> 0,0,^" 0x0	"ae
+	src,dst	ADD	stack = dst + src	[0x00000000]> 3,4,+" 0x7 [0x00000000]> 5,5,+" 0xa	"ae
-	src,dst	SUB	stack = dst - src	[0x00000000]> 3,4,-" 0x1 [0x00000000]> 5,5,-" 0x0 [0x00000000]> 4,3,-" 0xffffffffffffffffffff	"ae
*	src,dst	MUL	stack = dst * src	[0x00000000]> 3,4,*" 0xc [0x00000000]>	"ae

				5,5," 0x19
/	src,dst	DIV	stack = dst / src	[0x00000000]> "ae 2,4,/" 0x2 [0x00000000]> "ae 5,5,/" 0x1 [0x00000000]> "ae 5,9,/" 0x1
%	src,dst	MOD	stack = dst % src	[0x00000000]> "ae 2,4,"%" 0x0 [0x00000000]> "ae 5,5,"%" 0x0 [0x00000000]> "ae 5,9,"%" 0x4
!	src	NEG	stack = !!!src	[0x00000000]> "ae 1,!" 0x0 [0x00000000]> "ae 4,!" 0x0 [0x00000000]> "ae 0,!" 0x1
++	src	INC	stack = src++	[0x00000000]> ar r_00=0;ar r_00 0x00000000 [0x00000000]> "ae r_00,++" 0x1 [0x00000000]> ar r_00 0x00000000 [0x00000000]> "ae 1,++" 0x2
--	src	DEC	stack = src--	[0x00000000]> ar r_00=5;ar r_00 0x00000005 [0x00000000]> "ae r_00,--" 0x4 [0x00000000]> ar r_00 0x00000005 [0x00000000]> "ae 5,--" 0x4
				[0x00000000]> "ae

=	src,reg	EQU	reg = src	3,r_00,=" [0x00000000]> aer r_00 0x00000003 [0x00000000]> "ae r_00,r_01,=" [0x00000000]> aer r_01 0x00000003
+=	src,reg	ADD eq	reg = reg + src	[0x00000000]> ar r_01=5;ar r_00=0;ar r_00 0x00000000 [0x00000000]> "ae r_01,r_00,+=" [0x00000000]> ar r_00 0x00000005 [0x00000000]> "ae 5,r_00,+=" [0x00000000]> ar r_00 0x0000000a
-=	src,reg	SUB eq	reg = reg - src	[0x00000000]> "ae r_01,r_00,-=" [0x00000000]> ar r_00 0x00000004 [0x00000000]> "ae 3,r_00,-=" [0x00000000]> ar r_00 0x00000001
*=	src,reg	MUL eq	reg = reg * src	[0x00000000]> ar r_01=3;ar r_00=5;ar r_00 0x00000005 [0x00000000]> "ae r_01,r_00,*=" [0x00000000]> ar r_00 0x0000000f [0x00000000]> "ae 2,r_00,*=" [0x00000000]> ar r_00 0x0000001e
/=	src,reg	DIV eq	reg = reg / src	[0x00000000]> ar r_01=3;ar r_00=6;ar r_00 0x00000006 [0x00000000]> "ae r_01,r_00,/=" [0x00000000]> ar r_00 0x00000002 [0x00000000]> "ae

				1,r_00,/= [0x00000000]> ar r_00 0x00000002
%=	src,reg	MOD eq	reg = reg % src	[0x00000000]> ar r_01=3;ar r_00=7;ar r_00 0x00000007 [0x00000000]> "ae r_01,r_00,%=" [0x00000000]> ar r_00 0x00000001 [0x00000000]> ar r_00=9;ar r_00 0x00000009 [0x00000000]> "ae 5,r_00,%=" [0x00000000]> ar r_00 0x00000004
<=	src,reg	Shift Left eq	reg = reg << src	[0x00000000]> ar r_00=1;ar r_01=1;ar r_01 0x00000001 [0x00000000]> "ae r_00,r_01,<=" [0x00000000]> ar r_01 0x00000002 [0x00000000]> "ae 2,r_01,<=" [0x00000000]> ar r_01 0x00000008
>=	src,reg	Shift Right eq	reg = reg << src	[0x00000000]> ar r_00=1;ar r_01=8;ar r_01 0x00000008 [0x00000000]> "ae r_00,r_01,>=" [0x00000000]> ar r_01 0x00000004 [0x00000000]> "ae 2,r_01,>=" [0x00000000]> ar r_01 0x00000001
&=	src,reg	AND eq	reg = reg & src	[0x00000000]> ar r_00=2;ar r_01=6;ar r_01 0x00000006 [0x00000000]> "ae r_00,r_01,&=" [0x00000000]> ar r_01 0x00000002

&=	src,reg	AND eq	reg = reg & src	[0x00000000]> "ae 2,r_01,&=" [0x00000000]> ar r_01 0x00000002 [0x00000000]> "ae 1,r_01,&=" [0x00000000]> ar r_01 0x00000000
 =	src,reg	OR eq	reg = reg src	[0x00000000]> ar r_00=2;ar r_01=1;ar r_01 0x00000001 [0x00000000]> "ae r_00,r_01, = " [0x00000000]> ar r_01 0x00000003 [0x00000000]> "ae 4,r_01, = " [0x00000000]> ar r_01 0x00000007
^=	src,reg	XOR eq	reg = reg ^ src	[0x00000000]> ar r_00=2;ar r_01=0xab;ar r_01 0x000000ab [0x00000000]> "ae r_00,r_01,^= " [0x00000000]> ar r_01 0x000000a9 [0x00000000]> "ae 2,r_01,^= " [0x00000000]> ar r_01 0x000000ab
++=	reg	INC eq	reg = reg + 1	[0x00000000]> ar r_00=4;ar r_00 0x00000004 [0x00000000]> "ae r_00,++= " [0x00000000]> ar r_00 0x00000005
--=	reg	DEC eq	reg = reg - 1	[0x00000000]> ar r_00=4;ar r_00 0x00000004 [0x00000000]> "ae r_00,--= " [0x00000000]> ar r_00 0x00000003
				[0x00000000]> ar r_00=4;ar r_00 0x00000004

!=	reg	NOT eq	reg = !reg	r_00,!=" [0x00000000]> ar r_00 0x00000000 [0x00000000]> "ae r_00,!=" [0x00000000]> ar r_00 0x00000001
---	---	---	---	----- -----
=[] =[*] =[1] =[2] =[4] =[8]	src,dst	poke	*dst=src	[0x00010000]> "ae 0xdeadbeef,0x10000,=[4]," [0x00010000]> pxw 4@0x10000 0x00010000 0xdeadbeef [0x00010000]> "ae 0x0,0x10000,=[4]," [0x00010000]> pxw 4@0x10000 0x00010000 0x00000000
[] [*] [1] [2] [4] [8]	src	peek	stack=*src	[0x00010000]> w test@0x10000 [0x00010000]> "ae 0x10000,[4]," 0x74736574 [0x00010000]> ar r_00=0x10000 [0x00010000]> "ae r_00,[4]," 0x74736574
=[] =[1] =[2] =[4] =[8]	reg	nombre	code	[0x00000000]> [0x00000000]>
SWAP		Swap	Swap two top elements	SWAP
PICK	n	Pick	Pick nth element from the top of the stack	2,PICK
RPICK	m	Reverse Pick	Pick nth element from the base of the stack	0,RPICK
DUP		Duplicate	Duplicate top element in stack	DUP

			element in stack	
NUM		Numeric	If top element is a reference (register name, label, etc), dereference it and push its real value	NUM
CLEAR		Clear	Clear stack	CLEAR
BREAK		Break	Stops ESIL emulation	BREAK
GOTO	n	Goto	Jumps to Nth ESIL word	GOTO 5
TODO		To Do	Stops execution (reason: ESIL expression not completed)	TODO

ESIL Flags

ESIL VM has an internal state flags that are read only and can be used to export those values to the underlying target CPU flags. It is because the ESIL VM always calculates all flag changes, while target CPUs only update flags under certain conditions or at specific instructions.

Internal flags are prefixed with `$` character.

```

z      - zero flag, only set if the result of an operation is 0
b      - borrow, this requires to specify from which bit (example: $b4 - checks if borrow from bit 4)
c      - carry, same like above (example: $c7 - checks if carry from bit 7)
o      - overflow
p      - parity
r      - regsize (asm.bits/8 )
s      - sign
ds     - delay slot state
jt     - jump target
js     - jump target set
[0-9]* - Used to set flags and registers without having any side effects,
         i.e. setting esil_cur, esil_old and esil_lastsz.
         (example: "$0,of,=" to reset the overflow flag)

```

Syntax and Commands

A target opcode is translated into a comma separated list of ESIL expressions.

```
xor eax, eax      -> 0, eax, =, 1, zf, =
```

Memory access is defined by brackets operation:

```
mov eax, [0x80480]  -> 0x80480, [], eax, =
```

Default operand size is determined by size of operation destination.

```
movb $0, 0x80480  -> 0, 0x80480, =[1]
```

The `?{}` operator uses the value of its argument to decide whether to evaluate the expression in curly braces.

1. Is the value zero? -> Skip it.
2. Is the value non-zero? -> Evaluate it.

```
cmp eax, 123  -> 123, eax, ==, $z, zf, =
jz eax        -> zf, ?{}, eax, eip, =, }
```

If you want to run several expressions under a conditional, put them in curly braces:

```
zf, ?{}, eip, esp, =[[], eax, eip, =, $r, esp, -=, }
```

Whitespaces, newlines and other chars are ignored. So the first thing when processing a ESIL program is to remove spaces:

```
esil = r_str_replace (esil, " ", "", R_TRUE);
```

Syscalls need special treatment. They are indicated by '\$' at the beginning of an expression. You can pass an optional numeric value to specify a number of syscall. An ESIL emulator must handle syscalls. See (`r_esil_syscall`).

Arguments Order for Non-associative Operations

As discussed on IRC, current implementation works like this:

```
a, b, -      b - a
a, b, /=     b /= a
```

This approach is more readable, but it is less stack-friendly.

Special Instructions

NOPs are represented as empty strings. As it was said previously, syscalls are marked by '\$' command. For example, '0x80,\$'. It delegates emulation from the ESIL machine to a callback which implements syscalls for a specific OS/kernel.

Traps are implemented with the `<code>, TRAP` command. They are used to throw exceptions for invalid instructions, division by zero, memory read error, or any other needed by specific architectures.

Quick Analysis

Here is a list of some quick checks to retrieve information from an ESIL string. Relevant information will be probably found in the first expression of the list.

```
indexOf('[')    -> have memory references
indexOf("=[")   -> write in memory
indexOf("pc,=")  -> modifies program counter (branch, jump, call)
indexOf("sp,=")  -> modifies the stack (what if we found sp+= or sp-=?)
indexOf("=")     -> retrieve src and dst
indexOf(":")    -> unknown esil, raw opcode ahead
indexOf("$")    -> accesses internal esil vm flags ex: $z
indexOf("$")    -> syscall ex: 1,$
indexOf("TRAP") -> can trap
indexOf('++')   -> has iterator
indexOf('--')   -> count to zero
indexOf("?{")   -> conditional
equalsTo("")    -> empty string, aka nop (wrong, if we append pc+=x)
```

Common operations:

- Check dstreg
- Check srcreg
- Get destination
- Is jump
- Is conditional
- Evaluate
- Is syscall

CPU Flags

CPU flags are usually defined as single bit registers in the RReg profile. They are sometimes found under the 'flg' register type.

Variables

Properties of the VM variables:

1. They have no predefined bit width. This way it should be easy to extend them to 128, 256 and 512 bits later, e.g. for MMX, SSE, AVX, Neon SIMD.
2. There can be unbound number of variables. It is done for SSA-form compatibility.
3. Register names have no specific syntax. They are just strings.
4. Numbers can be specified in any base supported by RNum (dec, hex, oct, binary ...)
5. Each ESIL backend should have an associated RReg profile to describe the ESIL register specs.

Bit Arrays

What to do with them? What about bit arithmetics if use variables instead of registers?

Arithmetics

1. ADD ("+")
2. MUL ("**")
3. SUB ("-")
4. DIV ("/")
5. MOD ("%")

Bit Arithmetics

1. AND "&"
2. OR "|"
3. XOR "^"
4. SHL "<<"
5. SHR ">>"
6. ROL "<<<"
7. ROR ">>>"
8. NEG "!"

Floating Point Support

TODO

Handling x86 REP Prefix in ESIL

ESIL specifies that the parsing control-flow commands must be uppercase. Bear in mind that some architectures have uppercase register names. The corresponding register profile should take care not to reuse any of the following:

```
3,SKIP - skip N instructions. used to make relative forward GOTOS  
3,GOTO - goto instruction 3  
LOOP - alias for 0,GOTO  
BREAK - stop evaluating the expression  
STACK - dump stack contents to screen  
CLEAR - clear stack
```

Usage example:

rep cmpsb

```
cx,!,{BREAK},esi,[1],edi,[1]==,{BREAK},esi,++,edi,++,cx,--,0,GOTO
```

Unimplemented/unhandled Instructions

Those are expressed with the 'TODO' command. They act as a 'BREAK', but displays a warning message describing that an instruction is not implemented and will not be emulated. For example:

```
fmulp ST(1), ST(0)      =>      TODO,fmulp ST(1),ST(0)
```

ESIL Disassembly Example:

```
[0x1000010f8]> e asm.esil=true
[0x1000010f8]> pd $r @ entry0
0x1000010f8    55          8,rsp,-=,rbp,esp,=[8]
0x1000010f9    4889e5      rsp,rbp,=
0x1000010fc    4883c768    104,rdi,+=
0x100001100    4883c668    104,rsi,+=
0x100001104    5d          rsp,[8],rbp,=,8,esp,+=
0x100001105    e950350000  0x465a,rip,= ;[1]
0x10000110a    55          8,esp,-=,rbp,esp,=[8]
0x10000110b    4889e5      rsp,rbp,=
0x10000110e    488d4668    rsi,104,+ ,rax,=
0x100001112    488d7768    rdi,104,+ ,rsi,=
0x100001116    4889c7      rax,rdi,=
0x100001119    5d          rsp,[8],rbp,=,8,esp,+=
0x10000111a    e93b350000  0x465a,rip,= ;[1]
0x10000111f    55          8,esp,-=,rbp,esp,=[8]
0x100001120    4889e5      rsp,rbp,=
0x100001123    488b4f60    rdi,96,+ ,[8],rcx,=
0x100001127    4c8b4130    rcx,48,+ ,[8],r8,=
0x10000112b    488b5660    rsi,96,+ ,[8],rdx,=
0x10000112f    b801000000  1,eax,=
0x100001134    4c394230    rdx,48,+ ,[8],r8,==,cz,?=?
0x100001138    7f1a        sf,of,! ,^,zf,! ,&,?{,0x1154,rip,=,} ;[2]
0x10000113a    7d07        of,! ,sf,^,?{,0x1143,rip,} ;[3]
0x10000113c    b8ffffffff  0xffffffff, eax,= ; 0xffffffff
0x100001141    eb11        0x1154,rip,= ;[2]
0x100001143    488b4938    rcx,56,+ ,[8],rcx,=
0x100001147    48394a38    rdx,56,+ ,[8],rcx,==,cz,?=?
```

Introspection

To ease ESIL parsing we should have a way to express introspection expressions to extract data we want. For example, we may want to get the target address of a jump. The parser for ESIL expressions should offer API to make it possible to extract information by analyzing the expressions easily.

```
> ao~esil,opcode
opcode: jmp 0x10000465a
esil: 0x10000465a,rip,=
```

We need a way to retrieve the numeric value of 'rip'. This is a very simple example, but there are more complex, like conditional ones. We need expressions to be able to get:

- opcode type
- destination of jump
- condition depends on
- all regs modified (write)

- all regs accessed (read)

API HOOKS

It is important for emulation to be able to setup hooks in parser, so we can extend it to implement analysis without having to change parser again and again. That is, every time an operation is about to be executed, a user hook is called. It can be used for example to determine if `RIP` is going to change, or if the instruction updates the stack. Later, we can split that callback into several ones to have an event-based analysis API that may be extended in js like this:

```
esil.on('regset', function(){..  
esil.on('syscall', function(){esil.regset('rip'
```

For the API, see functions `hook_flag_read()` , `hook_execute()` , `hook_mem_read()` . A callback should return true if you want to override the action taken for a callback. For example, to deny memory reads in a region, or voiding memory writes, effectively making it read-only. Return false or 0 if you want to trace ESIL expression parsing.

Other operations that require bindings to external functionalities to work. In this case, `r_ref` and `r_io` . This must be defined when initializing the esil vm.

- Io Get/Set

```
Out ax, 44  
44,ax,:ou
```

- Selectors (cs,ds,gs...)

```
Mov eax, ds:[ebp+8]  
Ebp,8,+,:ds,eax,=
```

Data and Code Analysis

Radare2 has a very rich set of commands and configuration options to perform data and code analysis, to extract useful information from a binary, like pointers, string references, basic blocks, opcode data, jump targets, cross references and much more. These operations are handled by the `a` (analyze) command family:

```
|Usage: a[abdefFghoprstc] [...]
| aa[?]           analyze all (fcns + bbs) (aa0 to avoid sub renaming)
| a8 [hexpairs]   analyze bytes
| ab[b] [addr]    analyze block at given address
| abb [len]        analyze N basic blocks in [len] (section.size by default)
| abt [addr]      find paths in the bb function graph from current offset to given
address
| ac [cycles]     analyze which op could be executed in [cycles]
| ad[?]          analyze data trampoline (wip)
| ad [from] [to]  analyze data pointers to (from-to)
| ae[?] [expr]   analyze opcode eval expression (see ao)
| af[?]          analyze Functions
| aF              same as above, but using anal.depth=1
| ag[?] [options] draw graphs in various formats
| ah[?]          analysis hints (force opcode size, ...)
| ai [addr]       address information (show perms, stack, heap, ...)
| an [name] [@addr] show/rename/create whatever flag/function is used at addr
| ao[?] [len]     analyze Opcodes (or emulate it)
| a0[?] [len]     Analyze N instructions in M bytes
| ap              find prelude for current offset
| ar[?]          like 'dr' but for the esil vm. (registers)
| as[?] [num]    analyze syscall using dbg.reg
| av[?] [. ]     show vtables
| ax[?]          manage refs/xrefs (see also afix?)
```

In fact, `a` namespace is one of the biggest in radare2 tool and allows to control very different parts of the analysis:

- Code flow analysis
- Data references analysis
- Using loaded symbols
- Managing different type of graphs, like CFG and call graph
- Manage variables
- Manage types
- Emulation using ESIL VM
- Opcode introspection
- Objects information, like virtual tables

Code Analysis

Code analysis is a common technique used to extract information from assembly code.

Radare have different code analysis techniques implemented in the core and available in different commands.

As long as the whole functionalities of r2 are available with the API as well as using commands. This gives you the ability to implement your own analysis loops using any programming language, even with r2 oneliners, shellscripts, or analysis or core native plugins.

The analysis will show up the internal data structures to identify basic blocks, function trees and to extract opcode-level information.

The most common radare2 analysis command sequence is `aa`, which stands for "analyze all". That all is referring to all symbols and entrypoints. If your binary is stripped you will need to use other commands like aaa, aab, aar, aac or so.

Take some time to understand what each command does and the results after running them to find the best one for your needs.

```
[0x08048440]> aa
[0x08048440]> pdf @ main
; DATA XREF from 0x08048457 (entry0)
/ (fcn) fcn.08048648 141
|   ;-- main:
|   0x08048648    8d4c2404    lea ecx, [esp+0x4]
|   0x0804864c    83e4f0      and esp, 0xffffffff0
|   0x0804864f    ff71fc      push dword [ecx-0x4]
|   0x08048652    55          push ebp
|   ; CODE (CALL) XREF from 0x08048734 (fcn.080486e5)
|   0x08048653    89e5        mov ebp, esp
|   0x08048655    83ec28      sub esp, 0x28
|   0x08048658    894df4      mov [ebp-0xc], ecx
|   0x0804865b    895df8      mov [ebp-0x8], ebx
|   0x0804865e    8975fc      mov [ebp-0x4], esi
|   0x08048661    8b19        mov ebx, [ecx]
|   0x08048663    8b7104      mov esi, [ecx+0x4]
|   0x08048666    c744240c000. mov dword [esp+0xc], 0x0
|   0x0804866e    c7442408010. mov dword [esp+0x8], 0x1 ; 0x00000001
|   0x08048676    c7442404000. mov dword [esp+0x4], 0x0
|   0x0804867e    c7042400000. mov dword [esp], 0x0
|   0x08048685    e852fdffff  call sym..imp.ptrace
|       sym..imp.ptrace(unk, unk)
|   0x0804868a    85c0        test eax, eax
| ,=< 0x0804868c    7911        jns 0x804869f
| | 0x0804868e    c70424cf870. mov dword [esp], str.Don_tuseadebuguer_ ; 0x080487cf
| | 0x08048695    e882fdffff  call sym..imp.puts
| |     sym..imp.puts()
| | 0x0804869a    e80dfdffff  call sym..imp.abort
| |     sym..imp.abort()
| `-> 0x0804869f    83fb02      cmp ebx, 0x2
| ,==< 0x080486a2    7411        je 0x80486b5
|| 0x080486a4    c704240c880. mov dword [esp], str.Youmustgiveapasswordforusethisprogram_ ; 0x0804880c
|| 0x080486ab    e86cfdf000  call sym..imp.puts
||     sym..imp.puts()
|| 0x080486b0    e8f7fcffff  call sym..imp.abort
||     sym..imp.abort()
|`--> 0x080486b5    8b4604      mov eax, [esi+0x4]
|   0x080486b8    890424      mov [esp], eax
|   0x080486bb    e8e5feffff  call fcn.080485a5
|       fcn.080485a5() ; fcn.080484c6+223
|   0x080486c0    b800000000  mov eax, 0x0
|   0x080486c5    8b4df4      mov ecx, [ebp-0xc]
|   0x080486c8    8b5df8      mov ebx, [ebp-0x8]
|   0x080486cb    8b75fc      mov esi, [ebp-0x4]
|   0x080486ce    89ec        mov esp, ebp
|   0x080486d0    5d          pop ebp
|   0x080486d1    8d61fc      lea esp, [ecx-0x4]
\ 0x080486d4    c3          ret
```

In this example, we analyze the whole file (`aa`) and then print disassembly of the `main()` function (`pdf`). The `aa` command belongs to the family of autoanalysis commands and performs only the most basic autoanalysis steps. In radare2 there are many different types of the autoanalysis commands with a different analysis depth, including partial emulation: `aa` , `aaa` , `aab` , `aaaa` , ... There is also a mapping of those commands to the r2 CLI options: `r2 -A` , `r2 -AA` , and so on.

It is a common sense that completely automated analysis can produce non sequitur results, thus radare2 provides separate commands for the particular stages of the analysis allowing fine-grained control of the analysis process. Moreover, there is a treasure trove of configuration variables for controlling the analysis outcomes. You can find them in `anal.*` and `emu.* cfg` variables namespaces.

One of the most important "basic" analysis commands is a set of `af` subcommands. `af` means "analyze function". Using this command you can either allow automatic analysis of the particular function or perform completely manual one.

```
[0x0000000000]> af?
|Usage: af
| af ([name]) ([addr])      analyze functions (start at addr or $$)
| afr ([name]) ([addr])    analyze functions recursively
| af+ addr name [type] [diff]  hand craft a function (requires afb+)
| af- [addr]                clean all function analysis data (or function at addr)
| afb+ fcNA bbA sz [j] [f] ([t]( [d]))  add bb to function @ fcnaddr
| afb[?] [addr]              List basic blocks of given function
| afB 16                   set current function as thumb (change asm.bits)
| afC[lc] ([addr])@[addr]  calculate the Cycles (afC) or Cyclomatic Complexity (afCc)
| afc[?] type @[addr]     set calling convention for function
| afd[addr]                show function + delta for given offset
| aff                      re-adjust function boundaries to fit
| afF[1|0|]                fold/unfold/toggle
| afi [addr|fcn.name]     show function(s) information (verbose afi)
| afl[?] [l*] [fcn name]  list functions (addr, size, bbs, name) (see afll)
| afm name                 merge two functions
| afM name                 print functions map
| afn[?] name [addr]      rename name for function at address (change flag too)
| afna                     suggest automatic name for current offset
| afo [fcn.name]           show address for the function named like this
| afs [addr] [fcnsign]    get/set function signature at current address
| afS[stack_size]          set stack frame size for function at current address
| aft[?]                  type matching, type propagation
| afu [addr]                resize and analyze function from current address until addr
| afv[bsra]?               manipulate args, registers and variables in function
| afx                      list function references
```

One of the most challenging tasks while performing a function analysis - merge, crop or resize. As with other analysis commands you have two ways - semi-automatic and totally manual one. For the semi-automatic, you can use `afm <function name>` to merge current function with the function specified, `aff` to readjust function after analysis changes or function edits, `afu <address>` to do the resize and analysis of the current function until specified address.

Apart from those semi-automatic ways to edit/analyze the function, you can create it in complete manual mode with `af+` command and edit basic blocks of it using `afb` commands. Before changing the basic blocks of the function it is recommended to check the already presented ones:

```
[0x000003ac0]> afb
0x000003ac0 0x00003b7f 01:001A 191 f 0x00003b7f
0x00003b7f 0x00003b84 00:0000 5 j 0x00003b92 f 0x00003b84
0x00003b84 0x00003b8d 00:0000 9 f 0x00003b8d
0x00003b8d 0x00003b92 00:0000 5
0x00003b92 0x00003ba8 01:0030 22 j 0x00003ba8
0x00003ba8 0x00003bf9 00:0000 81
```

There are two very important commands: `afc` and `afB`. The latter is a must-know command for some platforms like ARM. It provides a way to change the "bitness" of the particular function. Basically, allowing to select between ARM and Thumb modes.

`afc` on the other side, allows to manually specify function calling convention. You can find more information on its usage in [calling conventions](#).

Recursive analysis

There are 4 important program wide half-automated analysis commands:

- `aab` - perform basic-block analysis ("Nucleus" algorithm)
- `aac` - analyze function calls from one (selected or current function)
- `aaf` - analyze all function calls
- `aar` - analyze data references
- `aad` - analyze pointers to pointers references

Those are only generic semi-automated reference searching algorithms. Radare2 provides a wide choice of manual references' creation of any kind. For this fine-grained control you can use `ax` commands.

```
|Usage: ax[?d-l*] # see also 'afx?'
| ax          list refs
| ax*         output radare commands
| ax addr [at] add code ref pointing to addr (from curseek)
| ax- [at]    clean all refs/refs from addr
| ax-*       clean all refs/refs
| axc addr [at] add generic code ref
| axC addr [at] add code call ref
| axg [addr]   show xrefs graph to reach current function
| axgj [addr]  show xrefs graph to reach current function in json format
| axd addr [at] add data ref
| axq          list refs in quiet/human-readable format
| axj          list refs in json format
| axF [flg-glob] find data/code references of flags
| axt [addr]   find data/code references to this address
| axf [addr]   find data/code references from this address
| axs addr [at] add string ref
```

The most commonly used `ax` commands are `axt` and `axf`, especially as a part of various r2pipe scripts. Lets say we see the string in the data or a code section and want to find all places it was referenced from, we should use `axt`:

```
[0x0001783a]> pd 2
;-- str.02x:
; STRING XREF from 0x00005de0 (sub.strlen_d50)
; CODE XREF from 0x00017838 (str.._s_s_s + 7)
0x0001783a      .string "%%%02x" ; len=7
;-- str.src_ls.c:
; STRING XREF from 0x0000541b (sub.free_b04)
; STRING XREF from 0x0000543a (sub.__assert_fail_41f + 27)
; STRING XREF from 0x00005459 (sub.__assert_fail_41f + 58)
; STRING XREF from 0x00005f9e (sub._setjmp_e30)
; CODE XREF from 0x0001783f (str.02x + 5)
0x00017841 .string "src/ls.c" ; len=9
[0x0001783a]> axt
sub.strlen_d50 0x5de0 [STRING] lea rcx, str.02x
(nofunc) 0x17838 [CODE] jae str.02x
```

Apart from predefined algorithms to identify functions there is a way to specify a function prelude with a configuration option `anal.prelude`. For example, like `e anal.prelude = 0x554889e5` which means

```
push rbp
mov rbp, rsp
```

on x86_64 platform. It should be specified _before any analysis commands.

Configuration

Radare2 allows to changing the behavior of almost any analysis stages or commands. There are different kinds of the configuration options:

- Flow control
- Basic blocks control
- References control
- IO/Ranges
- Jump tables analysis control
- Platform/target specific options

Control flow configuration

Two most commonly used options for changing the behavior of control flow analysis in radare2 are `anal.hasnext` and `anal.afterjump`. The first one allows forcing radare2 to continue the analysis after the end of the function, even if the next chunk of the code wasn't called anywhere, thus analyzing all of the available functions. The latter one allows forcing radare2 to continue the analysis even after unconditional jumps.

In addition to those we can also set `anal.ijmp` to follow the indirect jumps, continuing analysis; `anal.pushret` to analyze `push ...; ret` sequence as a jump; `anal.nopskip` to skip the NOP sequences at a function beginning.

For now, radare2 also allows you to change the maximum basic block size with `anal.bb.maxsize` option. The default value just works in most use cases, but it's useful to increase that for example when dealing with obfuscated code. Beware that some of basic blocks control options may disappear in the future in favor of more automated ways to set those.

For some unusual binaries or targets, there is an option `anal.noncode`. Radare2 doesn't try to analyze data sections as a code by default. But in some cases - malware, packed binaries, binaries for embedded systems, it is often a case. Thus - this option.

Reference control

The most crucial options that change the analysis results drastically. Sometimes some can be disabled to save the time and memory when analysing big binaries.

- `anal.jmpref` - to allow references creation for unconditional jumps
- `anal.cjmpref` - same, but for conditional jumps
- `anal.datarefs` - to follow the data references in code

- `anal.refstr` - search for strings in data references
- `anal.strings` - search for strings and creating references

Note that strings references control disabled by default because it increases analysis times.

Analysis ranges

There are a few options for this:

- `anal.limits` - enables the range limits for analysis operations
- `anal.from` - starting address of the limit range
- `anal.to` - the corresponding end of the limit range
- `anal.in` - specify search boundaries for analysis (`io.maps` , `io.sections.exec` , `dbg.maps` and many more - see `e anal.in=?` for the complete list)

Jump tables

Jump tables are being one of the trickiest targets in binary reverse engineering. There are hundreds of different types, the end result depending on the compiler/linker and LTO stages of optimization. Thus radare2 allows enabling some experimental jump tables detection algorithms using `anal.jmptbl` option. Eventually, algorithms moved into the default analysis loops once they start to work on every supported platform/target/testcase. Two more options can affect the jump tables analysis results too:

- `anal.ijmp` - follow the indirect jumps, some jump tables rely on them
- `anal.datarefs` - follow the data references, some jump tables use those

Platform specific controls

There are two common problems when analysing embedded targets: ARM/Thumb detection and MIPS GP value. In case of ARM binaries radare2 supports some autodetection of ARM/Thumb mode switches, but beware that it uses partial ESIL emulation, thus slowing the analysis process. If you will not like the results, particular functions' mode can be overridden with `aFB` command.

The MIPS GP problem is even trickier. It is a basic knowledge that GP value can be different not only for the whole program, but also for some functions. To partially solve that there are options `anal.gp` and `anal.gp2`. The first one sets the GP value for the whole program or particular function. The latter allows to "constantify" the GP value if some code is willing to change its value, always resetting it if the case. Those are heavily experimental and might be changed in the future in favor of more automated analysis.

Visuals

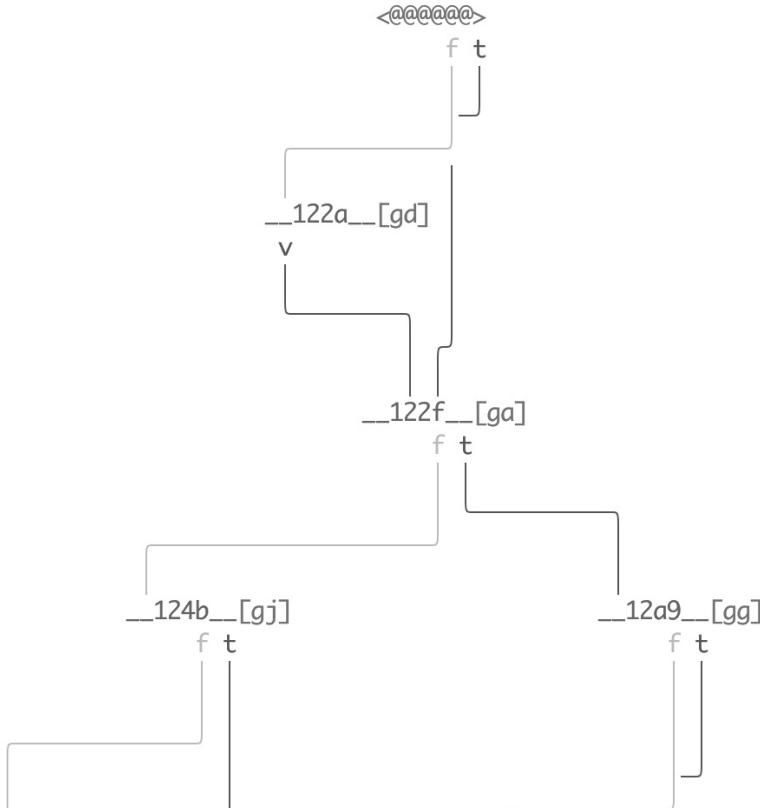
One of the easiest way to see and check the changes of the analysis commands and variables is to perform a scrolling in a `vv` special visual mode, allowing functions preview:

```
-[ functions ]-----
(a) add      (x)xrefs      (q)quit
(F) file     (c)calls      (g)go
(d) delete   (v)variables  (?)help
/* 0x00005480 43 entry0
0x000150f0 46 sym._obstack_allocated_p
0x00014fe0 179 sym._obstack_begin_1
0x00014fc0 158 sym._obstack_begin
0x00015130 97 sym._obstack_free
0x00015000 283 sym._obstack_newchunk
0x000151a0 38 sym._obstack_memory_used
0x000033f0 6 sym.imp._ctype_toupper_loc
0x000033e0 6 sym.imp._towlow
0x00003410 6 sym.imp._getchar
0x00003420 6 sym.imp._sigprocmask
0x00003430 6 sym.imp._sprintf_chk
0x00003440 6 sym.imp._raise
0x00000000 48 sym.imp.free
0x00003450 6 sym.imp.abort
0x00003460 6 sym.imp._errno_location
0x00003470 6 sym.imp.strncmp
0x00003480 6 sym.imp.localtime_r
0x00003490 6 sym.imp._exit
0x000034a0 6 sym.imp._strcpy
0x000034b0 6 sym.imp._fpending
0x000034c0 6 sym.imp.isatty
... Visual code review (pdf)
(fcn) entry0 43
entry0 () {
    xor ebp, ebp
    0x00005480 mov r9, rdx
    0x00005482 pop rsi
    0x00005486 mov rdx, rsp
    0x00005489 and rsp, 0xfffffffffffff0
    0x0000548d push rax
    0x0000548e push rsp
    0x0000548f lea r8, [0x00015e40]
    0x00005490 lea rcx, [0x00015dd0]
    0x00005493 lea rdi, [main]; section_.text, 0x3ac0 ; "AWAVAUATUS\x89\xfdH\x89\xf3H\x83
    0x00005496 call qword [reloc.__libc_start_main]; [0x21efc8:8]=0
    0x000054aa hit
}
```

When we want to check how analysis changes affect the result in the case of big functions, we can use minimap instead, allowing to see a bigger flow graph on the same screen size. To get into the minimap mode type `vv` then press `p` twice:

```
[0x100001200]> VV @ main (nodes 187 edges 266 zoom 0%) BB-MINI mouse:canvas-y mov-speed:5
```

```
[ 0x100001200 ]
;-- entry0:
;-- func.100001200:
;-- rip:
(fcn) main 2082
bp: 6 (vars 6, args 0)
sp: 0 (vars 0, args 0)
rg: 2 (vars 0, args 2)
    push rbp
    mov rbp, rsp
    push r15
    push r14
    push r13
    push r12
    push rbx
    sub rsp, 0x618
; arg2
    mov r15, rsi
; arg1
    mov r14d, edi
    lea rax, [local_240h]
    mov qword [local_30h], rax
    test r14d, r14d
[ga]jg 0x10000122f
```



This mode allows you to see the disassembly of each node separately, just navigate between them using `Tab` key.

Analysis hints

It is not an uncommon case that analysis results are not perfect even after you tried every single configuration option. This is where the "analysis hints" radare2 mechanism comes in. It allows to override some basic opcode or metainformation properties, or even to rewrite the whole opcode string. These commands are located under `ah` namespace:

```
|Usage: ah[lba-]Analysis Hints
| ah?                      show this help
| ah? offset                show hint of given offset
| ah                         list hints in human-readable format
| ah.                        list hints in human-readable format from current offset
| ah-                       remove all hints
| ah- offset [size]          remove hints at given offset
| ah* offset                 list hints in radare commands format
| aha ppc 51                 set arch for a range of N bytes
| ahb 16 @ $$                 force 16bit for current instruction
| ahc 0x804804                override call/jump address
| ahe 3,eax,+=               set vm analysis string
| ahf 0x804840                override fallback address for call
| ahh 0x804840                highlight this address offset in disasm
| ahi[?] 10                  define numeric base for immediates (1, 8, 10, 16, s)
| ahj                        list hints in JSON
| aho foo a0,33               replace opcode string
| ahp addr                   set pointer hint
| ahr val                    set hint for return value of a function
| ahs 4                      set opcode size=4
| ahS jz                     set asm.syntax=jz for this opcode
```

One of the most common case is to set a particular numeric base for immediates:

```
[0x000003d54]> ah?
|Usage ah? [sbodh] [@ offset] Define numeric base
| ah? [base] set numeric base (1, 2, 8, 10, 16)
| ah? b      set base to binary (2)
| ah? d      set base to decimal (10)
| ah? h      set base to hexadecimal (16)
| ah? o      set base to octal (8)
| ah? p      set base to htons(port) (3)
| ah? i      set base to IP address (32)
| ah? S      set base to syscall (80)
| ah? s      set base to string (1)
[0x000003d54]> pd 2
0x000003d54      0583000000    add eax, 0x83
0x000003d59      3d13010000    cmp eax, 0x113
[0x000003d54]> ah? d
[0x000003d54]> pd 2
0x000003d54      0583000000    add eax, 131
0x000003d59      3d13010000    cmp eax, 0x113
[0x000003d54]> ah? b
[0x000003d54]> pd 2
0x000003d54      0583000000    add eax, 100000011b
0x000003d59      3d13010000    cmp eax, 0x113
```

It is notable that some analysis stages or commands add the internal analysis hints, which can be checked with `ah?` command:

```
[0x000003d54]> ah
0x000003d54 - 0x000003d54 => immbase=2
[0x000003d54]> ah?*
ahi 2 @ 0x3d54
```

Sometimes we need to override jump or call address, for example in case of tricky relocation, which is unknown for radare2, thus we can change the value manually. The current analysis information about a particular opcode can be checked with `ao?` command. We can use `ahc` command for performing such a change:

```
[0x00003cee]> pd 2
0x00003cee      e83d080100    call sub.__errno_location_530
0x00003cf3      85c0          test eax, eax
[0x00003cee]> ao
address: 0x3cee
opcode: call 0x14530
mnemonic: call
prefix: 0
id: 56
bytes: e83d080100
refptr: 0
size: 5
sign: false
type: call
cycles: 3
esil: 83248,rip,8,rsp,-=,rsp,=[],rip,=
jump: 0x00014530
direction: exec
fail: 0x00003cf3
stack: null
family: cpu
stackop: null
[0x00003cee]> ahc 0x5382
[0x00003cee]> pd 2
0x00003cee      e83d080100    call sub.__errno_location_530
0x00003cf3      85c0          test eax, eax
[0x00003cee]> ao
address: 0x3cee
opcode: call 0x14530
mnemonic: call
prefix: 0
id: 56
bytes: e83d080100
refptr: 0
size: 5
sign: false
type: call
cycles: 3
esil: 83248,rip,8,rsp,-=,rsp,=[],rip,=
jump: 0x00005382
direction: exec
fail: 0x00003cf3
stack: null
family: cpu
stackop: null
[0x00003cee]> ah
0x00003cee - 0x00003cee => jump: 0x5382
```

As you can see, despite the unchanged disassembly view the jump address in opcode was changed (`jump` option).

If anything of the previously described didn't help, you can simply override shown disassembly with anything you like:

```
[0x000003d54]> pd 2
0x000003d54      0583000000    add eax, 100000011b
0x000003d59      3d13010000    cmp eax, 0x113
[0x000003d54]> "aho myopcode bla, foo"
[0x000003d54]> pd 2
0x000003d54          myopcode bla, foo
0x000003d55      830000      add dword [rax], 0
```

Managing variables

Radare2 allows managing local variables, no matter their location, stack or registers. The variables autoanalysis is enabled by default but can be disabled with `anal.vars` configuration option.

The main variables commands are located in `afv` namespace:

```
|Usage: afv[rbs]
| afvr[?]           manipulate register based arguments
| afvb[?]          manipulate bp based arguments/locals
| afvs[?]          manipulate sp based arguments/locals
| afv*              output r2 command to add args/locals to flagspace
| afvR [varname]    list addresses where vars are accessed (READ)
| afvW [varname]    list addresses where vars are accessed (WRITE)
| afva              analyze function arguments/locals
| afvd name        output r2 command for displaying the value of args/local
s in the
debugger
| afvn [old_name] [new_name] rename argument/local
| afvt [name] [new_type]   change type for given argument/local
| afv-([name])       remove all or given var
```

`afvr`, `afvb` and `afvs` commands are uniform but allows manipulation of register-based arguments and variables, BP/FP-based arguments and variables, and SP-based arguments and variables respectively. If we check the help for `afvr` we will get the way two others commands works too:

```
|Usage: afvr [reg] [type] [name]
| afvr                  list register based arguments
| afvr*                 same as afvr but in r2 commands
| afvr [reg] [name] ([type]) define register arguments
| afvrj                return list of register arguments in JSON format
| afvr- [name]           delete register arguments at the given index
| afvrg [reg] [addr]     define argument get reference
| afvrs [reg] [addr]     define argument set reference
```

Like many other things variables detection performed by radare2 automatically, but results can be changed with those arguments/variables control commands. This kind of analysis relies heavily on preloaded function prototypes and the calling-convention, thus loading symbols can improve it. Moreover, after changing something we can rerun variables analysis with `afva` command. Quite often variables analysis is accompanied with [types analysis](#), see `afta` command.

The most important aspect of reverse engineering - naming things. Of course, you can rename variable too, affecting all places it was referenced. This can be achieved with `afvn` for *any* type of argument or variable. Or you can simply remove the variable or argument with `afv-` command.

As mentioned before the analysis loop relies heavily on types information while performing variables analysis stages. Thus comes next very important command - `afvt`, which allows you to change the type of variable:

```
[0x000003b92]> afvs
var int local_8h @ rsp+0x8
var int local_10h @ rsp+0x10
var int local_28h @ rsp+0x28
var int local_30h @ rsp+0x30
var int local_32h @ rsp+0x32
var int local_38h @ rsp+0x38
var int local_45h @ rsp+0x45
var int local_46h @ rsp+0x46
var int local_47h @ rsp+0x47
var int local_48h @ rsp+0x48
[0x000003b92]> afvt local_10h char*
[0x000003b92]> afvs
var int local_8h @ rsp+0x8
var char* local_10h @ rsp+0x10
var int local_28h @ rsp+0x28
var int local_30h @ rsp+0x30
var int local_32h @ rsp+0x32
var int local_38h @ rsp+0x38
var int local_45h @ rsp+0x45
var int local_46h @ rsp+0x46
var int local_47h @ rsp+0x47
var int local_48h @ rsp+0x48
```

Less commonly used feature, which is still under heavy development - distinction between variables being read and write. You can list those being read with `afvR` command and those being written with `afvw` command. Both commands provide a list of the places those operations are performed:

```
[0x00003b92]> afvR
local_48h 0x48ee
local_30h 0x3c93, 0x520b, 0x52ea, 0x532c, 0x5400, 0x3cfb
local_10h 0x4b53, 0x5225, 0x53bd, 0x50cc
local_8h 0x4d40, 0x4d99, 0x5221, 0x53b9, 0x50c8, 0x4620
local_28h 0x503a, 0x51d8, 0x51fa, 0x52d3, 0x531b
local_38h
local_45h 0x50a1
local_47h
local_46h
local_32h 0x3cb1
[0x00003b92]> afvW
local_48h 0x3adf
local_30h 0x3d3e, 0x4868, 0x5030
local_10h 0x3d0e, 0x5035
local_8h 0x3d13, 0x4d39, 0x5025
local_28h 0x4d00, 0x52dc, 0x53af, 0x5060, 0x507a, 0x508b
local_38h 0x486d
local_45h 0x5014, 0x5068
local_47h 0x501b
local_46h 0x5083
local_32h
[0x00003b92]>
```

Type inference

The type inference for local variables and arguments is well integrated with the command `afta .`

Let's see an example of this with a simple `hello_world` binary

```
[0x0000007aa]> pdf
|           ;-- main:
/ (fcn) sym.main 157
| sym.main ();
| ; var int local_20h @ rbp-0x20
| ; var int local_1ch @ rbp-0x1c
| ; var int local_18h @ rbp-0x18
| ; var int local_10h @ rbp-0x10
| ; var int local_8h @ rbp-0x8
| ; DATA XREF from entry0 (0x6bd)
| 0x0000007aa  push rbp
| 0x0000007ab  mov rbp, rsp
| 0x0000007ae  sub rsp, 0x20
| 0x0000007b2  lea rax, str.Hello      ; 0x8d4 ; "Hello"
| 0x0000007b9  mov qword [local_18h], rax
| 0x0000007bd  lea rax, str.r2_folks   ; 0x8da ; " r2-folks"
| 0x0000007c4  mov qword [local_10h], rax
| 0x0000007c8  mov rax, qword [local_18h]
| 0x0000007cc  mov rdi, rax
| 0x0000007cf  call sym.imp.strlen     ; size_t strlen(const char *s)
```

- After applying `afta`

```
[0x0000007aa]> afta
[0x0000007aa]> pdf
| ;-- main:
| ;-- rip:
/ (fcn) sym.main 157
| sym.main ();
| ; var size_t local_20h @ rbp-0x20
| ; var size_t size @ rbp-0x1c
| ; var char *src @ rbp-0x18
| ; var char *s2 @ rbp-0x10
| ; var char *dest @ rbp-0x8
| ; DATA XREF from entry0 (0x6bd)
| 0x0000007aa  push rbp
| 0x0000007ab  mov rbp, rsp
| 0x0000007ae  sub rsp, 0x20
| 0x0000007b2  lea rax, str.Hello      ; 0x8d4 ; "Hello"
| 0x0000007b9  mov qword [src], rax
| 0x0000007bd  lea rax, str.r2_folks   ; 0x8da ; " r2-folks"
| 0x0000007c4  mov qword [s2], rax
| 0x0000007c8  mov rax, qword [src]
| 0x0000007cc  mov rdi, rax          ; const char *s
| 0x0000007cf  call sym.imp.strlen    ; size_t strlen(const char *s)
```

It also extracts type information from format string like `printf ("fmt : %s , %u , %d", ...)`,
the format specifications are extracted from `anal/d/spec.sdb`

You could create a new profile for specifying set of format chars depending upon different libraries/operating systems/programming languages like this :

```
win=spec  
spec.win.u32=unsigned int
```

Then change your default specification to newly created one using this config variable `e anal.spec = win`

For more information about primitive and user-defined types support in radare2 refer [types chapter](#).

Radare2 supports the C-syntax data types description. Those types are parsed by a C11-compatible parser and stored in the internal SDB, thus introspectable with `k` command.

Most of the related commands are located in `t` namespace:

```
[0x0000051c0]> t?
|Usage: t # cparse types commands
| t          List all loaded types
| tj         List all loaded types as json
| t <type>   Show type in 'pf' syntax
| t*         List types info in r2 commands
| t- <name>  Delete types by its name
| t-*        Remove all types
| ta <type>  Mark immediate as a type offset
| tc ([cctype]) calling conventions listing and manipulations
| te[?]      List all loaded enums
| td[?] <string> Load types from string
| tf          List all loaded functions signatures
| tk <sdb-query> Perform sdb query
| tl[?]      Show/Link type to an address
| tn[?] [-][addr] manage noreturn function attributes and marks
| to -        Open cfg.editor to load types
| to <path>   Load types from C header file
| tos <path>  Load types from parsed Sdb database
| tp <type> [addr|varname] cast data at <address> to <type> and print it
| tpx <type> <hexpairs> Show value for type with specified byte sequence
| ts[?]       print loaded struct types
| tu[?]       print loaded union types
| tt[?]       List all loaded typedefs
```

Note, that the basic (atomic) types are not those from C standard - not `char`, `_Bool`, or `short`. Because those types can be different from one platform to another, radare2 uses definite types like as `int8_t` or `uint64_t` and will convert `int` to `int32_t` or `int64_t` depending on the binary or debugger platform/compiler.

Basic types can be listed using `t` command, for the structured types you need to use `ts`, `tu` or `te` for enums:

```
[0x0000051c0]> t
char
char *
int
int16_t
int32_t
int64_t
int8_t
long
long long
...
```

Loading types

There are three easy ways to define a new type:

- Directly from the string using `td` command
- From the file using `to <filename>` command
- Open an `$EDITOR` to type the definitions in place using `to -`

```
[0x0000051c0]> "td struct foo {char* a; int b;}"
[0x0000051c0]> cat ~/radare2-regressions/bins/headers/s3.h
struct S1 {
    int x[3];
    int y[4];
    int z;
};
[0x0000051c0]> to ~/radare2-regressions/bins/headers/s3.h
[0x0000051c0]> ts
foo
S1
```

Also note there is a config option to specify include directories for types parsing

```
[0x000000000]> e??~dir.type
dir.types: Default path to look for cparse type files
[0x000000000]> e dir.types
/usr/include
```

Printing types

Notice below we have used `ts` command, which basically converts the C type description (or to be precise it's SDB representation) into the sequence of `pf` commands. See more about [print format](#).

The `tp` command uses the `pf` string to print all the members of type at the current offset/given address:

```
[0x0000051c0]> ts foo
pf zd a b
[0x0000051c0]> tp foo
a : 0x0000051c0 = 'hello'
b : 0x0000051cc = 10
[0x0000051c0]> tp foo 0x0000053c0
a : 0x0000053c0 = 'world'
b : 0x0000053cc = 20
```

Also, you could fill your own data into the struct and print it using `tpx` command

```
[0x0000051c0]> tpx foo 41414141441414141414420010000000
a : 0x0000051c0 = AAAAD.....B
b : 0x0000051cc = 16
```

Linking Types

The `tp` command just performs a temporary cast. But if we want to link some address or variable with the chosen type, we can use `t1` command to store the relationship in SDB.

```
[0x0000051c0]> t1 s1 = 0x51cf
[0x0000051c0]> t1
(S1)
x : 0x0000051cf = [ 2315619660, 1207959810, 34803085 ]
y : 0x0000051db = [ 2370306049, 4293315645, 3860201471, 4093649307 ]
z : 0x0000051eb = 4464399
```

Moreover, the link will be shown in the disassembly output or visual mode:

```
[0x0000051c0 15% 300 /bin/ls]> pd $r @ entry0
;-- entry0:
0x0000051c0      xor ebp, ebp
0x0000051c2      mov r9, rdx
0x0000051c5      pop rsi
0x0000051c6      mov rdx, rsp
0x0000051c9      and rsp, 0xfffffffffffffff0
0x0000051cd      push rax
0x0000051ce      push rsp
(S1)
x : 0x0000051cf = [ 2315619660, 1207959810, 34803085 ]
y : 0x0000051db = [ 2370306049, 4293315645, 3860201471, 4093649307 ]
z : 0x0000051eb = 4464399
0x0000051f0      lea rdi, loc._edata           ; 0x21f248
0x0000051f7      push rbp
0x0000051f8      lea rax, loc._edata           ; 0x21f248
0x0000051ff      cmp rax, rdi
0x000005202      mov rbp, rsp
```

Once the struct is linked, radare2 tries to propagate structure offset in the function at current offset, to run this analysis on whole program or at any targeted functions after all structs is linked you have `taa` command:

```
[0x0000000000]> ta?
| taa [fcn]          Analyze all/given function to convert immediate to linked struct
ure offsets (see t1?)
```

Note sometimes the emulation may not be accurate, for example as below :

```
|0x0000006da push rbp
|0x0000006db mov rbp, rsp
|0x0000006de sub rsp, 0x10
|0x0000006e2 mov edi, 0x20 ; "@"
|0x0000006e7 call sym.imp.malloc ; void *malloc(size_t size)
|0x0000006ec mov qword [local_8h], rax
|0x0000006f0 mov rax, qword [local_8h]
```

The return value of `malloc` may differ between two emulations, so you have to set the hint for return value manually using `ahr` command, so run `t1` or `taa` command after setting up the return value hint.

```
[0x0000006da]> ah?
| ahr val           set hint for return value of a function
```

Structure Immediates

There is one more important aspect of using types in radare2 - using `ta` you can change the immediate in the opcode to the structure offset. Lets see a simple example of [R]SI-relative addressing

```
[0x0000052f0]> pd 1
0x0000052f0      mov rax, qword [rsi + 8] ; [0x8:8]=0
```

Here `8` - is some offset in the memory, where `rsi` probably holds some structure pointer. Imagine that we have the following structures

```
[0x0000052f0]> "td struct ms { char b[8]; int member1; int member2; };" 
[0x0000052f0]> "td struct ms1 { uint64_t a; int member1; };" 
[0x0000052f0]> "td struct ms2 { uint16_t a; int64_t b; int member1; };"
```

Now we need to set the proper structure member offset instead of `8` in this instruction. At first, we need to list available types matching this offset:

```
[0x0000052f0]> tas 8
ms.member1
ms1.member1
```

Note, that `ms2` is not listed, because it has no members with offset `8`. After listing available options we can link it to the chosen offset at the current address:

```
[0x0000052f0]> ta ms1.member1
[0x0000052f0]> pd 1
0x0000052f0      488b4608      mov rax, qword [rsi + ms1.member1] ; [0x8:8]=0
```

Managing enums

- Printing all fields in enum using `te` command

```
[0x000000000]> "td enum Foo {COW=1,BAR=2};"
[0x000000000]> te Foo
COW = 0x1
BAR = 0x2
```

- Finding matching enum member for given bitfield and vice-versa

```
[0x000000000]> te Foo 0x1
COW
[0x000000000]> теб Foo COW
0x1
```

Internal representation

To see the internal representation of the types you can use `tk` command:

```
[0x0000051c0]> tk~S1
S1=struct
struct.S1=x,y,z
struct.S1.x=int32_t,0,3
struct.S1.x.meta=4
struct.S1.y=int32_t,12,4
struct.S1.y.meta=4
struct.S1.z=int32_t,28,0
struct.S1.z.meta=0
[0x0000051c0]>
```

Defining primitive types requires an understanding of basic `pf` formats, you can find the whole list of format specifier in `pf??`:

format	explanation
b	byte (unsigned)
c	char (signed byte)
d	0x%08x hexadecimal value (4 bytes)
f	float value (4 bytes)
i	%i integer value (4 bytes)
o	0x%08o octal value (4 byte)
p	pointer reference (2, 4 or 8 bytes)
q	quadword (8 bytes)
s	32bit pointer to string (4 bytes)
S	64bit pointer to string (8 bytes)
t	UNIX timestamp (4 bytes)
T	show Ten first bytes of buffer
u	uleb128 (variable length)
w	word (2 bytes unsigned short in hex)
x	0x%08x hex value and flag (fd @ addr)
X	show formatted hexpairs
z	\0 terminated string
Z	\0 terminated wide string

there are basically 3 mandatory keys for defining basic data types: `x=type` `type.X=formatSpecifier` `type.X.size=sizeInBits` For example, let's define `UNIT`, according to [Microsoft documentation.aspx#UINT](#)) `UINT` is just equivalent of standard C `unsigned int` (or `uint32_t` in terms of TCC engine). It will be defined as:

```
UINT=type
type.UNIT=d
type.UNIT.size=32
```

Now there is an optional entry:

```
x.type.pointto=Y
```

This one may only be used in case of pointer `type.x=p`, one good example is `LPFILETIME` definition, it is a pointer to `_FILETIME` which happens to be a structure. Assuming that we are targeting only 32-bit windows machine, it will be defined as the following:

```
LPFILETIME=type
type.LPFILETIME=p
type.LPFILETIME.size=32
type.LPFILETIME.pointto=_FILETIME
```

This last field is not mandatory because sometimes the data structure internals will be property, and we will not have a clean representation for it.

There is also one more optional entry:

```
type.UINT.meta=4
```

This entry is for integration with C parser and carries the type class information: integer size, signed/unsigned, etc.

Structures

Those are the basic keys for structs (with just two elements):

```
X=struct
struct.X=a,b
struct.X.a=a_type,a_offset,a_number_of_elements
struct.X.b=b_type,b_offset,b_number_of_elements
```

The first line is used to define a structure called `x`, the second line defines the elements of `x` as comma separated values. After that, we just define each element info.

For example, we can have a struct like this one:

```
struct _FILETIME {
    DWORD dwLowDateTime;
    DWORD dwHighDateTime;
}
```

assuming we have `DWORD` defined, the struct will look like this

```
_FILETIME=struct
struct._FILETIME=dwLowDateTime,dwHighDateTime
struct._FILETIME.dwLowDateTime=DWORD,0,0
struct._FILETIME.dwHighDateTime=DWORD,4,0
```

Note that the number of elements filed is used in case of arrays only to identify how many elements are in arrays, other than that it is zero by default.

Unions

Unions are defined exactly like structs the only difference is that you will replace the word `struct` with the word `union`.

Function prototypes

Function prototypes representation is the most detail oriented and the most important one of them all. Actually, this is the one used directly for type matching

```
X=func
func.X.args=NumberOfArgs
func.x.arg0=Arg_type,arg_name
.
.
.
func.X.ret=Return_type
func.X.cc=calling_convention
```

It should be self-explanatory. Let's do `strncasecmp` as an example for x86 arch for Linux machines. According to man pages, `strncasecmp` is defined as the following:

```
int strcasecmp(const char *s1, const char *s2, size_t n);
```

When converting it into its sdb representation it will look like the following:

```
strcasecmp=func
func.strcasecmp.args=3
func.strcasecmp.arg0=char *,s1
func.strcasecmp.arg1=char *,s2
func.strcasecmp.arg2=size_t,n
func.strcasecmp.ret=int
func.strcasecmp.cc=cdecl
```

Note that the `.cc` part is optional and if it didn't exist the default calling-convention for your target architecture will be used instead. There is one extra optional key

```
func.x.noreturn=true/false
```

This key is used to mark functions that will not return once called, such as `exit` and `_exit`.

Calling Conventions

Radare2 uses calling conventions to help in identifying function formal arguments and return types. It is used also as guide for basic function prototype and type propagation.

```
[0x0000000000]> afc?
|Usage: afc[agl?]
| afc convention Manually set calling convention for current function
| afc Show Calling convention for the Current function
| afcr[j] Show register usage for the current function
| afca Analyse function for finding the current calling convention
| afcf name Prints return type function(arg1, arg2...)
| afcl List all available calling conventions
| afco path Open Calling Convention sdb profile from given path
[0x0000000000]>
```

- To list all available calling conventions for current architecture using `afcl` command

```
[0x0000000000]> afcl
amd64
ms
```

- To display function prototype of standard library functions you have `afcf` command

```
[0x0000000000]> afcf printf
int printf(const char *format)
[0x0000000000]> afcf fgets
char *fgets(char *s, int size, FILE *stream)
```

All this information is loaded via sdb under `/libr/anal/d/cc-[arch]-[bits].sdb`

```
default.cc=amd64

ms=cc
cc.ms.name=ms
cc.ms.arg1=rcx
cc.ms.arg2=rdx
cc.ms.arg3=r8
cc.ms.arg3=r9
cc.ms.argv=stack
cc.ms.ret=rax
```

`cc.x.argi=rax` is used to set the *i*th argument of this calling convention to register name `rax`

`cc.x.argv=stack` means that all the arguments (or the rest of them in case there was argi for any i as counting number) will be stored in stack from left to right

`cc.x.argv=stack_rev` same as `cc.x.argv=stack` except for it means argument are passed right to left

There is a basic support of virtual tables parsing (RTTI and others). The most important thing before you start to perform such kind of analysis is to check if the `anal.cpp.abi` option is set correctly, and change if needed.

All commands to work with virtual tables are located in the `av` namespace. Currently, the support is very basic, allowing you only to inspect parsed tables.

```
|Usage: av[?jr*] C++ vtables and RTTI
| av          search for vtables in data sections and show results
| avj         like av, but as json
| av*         like av, but as r2 commands
| avr[j@addr] try to parse RTTI at vtable addr (see anal.cpp.abi)
| avra[j]     search for vtables and try to parse RTTI at each of them
```

The main commands here are `av` and `avr`. `av` lists all virtual tables found when r2 opened the file. If you are not happy with the result you may want to try to parse virtual table at a particular address with `avr` command. `avra` performs the search and parsing of all virtual tables in the binary, like r2 does during the file opening.

Introduction

One of the most important things to remember in reverse engineering is a core difference between static analysis and dynamic analysis. As many already know, static analysis suffers from the path exploration problem, which is impossible to solve even in the most basic way without at least a partial emulation.

Thus many professional reverse engineering tools use code emulation while performing an analysis of binary code, and radare2 is no different here.

For partial emulation (or imprecise full emulation) radare2 uses its own [ESIL](#) intermediate language and virtual machine.

Radare2 supports this kind of partial emulation for all platforms that implements ESIL uplifting (x86/x86_64, ARM, arm64, MIPS, powerpc, sparc, AVR, 8051, Gameboy, ...).

One of the most common usages of such emulation is to calculate indirect jumps and conditional jumps.

To see the ESIL representation of the program one can use the `ao` command or enable the `asm.esil` configuration variable, to check if the program uplifted correctly, and to grasp how ESIL works:

```
[0x000001660]> pdf
. (fcn) fcn.000001660 40
| fcn.000001660 ();
| ; CALL XREF from 0x000001713 (entry2.fini)
| 0x000001660 lea rdi, obj.__progname ; 0x207220
| 0x000001667 push rbp
| 0x000001668 lea rax, obj.__progname ; 0x207220
| 0x00000166f cmp rax, rdi
| 0x000001672 mov rbp, rsp
| .-< 0x000001675 je 0x1690
| | 0x000001677 mov rax, qword [reloc._ITM_deregisterTMCloneTable] ; [0x206fd8:8]=0
| | 0x00000167e test rax, rax
| .--< 0x000001681 je 0x1690
||| 0x000001683 pop rbp
||| 0x000001684 jmp rax
|`-> 0x000001690 pop rbp
` 0x000001691 ret

[0x000001660]> e asm.esil=true
[0x000001660]> pdf
. (fcn) fcn.000001660 40
| fcn.000001660 ();
| ; CALL XREF from 0x000001713 (entry2.fini)
| 0x000001660 0x205bb9,rip,+,rdi,=
| 0x000001667 rbp,8,rsp,-=,rsp,=[8]
| 0x000001668 0x205bb1,rip,+,rax,=
| 0x00000166f rdi,rax,==$z,zf,==$b64,cf,==$p,pf,==$s,sf,==$o,of,=
| 0x000001672 rsp,rbp,=
| .-< 0x000001675 zf,{,5776,rip,=,}
| | 0x000001677 0x20595a,rip,+,[8],rax,=
| | 0x00000167e 0,rax,rax,&==$z,zf,==$p,pf,==$s,sf,==$o,cf,==$0,of,=
| .--< 0x000001681 zf,{,5776,rip,=,}
||| 0x000001683 rsp,[8],rbp,=,8,esp,+=
||| 0x000001684 rax,rip,=
|`-> 0x000001690 esp,[8],rbp,=,8,esp,+=
` 0x000001691 esp,[8],rip,=,8,esp,+=
```

To manually setup the ESIL imprecise emulation you need to run this command sequence:

- `aei` to initialize ESIL VM
- `aeim` to initialize ESIL VM memory (stack)
- `aeip` to set the initial ESIL VM IP (instruction pointer)
- a sequence of `aer` commands to set the initial register values.

While performing emulation, please remember, that ESIL VM cannot emulate external calls or system calls, along with SIMD instructions. Thus the most common scenario is to emulate only a small chunk of the code, like encryption/decryption, unpacking or calculating something.

After we successfully set up the ESIL VM we can interact with it like with a usual debugging mode. Commands interface for ESIL VM is almost identical to the debugging one:

- `aes` to step (or `s` key in visual mode)
- `aesi` to step over the function calls
- `aesu <address>` to step until some specified address
- `aesue <ESIL expression>` to step until some specified ESIL expression met
- `aec` to continue until break (Ctrl-C), this one is rarely used though, due to the omnipresence of external calls
- `aecu <address>` to continue until some specified address

In visual mode, all of the debugging hotkeys will work also in ESIL emulation mode.

Along with usual emulation, there is a possibility to record and replay mode:

- `aets` to list all current ESIL R&R sessions
- `aets+` to create a new one
- `aesb` to step back in the current ESIL R&R session

More about this operation mode you can read in [Reverse Debugging](#) chapter.

Emulation in analysis loop

Apart from the manual emulation mode, it can be used automatically in the analysis loop. For example, the `aaaa` command performs the ESIL emulation stage along with others. To disable or enable its usage you can use `anal.esil` configuration variable. There is one more important option, though setting it might be quite dangerous, especially in the case of malware - `emu.write` which allows ESIL VM to modify memory. Sometimes it is required though, especially in the process of deobfuscating or unpacking code.

To show the process of emulation you can set `asm.emu` variable, which will show calculated register and memory values in disassembly comments:

```
[0x000001660]> e asm.emu=true
[0x000001660]> pdf
. (fcn) fcn.000001660 40
|   fcn.000001660 ();
|   ; CALL XREF from 0x000001713 (entry2.fini)
|   0x000001660  lea rdi, obj.__progname ; 0x207220 ; rdi=0x207220 -> 0x464c457f
|   0x000001667  push rbp           ; rsp=0xfffffffffffffff8
|   0x000001668  lea rax, obj.__progname ; 0x207220 ; rax=0x207220 -> 0x464c457f
|   0x00000166f  cmp rax, rdi       ; zf=0x1 -> 0x2464c45 ; cf=0x0 ; pf=0x1 -> 0
x2464c45 ; sf=0x0 ; of=0x0
|   0x000001672  mov rbp, rsp       ; rbp=0xfffffffffffffff8
| .-< 0x000001675  je 0x1690        ; rip=0x1690 -> 0x1f0fc35d ; likely
| | 0x000001677  mov rax, qword [reloc._ITM_deregisterTMCloneTable] ; [0x206fd8:8]=0
; rax=0x0
| | 0x00000167e  test rax, rax     ; zf=0x1 -> 0x2464c45 ; pf=0x1 -> 0x2464c45
; sf=0x0 ; cf=0x0 ; of=0x0
| .--< 0x000001681  je 0x1690        ; rip=0x1690 -> 0x1f0fc35d ; likely
| || 0x000001683  pop rbp          ; rbp=0xfffffffffffffff -> 0x4c457fff ; rsp
=0x0
| || 0x000001684  jmp rax          ; rip=0x0 ..
| ``-> 0x000001690  pop rbp          ; rbp=0x10102464c457f ; rsp=0x8 -> 0x464c457
f
`   0x000001691  ret              ; rip=0x0 ; rsp=0x10 -> 0x3e0003
```

Note here `likely` comments, which indicates that ESIL emulation predicted for particular conditional jump to happen.

Apart from the basic ESIL VM setup, you can change the behavior with other options located in `emu.` and `esil.` configuration namespaces.

For manipulating ESIL working with memory and stack you can use the following options:

- `esil.stack` to enable or disable temporary stack for `asm.emu` mode
- `esil.stack.addr` to set stack address in ESIL VM (like `aeim` command)
- `esil.stack.size` to set stack size in ESIL VM (like `aeim` command)
- `esil.stack.depth` limits the number of PUSH operations into the stack
- `esil.romem` specifies read-only access to the ESIL memory
- `esil.fillstack` and `esil.stack.pattern` allows you to use a various pattern for filling ESIL VM stack upon initialization
- `esil.nonull` when set stops ESIL execution upon NULL pointer read or write.

Radare2 automatically parses available imports and exports sections in the binary, but moreover, it can load additional debugging information if presented. Two main formats are supported: DWARF and PDB (for Windows binaries). Note, that unlike many tools radare2 doesn't rely on Windows API to parse PDB files, thus they can be loaded on any other supported platform - e.g. Linux or OS X.

DWARF debuginfo loads automatically by default because usually it's stored right in the executable file. PDB is a bit of a different beast - it is always stored as a separate binary, thus the different logic of handling it.

At first, one of the common scenarios is to analyze the file from Windows distribution. In this case, all PDB files are available on the Microsoft server, which is by default is in options. See all pdb options in radare2:

```
pdb.autoload = 0  
pdb.extract = 1  
pdb.server = https://msdl.microsoft.com/download/symbols  
pdb.useragent = Microsoft-Symbol-Server/6.11.0001.402
```

Using the variable `pdb.server` you can change the address where radare2 will try to download the PDB file by the GUID stored in the executable header. Usually, there is no reason to change default `pdb.useragent`, but who knows where could it be handy?

Because those PDB files are stored as "cab" archives on the server, `pdb.extract=1` says to automatically extract them.

Note, that for automatical downloading to work you need "cabextract" tool, and wget/curl installed.

Sometimes you don't need to do that from the radare2 itself, thus - two handy rabin2 options:

```
-P          show debug/pdb information  
-PP         download pdb file for binary
```

where `-PP` automatically downloads the pdb for the selected binary, using those `pdb.*` config options. `-P` will dump the contents of the PDB file, which is useful sometimes for a quick understanding of the symbols stored in it.

Apart from the basic scenario of just opening a file, PDB information can be additionally manipulated by the `id` commands:

```
[0x0000051c0]> id?
|Usage: id Debug information
| Output mode:
| '*'          Output in radare commands
| id           Source lines
| idp [file.pdb] Load pdb file information
| idpi [file.pdb] Show pdb file information
| idpd         Download pdb file on remote server
```

Where `idpi` is basically the same as `rabin2 -P`. Note, that `idp` can be also used not only in the static analysis mode, but also in the debugging mode, even if connected via WinDbg.

For simplifying the loading PDBs, especially for the processes with many linked DLLs, radare2 can autoload all required PDBs automatically - you need just set the `e pdb.autoload=true` option. Then if you load some file in debugging mode in Windows, using `r2 -d file.exe` or `r2 -d 2345` (attach to pid 2345), all related PDB files will be loaded automatically.

DWARF information loading, on the other hand, is completely automated. You don't need to run any commands/change any options:

```
r2 `which rabin2`
[0x000002437 8% 300 /usr/local/bin/rabin2]> pd $r
0x000002437 jne 0x2468          ;[1]
0x000002439 cmp qword reloc.__cxa_finalize_224, 0
0x000002441 push rbp
0x000002442 mov rbp, rsp
0x000002445 je 0x2453          ;[2]
0x000002447 lea rdi, obj.__dso_handle ; 0x207c40 ; "@| "
0x00000244e call 0x2360          ;[3]
0x000002453 call sym.deregister_tm_clones ;[4]
0x000002458 mov byte [obj.completed.6991], 1 ; obj.__TMC_END__ ; [0x2082f0:1]=0
0x00000245f pop rbp
0x000002460 ret
0x000002461 nop dword [rax]
0x000002468 ret
0x00000246a nop word [rax + rax]
-- entry1.init:
-- frame_dummy:
0x000002470 push rbp
0x000002471 mov rbp, rsp
0x000002474 pop rbp
0x000002475 jmp sym.register_tm_clones ;[5]
-- blob_version:
0x00000247a push rbp          ; ../blob/version.c:18
0x00000247b mov rbp, rsp
0x00000247e sub rsp, 0x10
0x000002482 mov qword [rbp - 8], rdi
```

```
0x000002486 mov eax, 0x32          ; ../blob/version.c:24 ; '2'
0x00000248b test al, al           ; ../blob/version.c:19
0x00000248d je 0x2498            ;[6]
0x00000248f lea rax, str.2.0.1_182_gf1aa3aa4d ; 0x60b8 ; "2.0.1-182-gf1aa3aa4d"
0x000002496 jmp 0x249f            ;[7]
0x000002498 lea rax, 0x0000060cd
0x00000249f mov rsi, qword [rbp - 8]
0x0000024a3 mov r8, rax
0x0000024a6 mov ecx, 0x40        ; section_end.ehdr
0x0000024ab mov edx, 0x40c0
0x0000024b0 lea rdi, str._s_2.1.0_git__d__linux_x86__d_git._s_n ; 0x60d0 ; "%s 2.1.0-
git %d @ linux-x86-%d git.%s\n"
0x0000024b7 mov eax, 0
0x0000024bc call 0x2350          ;[8]
0x0000024c1 mov eax, 0x66        ; ../blob/version.c:25 ; 'f'
0x0000024c6 test al, al
0x0000024c8 je 0x24d6            ;[9]
0x0000024ca lea rdi, str.commit:_f1aa3aa4d2599c1ad60e3ecbe5f4d8261b282385_build:_2017_
11_06_12:18:39 ; ../blob/version.c:26 ; 0x60f8 ; "commit: f1aa3aa4d2599c1ad60e3ecbe5f
4d8261b282385 build: 2017-11-06_1
0x0000024d1 call sym.imp.puts    ;[?]
0x0000024d6 mov eax, 0          ; ../blob/version.c:28
0x0000024db leave              ; ../blob/version.c:29
0x0000024dc ret
-- rabin_show_help:
0x0000024dd push rbp            ; ./rabin2.c:27
```

As you can see, it loads function names and source line information.

Radare2 has its own format of the signatures, allowing to both load/apply and create them on the fly. They are available under the `z` command namespace:

```
[0x0000100b0]> z?
|Usage: z[*j-aof/cs] [args] # Manage zignatures
| z           show zignatures
| z*          show zignatures in radare format
| zj          show zignatures in json format
| z-zignature delete zignature
| z-*         delete all zignatures
| za[?]       add zignature
| zo[?]       manage zignature files
| zf[?]       manage FLIRT signatures
| z/[?]       search zignatures
| zc          check zignatures at address
| zs[?]       manage zignspaces
```

To load the created signature file you need to load it from SDB file using `zo` command or from the compressed SDB file using `zoz` command.

To create signature you need to make function first, then you can create it from the function:

```
r2 /bin/ls
[0x0000051c0]> aaa # this creates functions, including 'entry0'
[0x0000051c0]> zaf entry0 entry
[0x0000051c0]> z
entry:
  bytes: 31ed4989d15e4889e24883e4f050544c.....48.....48.....ff...
  .....f4
  graph: cc=1 nbbs=1 edges=0 ebbs=1
  offset: 0x0000051c0
[0x0000051c0]>
```

As you can see it made a new signature with a name `entry` from a function `entry0`. You can show it in JSON format too, which can be useful for scripting:

```
[0x0000051c0]> zj~{}
[
  {
    "name": "entry",
    "bytes": "31ed4989d15e4889e24883e4f050544c.....48.....48.....
ff.....f4",
    "graph": {
      "cc": "1",
      "nbbs": "1",
      "edges": "0",
      "ebbs": "1"
    },
    "offset": 20928,
    "refs": [
    ]
  }
]
[0x0000051c0]>
```

To remove it just run `z-entry`. But if you want to save all created signatures, you need to save it into the SDB file using command `zos myentry`. Then we can apply them. Lets open a file again:

```
r2 /bin/ls
-- Log On. Hack In. Go Anywhere. Get Everything.
[0x0000051c0]> zo myentry
[0x0000051c0]> z
entry:
  bytes: 31ed4989d15e4889e24883e4f050544c.....48.....48.....
.....f4
  graph: cc=1 nbbs=1 edges=0 ebbs=1
  offset: 0x0000051c0
[0x0000051c0]>
```

This means that the signatures were successfully loaded from the file `myentry` and now we can search matching functions:

```
[0x0000051c0]> zc
[+] searching 0x0000051c0 - 0x0000052c0
[+] searching function metrics
hits: 1
[0x0000051c0]>
```

Note that `zc` command just checks the signatures against the current address. To search signatures across the all file we need to do a bit different thing. There is an important moment though, if we just run it "as is" - it wont find anything:

```
[0x0000051c0]> z/
[+] searching 0x0021dfd0 - 0x002203e8
[+] searching function metrics
hits: 0
[0x0000051c0]>
```

Note the searching address - this is because we need to [adjust the searching range first](#):

```
[0x0000051c0]> e search.in=io.section
[0x0000051c0]> z/
[+] searching 0x000038b0 - 0x00015898
[+] searching function metrics
hits: 1
[0x0000051c0]>
```

We are setting the search mode to `io.section` (it was `file` by default) to search in the current section (assuming we are currently in the `.text` section of course). Now we can check, what radare2 found for us:

```
[0x0000051c0]> pd 5
;-- entry0:
;-- sign.bytes.entry_0:
0x0000051c0      31ed          xor    ebp,  ebp
0x0000051c2      4989d1        mov    r9,  rdx
0x0000051c5      5e             pop    rsi
0x0000051c6      4889e2        mov    rdx,  rsp
0x0000051c9      4883e4f0      and    rsp,  0xfffffffffffffff0
[0x0000051c0]>
```

Here we can see the comment of `entry0`, which is taken from the ELF parsing, but also the `sign.bytes.entry_0`, which is exactly the result of matching signature.

Signatures configuration stored in the `zign.` config vars' namespace:

```
[0x0000051c0]> e zign.
zign.bytes = true
zign.graph = true
zign.maxsz = 500
zign.mincc = 10
zign.minsz = 16
zign.offset = true
zign.prefix = sign
zign.refs = true
[0x0000051c0]>
```

Signatures

Graph commands

When analyzing data it is usually handy to have different ways to represent it in order to get new perspectives to allow the analyst to understand how different parts of the program interact.

Representing basic block edges, function calls, string references as graphs show a very clear view of this information.

Radare2 supports various types of graph available through commands starting with `ag` :

```
[0x000005000]> ag?
|Usage: ag<graphtype><format> [addr]
| Graph commands:
| agc[format] [fcn addr] Function callgraph
| agf[format] [fcn addr] Basic blocks function graph
| agx[format] [addr] Cross references graph
| agr[format] [fcn addr] References graph
| aga[format] [fcn addr] Data references graph
| agd[format] [fcn addr] Diff graph
| agi[format] Imports graph
| agC[format] Global callgraph
| agR[format] Global references graph
| agA[format] Global data references graph
| agg[format] Custom graph
| ag- Clear the custom graph
| agn[?] title body Add a node to the custom graph
| age[?] title1 title2 Add an edge to the custom graph
|
| Output formats:
| <blank> Ascii art
| v Interactive ASCII art
| t Tiny ASCII art
| d Graphviz dot
| j JSON ('J' for formatted disassembly)
| g Graph Modelling Language (GML)
| k SDB key-value
| * r2 commands
| w Web/image (see graph.extension and graph.web)
```

The structure of the commands is as follows: `ag <graph type> <output format>`.

For example, `agid` displays the imports graph in dot format, while `aggj` outputs the custom graph in JSON format.

Here's a short description for every output format available:

Ascii Art ** (e.g. `agf`)

Displays the graph directly to stdout using ASCII art to represent blocks and edges.

Warning: displaying large graphs directly to stdout might prove to be computationally expensive and will make r2 not responsive for some time. In case of a doubt, prefer using the interactive view (explained below).

Interactive Ascii Art (e.g. `agfv`)

Displays the ASCII graph in an interactive view similar to `vv` which allows to move the screen, zoom in / zoom out, ...

Tiny Ascii Art (e.g. `agft`)

Displays the ASCII graph directly to stdout in tiny mode (which is the same as reaching the maximum zoom out level in the interactive view).

Graphviz dot (e.g. `agfd`)

Prints the dot source code representing the graph, which can be interpreted by programs such as [graphviz](#) or online viewers like [this](#)

JSON (e.g. `agfj`)

Prints a JSON string representing the graph.

- In case of the `f` format (basic blocks of function), it will have detailed information about the function and will also contain the disassembly of the function (use `j` format for the formatted disassembly).
- In all other cases, it will only have basic information about the nodes of the graph (id, title, body, and edges).

Graph Modelling Language (e.g. `agfg`)

Prints the GML source code representing the graph, which can be interpreted by programs such as [yEd](#)

SDB key-value (e.g. `agfk`)

Prints key-value strings representing the graph that was stored by sdb (radare2's string database).

R2 custom graph commands (e.g. `agf*`)

Prints r2 commands that would recreate the desired graph. The commands to construct the graph are `agn [title] [body]` to add a node and `age [title1] [title2]` to add an edge. The `[body]` field can be expressed in base64 to include special formatting (such as newlines).

To easily execute the printed commands, it is possible to prepend a dot to the command (`.agf*`).

Web / image (e.g. `agfw`)

Radare2 will convert the graph to dot format, use the `dot` program to convert it to a `.gif` image and then try to find an already installed viewer on your system (`xdg-open`, `open`, ...) and display the graph there.

The extension of the output image can be set with the `graph.extension` config variable. Available extensions are `png`, `jpg`, `gif`, `pdf`, `ps`.

Note: for particularly large graphs, the most recommended extension is `svg` as it will produce images of much smaller size

If `graph.web` config variable is enabled, radare2 will try to display the graph using the browser (*this feature is experimental and unfinished, and disabled by default.*)

Radare2 provides a wide set of features to automate boring work. It ranges from the simple sequencing of the commands to the calling scripts/another programs via IPC (Inter-Process Communication), called r2pipe.

As mentioned a few times before there is an ability to sequence commands using ; semicolon operator.

```
[0x00404800]> pd 1 ; ao 1
    0x00404800      b827e66100      mov eax, 0x61e627      ; "tab"
address: 0x404800
opcode: mov eax, 0x61e627
prefix: 0
bytes: b827e66100
ptr: 0x0061e627
refptr: 0
size: 5
type: mov
esil: 6415911,rax,=
stack: null
family: cpu
[0x00404800]>
```

It simply runs the second command after finishing the first one, like in a shell.

The second important way to sequence the commands is with a simple pipe |

```
ao|grep address
```

Note, the | pipe only can pipe output of r2 commands to external (shell) commands, like system programs or builtin shell commands. There is a similar way to sequence r2 commands, using the backtick operator `command`. The quoted part will undergo command substitution and the output will be used as an argument of the command line.

For example, we want to see a few bytes of the memory at the address referred to by the 'mov eax, addr' instruction. We can do that without jumping to it, using a sequence of commands:

```
[0x00404800]> pd 1
    0x00404800      b827e66100      mov eax, 0x61e627      ; "tab"
[0x00404800]> ao
address: 0x404800
opcode: mov eax, 0x61e627
prefix: 0
bytes: b827e66100
ptr: 0x0061e627
refptr: 0
size: 5
type: mov
esil: 6415911,rax,=
stack: null
family: cpu
[0x00404800]> ao~ptr[1]
0x0061e627
0
[0x00404800]> px 10 @ `ao~ptr[1]`
- offset - 0 1 2 3 4 5 6 7 8 9 A B C D E F 0123456789ABCDEF
0x0061e627 7461 6200 2e69 6e74 6572                      tab..inter
[0x00404800]>
```

And of course it's possible to redirect the output of an r2 command into a file, using the `>` and `>>` commands

```
[0x00404800]> px 10 @ `ao~ptr[1]` > example.txt
[0x00404800]> px 10 @ `ao~ptr[1]` >> example.txt
```

The `?$?` command describes several helpful variables you can use to do similar actions even more easily, like the `$v` "immediate value" variable, or the `$m` opcode memory reference variable.

One of the most common task in automation is looping through something, there are multiple ways to do this in radare2.

We can loop over flags:

```
@@ flagname-regex
```

For example, we want to see function information with `afi` command:

```
[0x004047d6]> afi
#
offset: 0x004047d0
name: entry0
size: 42
realsz: 42
stackframe: 0
call-convention: amd64
cyclomatic-complexity: 1
bits: 64
type: fcn [NEW]
num-bbs: 1
edges: 0
end-bbs: 1
call-refs: 0x00402450 C
data-refs: 0x004136c0 0x00413660 0x004027e0
code-xrefs:
data-xrefs:
locals:0
args: 0
diff: type: new
[0x004047d6]>
```

Now let's say, for example, that we'd like see a particular field from this output for all functions found by analysis. We can do that with a loop over all function flags (whose names begin with `fcn.`):

```
[0x004047d6]> afi @@ fcn.* ~name
```

This command will extract the `name` field from the `afi` output of every flag with a name matching the regexp `fcn.*`.

We can also loop over a list of offsets, using the following syntax:

```
@@=1 2 3 ... N
```

For example, say we want to see the opcode information for 2 offsets: the current one, and at current + 2:

```
[0x004047d6]> ao @@=$$ $$+2
address: 0x4047d6
opcode: mov rdx, rsp
prefix: 0
bytes: 4889e2
refptr: 0
size: 3
type: mov
esil: rsp,rdx,=
stack: null
family: cpu
address: 0x4047d8
opcode: loop 0x404822
prefix: 0
bytes: e248
refptr: 0
size: 2
type: cjmp
esil: 1,rcx,-=,rcx,{,4212770,rip,=,}
jump: 0x00404822
fail: 0x004047da
stack: null
cond: al
family: cpu
[0x004047d6]>
```

Note we're using the `$$` variable which evaluates to the current offset. Also note that `$$+2` is evaluated before looping, so we can use the simple arithmetic expressions.

A third way to loop is by having the offsets be loaded from a file. This file should contain one offset per line.

```
[0x004047d0]> ?v $$ > offsets.txt
[0x004047d0]> ?v $$+2 >> offsets.txt
[0x004047d0]> !cat offsets.txt
4047d0
4047d2
[0x004047d0]> pi 1 @@.offsets.txt
xor ebp, ebp
mov r9, rdx
```

radare2 also offers various `foreach` constructs for looping. One of the most useful is for looping through all the instructions of a function:

```
[0x004047d0]> pdf
F (fcn) entry0 42
| ; UNKNOWN XREF from 0x00400018 (unk)
| ; DATA XREF from 0x004064bf (sub.strlen_460)
| ; DATA XREF from 0x00406511 (sub.strlen_460)
| ; DATA XREF from 0x0040b080 (unk)
| ; DATA XREF from 0x0040b0ef (unk)
|0x004047d0 xor ebp, ebp
|0x004047d2 mov r9, rdx
|0x004047d5 pop rsi
|0x004047d6 mov rdx, rsp
|0x004047d9 and rsp, 0xfffffffffffffff0
|0x004047dd push rax
|0x004047de push rsp
|0x004047df mov r8, 0x4136c0
|0x004047e6 mov rcx, 0x413660      ; "AWA..AVI..AUI..ATL%.. "
OA..AVI..AUI.
|0x004047ed mov rdi, main      ; "AWAVAUATUH..S..H...." @
0
|0x004047f4 call sym.imp.__libc_start_main
↳0x004047f9 hlt
[0x004047d0]> pi 1 @@i
mov r9, rdx
pop rsi
mov rdx, rsp
and rsp, 0xfffffffffffffff0
push rax
push rsp
mov r8, 0x4136c0
mov rcx, 0x413660
mov rdi, main
call sym.imp.__libc_start_main
hlt
```

In this example the command `pi 1` runs over all the instructions in the current function (`entry0`). There are other options too (not complete list, check `@@?` for more information):

- `@@k sdbquery` - iterate over all offsets returned by that sdbquery
- `@@t` - iterate over on all threads (see `dp`)
- `@@b` - iterate over all basic blocks of current function (see `afb`)
- `@@f` - iterate over all functions (see `aflq`)

The last kind of looping lets you loop through predefined iterator types:

- `symbols`
- `imports`
- `registers`
- `threads`
- `comments`

- functions
- flags

This is done using the `@@@` command. The previous example of listing information about functions can also be done using the `@@@` command:

```
[0x004047d6]> afi @@@ functions ~name
```

This will extract `name` field from `afi` output and will output a huge list of function names. We can choose only the second column, to remove the redundant `name:` on every line:

```
[0x004047d6]> afi @@@ functions ~name[1]
```

Apart from simple sequencing and looping, radare2 allows to write simple macros, using this construction:

```
[0x00404800]> (qwe, pd 4, ao)
```

This will define a macro called 'qwe' which runs sequentially first 'pd 4' then 'ao'. Calling the macro using syntax `.(macro)` is simple:

```
[0x00404800]> (qwe, pd 4, ao)
[0x00404800]> .(qwe)
0x00404800  mov eax, 0x61e627      ; "tab"
0x00404805  push rbp
0x00404806  sub rax, section_end.LOAD1
0x0040480c  mov rbp, rsp

address: 0x404800
opcode: mov eax, 0x61e627
prefix: 0
bytes: b827e66100
ptr: 0x0061e627
refptr: 0
size: 5
type: mov
esil: 6415911,rax,=
stack: null
family: cpu
[0x00404800]>
```

To list available macroses simply call `(* :`

```
[0x00404800]> (*
(qwe , pd 4, ao)
```

And if want to remove some macro, just add '-' before the name:

```
[0x00404800]> (-qwe)
Macro 'qwe' removed.
[0x00404800]>
```

Moreover, it's possible to create a macro that takes arguments, which comes in handy in some simple scripting situations. To create a macro that takes arguments you simply add them to macro definition. Be sure, if you're using characters like ',', to quote the whole command for proper parsing.

```
[0x00404800]
[0x004047d0]> "(foo x y,pd $0; s +$1)"
[0x004047d0]> .(foo 5 6)
;-- entry0:
0x004047d0      xor ebp, ebp
0x004047d2      mov r9, rdx
0x004047d5      pop rsi
0x004047d6      mov rdx, rsp
0x004047d9      and rsp, 0xfffffffffffffff0
[0x004047d6]>
```

As you can see, the arguments are named by index, starting from 0: \$0, \$1, ...

R2pipe

The r2pipe api was initially designed for NodeJS in order to support reusing the web's r2.js API from the commandline. The r2pipe module permits interacting with r2 instances in different methods:

- spawn pipes (r2 -0)
- http queries (cloud friendly)
- tcp socket (r2 -c)

	pipe	spawn	async	http	tcp	rap	json
nodejs	x	x	x	x	x	-	x
python	x	x	-	x	x	x	x
swift	x	x	x	x	-	-	x
dotnet	x	x	x	x	-	-	-
haskell	x	x	-	x	-	-	x
java	-	x	-	x	-	-	-
golang	x	x	-	-	-	-	x
ruby	x	x	-	-	-	-	x
rust	x	x	-	-	-	-	x
vala	-	x	x	-	-	-	-
erlang	x	x	-	-	-	-	-
newlisp	x	-	-	-	-	-	-
dlang	x	-	-	-	-	-	x
perl	x	-	-	-	-	-	-

Examples

Python

```
$ pip install r2pipe
```

```
import r2pipe

r2 = r2pipe.open("/bin/ls")
r2.cmd('aa')
print(r2.cmd("afl"))
print(r2.cmdj("aflj")) # evaluates JSONs and returns an object
```

NodeJS

Use this command to install the r2pipe bindings

```
$ npm install r2pipe
```

Here's a sample hello world

```
const r2pipe = require('r2pipe');
r2pipe.open('/bin/ls', (err, res) => {
    if (err) {
        throw err;
    }
    r2.cmd ('af @ entry0', function (o) {
        r2.cmd ("pdf @ entry0", function (o) {
            console.log (o);
            r.quit ()
        });
    });
});
```

Checkout the GIT repository for more examples and details.

<https://github.com/radare/radare2-r2pipe/blob/master/nodejs/r2pipe/README.md>

Go

```
$ r2pm -i r2pipe-go
```

<https://github.com/radare/r2pipe-go>

```

package main

import (
    "fmt"
    "github.com/radare/r2pipe-go"
)

func main() {
    r2p, err := r2pipe.NewPipe("/bin/ls")
    if err != nil {
        panic(err)
    }
    defer r2p.Close()

    _, err = r2p.Cmd("aaaa")
    if err != nil {
        panic(err)
    }
    buf0, err := r2p.Cmd("S*")
    if err != nil {
        panic(err)
    }
    fmt.Println(buf0)

    buf1, err := r2p.Cmd("pi 10")
    if err != nil {
        panic(err)
    }
    fmt.Println(buf1)

    buf2, err := r2p.Cmd("px 64")
    if err != nil {
        panic(err)
    }
    fmt.Println(buf2)
}

```

Rust

```

$ cat Cargo.toml
...
[dependencies]
r2pipe = "*"

```

```

#[macro_use]
extern crate r2pipe;
use r2pipe::R2Pipe;

fn main() {
    // Initialize a new pipe
    let mut r2p = open_pipe!(Some("/bin/ls")).unwrap();

    // r2p.cmd() to send a command to r2
    println!("{}: {}", r2p.cmd("?e Hello World"));

    // r2p.cmdj() to send a command and parse the returned JSON
    let json = r2p.cmdj("ij").unwrap();
    println!("{}: {}", json.pretty());
    println!("{}: {}", "ARCH", json.find_path(&["bin", "arch"]).unwrap());

    // Closed and Done!
    r2p.close();
}

```

Ruby

```
$ gem install r2pipe
```

```

require 'r2pipe'
puts 'r2pipe ruby api demo'
puts '=====
r2p = R2Pipe.new '/bin/ls'
puts r2p.cmd 'pi 5'
puts r2p.cmd 'pij 1'
puts r2p.json(r2p.cmd 'pij 1')
puts r2p.cmd 'px 64'
r2p.quit

```

Perl

```
#!/usr/bin/perl

use R2::Pipe;
use strict;

my $r = R2::Pipe->new ("/bin/ls");
print $r->cmd ("pd 5")."\n";
print $r->cmd ("px 64")."\n";
$r->quit ();
```

Erlang

```
#!/usr/bin/env escript
%% -*- erlang -*-
%%! -smp enable

%% -sname hr
-mode(compile).

-export([main/1]).

main(_Args) ->
    %% adding r2pipe to modulepath, set it to your r2pipe_eri location
    R2pipePATH = filename:dirname(escript:script_name()) ++ "/ebin",
    true = code:add_pathz(R2pipePATH),

    %% initializing the link with r2
    H = r2pipe:init(lpipe),

    %% all work goes here
    io:format("~s", [r2pipe:cmd(H, "i")]).
```

Haskell

```
import R2pipe
import qualified Data.ByteString.Lazy as L

showMainFunction ctx = do
    cmd ctx "s main"
    L.putStr =<< cmd ctx "pD `f1 $$`"

main = do
    -- Run r2 locally
    open "/bin/ls" >>= showMainFunction
    -- Connect to r2 via HTTP (e.g. if "r2 -qc=h /bin/ls" is running)
    open "http://127.0.0.1:9090" >>= showMainFunction
```

Dotnet

```

using System;
using System.Collections.Generic;
using System.Diagnostics;
using System.Linq;
using System.Text;
using System.Threading.Tasks;
using r2pipe;

namespace LocalExample
{
    class Program
    {
        static void Main(string[] args)
        {
#if __Monocs__
            using(IR2Pipe pipe = new R2Pipe("/bin/ls"))
#else
            using (IR2Pipe pipe = new R2Pipe(@"C:\Windows\notepad.exe",
                @"C:\radare2\radare2.exe"))
#endif
            {
                Console.WriteLine("Hello r2! " + pipe.RunCommand("?V"));
                Task<string> async = pipe.RunCommandAsync("?V");
                Console.WriteLine("Hello async r2!" + async.Result);
                QueuedR2Pipe qr2 = new QueuedR2Pipe(pipe);

                qr2.Enqueue(new R2Command("x", (string result) => {
                    Console.WriteLine("Result of x:\n {0}", result); }));
                qr2.Enqueue(new R2Command("pi 10", (string result) => {
                    Console.WriteLine("Result of pi 10:\n {0}", result); }));

                qr2.ExecuteCommands();
            }
        }
    }
}

```

Java

```
import org.radare.r2pipe.R2Pipe;

public class Test {
    public static void main (String[] args) {
        try {
            R2Pipe r2p = new R2Pipe ("/bin/ls");
            //R2Pipe r2p = new R2Pipe ("http://cloud.rada.re/cmd/", true);
            System.out.println (r2p.cmd ("pd 10"));
            System.out.println (r2p.cmd ("px 32"));
            r2p.quit();
        } catch (Exception e) {
            System.err.println (e);
        }
    }
}
```

Swift

```
if let r2p = R2Pipe(url:nil) {
    r2p.cmd ("?V", closure:{ 
        (str:String?) in
        if let s = str {
            print ("Version: \(s)");
            exit (0);
        } else {
            debugPrint ("R2PIPE. Error");
            exit (1);
        }
    });
    NSRunLoop.currentRunLoop().run();
} else {
    print ("Needs to run from r2")
}
```

Vala

```

public static int main (String[] args) {
    MainLoop loop = new MainLoop ();
    var r2p = new R2Pipe ("/bin/ls");
    r2p.cmd ("pi 4", (x) => {
        stdout.printf ("DISASM(%s)\n", x);
        r2p.cmd ("ie", (x) => {
            stdout.printf ("entry(%s)\n", x);
            r2p.cmd ("q");
        });
    });
    ChildWatch.add (r2p.child_pid, (pid, status) => {
        // Triggered when the child indicated by child_pid exits
        Process.close_pid (pid);
        loop.quit ();
    });
    loop.run ();
    return 0;
}

```

NewLisp

```

(load "r2pipe.lsp")
(println "pd 3:\n" (r2pipe:cmd "pd 3"))
(exit)

```

DLang

```

import std.stdio;
import r2pipe;

void main() {
    auto r2 = r2pipe.open ();
    writeln ("Hello " ~ r2.cmd("?e World"));
    writeln ("Hello " ~ r2.cmd("?e Works"));

    string uri = r2.cmdj("ij")["core"]["uri"].str;
    writeln ("Uri: ", uri);
}

```

Debugger

Debuggers are implemented as IO plugins. Therefore, radare can handle different URI types for spawning, attaching and controlling processes. The complete list of IO plugins can be viewed with `r2 -L`. Those that have "d" in the first column ("rwd") support debugging. For example:

```
r_d  debug      Debug a program or pid. dbg:///bin/ls, dbg://1388 (LGPL3)
rwd  gdb        Attach to gdbserver, 'qemu -s', gdb://localhost:1234 (LGPL3)
```

There are different backends for many target architectures and operating systems, e.g., GNU/Linux, Windows, MacOS X, (Net,Free,Open)BSD and Solaris.

Process memory is treated as a plain file. All mapped memory pages of a debugged program and its libraries can be read and interpreted as code or data structures.

Communication between radare and the debugger IO layer is wrapped into `system()` calls, which accept a string as an argument, and executes it as a command. An answer is then buffered in the output console, its contents can be additionally processed by a script. Access to the IO system is achieved with `=!`. Most IO plugins provide help with `=!?` or `=!help`. For example:

```
$ r2 -d /bin/ls
...
[0x7fc15afa3cc0]> =!help
Usage: =!cmd args
      =!ptrace - use ptrace io
      =!mem    - use /proc/pid/mem io if possible
      =!pid    - show targeted pid
      =!pid <#> - select new pid
```

In general, debugger commands are portable between architectures and operating systems. Still, as radare tries to support the same functionality for all target architectures and operating systems, certain things have to be handled separately. They include injecting shellcodes and handling exceptions. For example, in MIPS targets there is no hardware-supported single-stepping feature. In this case, radare2 provides its own implementation for single-step by using a mix of code analysis and software breakpoints.

To get basic help for the debugger, type 'd?':

```
Usage: d # Debug commands
db[?]           Breakpoints commands
dbt[?]          Display backtrace based on dbg.btdepth and dbg.btalgo
dc[?]           Continue execution
dd[?]           File descriptors (!fd in r1)
de[-sc] [rwx] [rm] [e] Debug with ESIL (see de?)
dg <file>       Generate a core-file (WIP)
dH [handler]    Transplant process to a new handler
di[?]           Show debugger backend information (See dh)
dk[?]           List, send, get, set, signal handlers of child
dL [handler]    List or set debugger handler
dm[?]           Show memory maps
do[?]           Open process (reload, alias for 'oo')
doo[args]        Reopen in debugger mode with args (alias for 'ood')
dp[?]           List, attach to process or thread id
dr[?]           Cpu registers
ds[?]           Step, over, source line
dt[?]           Display instruction traces (dtr=reset)
dw <pid>        Block prompt until pid dies
dx[?]           Inject and run code on target process (See gs)
```

To restart your debugging session, you can type `oo` or `oo+`, depending on desired behavior.

```
oo               reopen current file (kill+fork in debugger)
oo+              reopen current file in read-write
```

Getting Started

Small session in radare2 debugger

- `r2 -d /bin/ls` : Opens radare2 with file `/bin/ls` in debugger mode using the radare2 native debugger, but does not run the program. You'll see a prompt (radare2) - all examples are from this prompt.
- `db flag` : place a breakpoint at flag, where flag can be either an address or a function name
- `db - flag` : remove the breakpoint at flag, where flag can be either an address or a function name
- `db` : show list of breakpoint
- `dc` : run the program
- `dr` : Show registers state
- `drr` : Show registers references (telescoping) (like peda)
- `ds` : Step into instruction
- `dso` : Step over instruction
- `dbt` : Display backtrace
- `dm` : Show memory maps
- `dk <signal>` : Send KILL signal to child
- `ood` : reopen in debug mode
- `ood arg1 arg2` : reopen in debug mode with arg1 and arg2

Migration from ida, GDB or WinDBG

How to run the program using the debugger

```
r2 -d /bin/ls - start in debugger mode => [video]
```

How do I attach/detach to running process ? (gdb -p)

```
r2 -d <pid> - attach to process
```

```
r2 ptrace://pid - same as above, but only for io (not debugger backend hooked)
```

```
[0x7fff6ad90028]> o-225 - close fd=225 (listed in o~[1]:0 )
```

```
r2 -D gdb gdb://localhost:1234 - attach to gdbserver
```

How to set args/environnement variable/load a specific libraries for the debugging session of radare

```
Use rarun2 ( libpath=$PWD:/tmp/lib , arg2=hello , setenv=FOO=BAR ...) see rarun2 -h / man rarun2
```

How to script radare2 ?

```
r2 -i <scriptfile> ... - run a script after loading the file => [video]
```

```
r2 -I <scriptfile> ... - run a script before loading the file
```

```
r2 -c $@ | awk $@ - run thru awk get asm from function => [link]
```

```
[0x80480423]> . scriptfile - interpret this file => [video]
```

```
[0x80480423]> #!c - enter C repl (see #! to list all available RLang plugins) => [video], everything have to be done in a oneliner or a .c file must be passed as an argument.
```

To get `#!python` and much more, just build [radare2-bindings](#)

How to list Source code as in gdb list ?

CL TODO, see [#1783](#)

shortcuts

Command	IDA Pro	radare2	r2 (visual mode)	GDB
Analysis				
Analysis of everything	Automatically launched when opening a binary	aaa or -A (aaaa or -AA for even experimental analysis)	N/A	N/A
Navigation				
xref to	x	axt	x	N/A
xref from	ctrl + j	axf	x	N/A
xref to graph	?	agt [offset]	?	N/A
xref from graph	?	agf [offset]	?	N/A
list functions	alt + 1	afl;is	t	N/A
listing	alt + 2	pdf	p	N/A
hex mode	alt + 3	pxa	P	N/A
imports	alt + 6	ii	:ii	N/A
exports	alt + 7	is~FUNC	?	N/A
follow jmp/call	enter	s offset	enter or 0 - 9	N/A
undo seek	esc	s-	u	N/A
redo seek	ctrl+enter	s+	U	N/A
show graph	space	agv	v	N/A
Edit				
rename	n	afn	dr	N/A
graph view	space	agv	v	N/A
define as data	d	Cd [size]	dd , db , dw , dw	N/A
define as code	c	C- [size]	d- or du	N/A
define as undefined	u	C- [size]	d- or du	N/A
define as string	A	Cs [size]	ds	N/A

define as struct	Alt+Q	Cf [size]	dF	N/A
Debugger				
Start Process/ Continue execution	F9	dc	F9	r ar
Terminate Process	Ctrl+F2	dk 9	?	kill
Detach	?	o-	?	detach
step into	F7	ds	s	n
step into 4 instructions	?	ds 4	F7	n 4
step over	F8	dso	s	s
step until a specific address	?	dsu <addr>	?	s
Run until return	Ctrl+F7	dcr	?	finis
Run until cursor	F4	#249	#249	N/A
Show Backtrace	?	dbt	?	bt
display Register	On register Windows	dr all	Shown in Visual mode	regist
display eax	On register Windows	dr?eax	Shown in Visual mode	regist eax
display old state of all registers	?	dro	?	?
display function addr + N	?	afi \$\$ - display function information of current offset (\$\$)	?	?
display frame state	?	pxw rbp-rsp@rsp	?	i f
How to step until condition is true	?	dsi	?	?
Update a register value	?	dr rip=0x456	?	\$rip=6
Disassembly				
disassembly forward	N/A	pd	Vp	disas
disassembly instructions	N	pd X	Vp	x/i
disassembly	N	pd -X	Vp	disas

(backward)		pd -x	Vp	<a>
Information on the bin				
Sections/regions	sections Menu	is or s (append j for json)	N/A	maint sectio
Load symbol file				
Sections/regions	pdb menu	asm.dwarf.file , pdb.xx)	N/A	add- symbol
BackTrace				
Stack Trace	N/A	dbt	N/A	bt
Stack Trace in Json	N/A	dbtj	N/A	
Partial Backtrace (innermost)	N/A	dbt (dbg.btdepth dbg.btalgo)	N/A	bt
Partial Backtrace (outermost)	N/A	dbt (dbg.btdepth dbg.btalgo)	N/A	bt -
Stacktrace for all threads	N/A	dbt@t	N/A	apply bt
Breakpoints				
Breakpoint list	Ctrl+Alt+B	db	?	breakp
add breakpoint	F2	db [offset]	F2	break
Threads				
Switch to thread	Thread menu	dp	N/A	thread
Frames				
Frame Numbers	N/A	?	N/A	an- commar
Select Frame	N/A	?	N/A	frame
Parameters/Locals				
Display parameters	N/A	afv	N/A	info
Display parameters	N/A	afv	N/A	locals
Display parameters/locals in json	N/A	afvj	N/A	locals
list addresses				

where vars are accessed(R/W)	N/A	afvR/afvW	N/A	?
Project Related				
open project		Po [file]		?
save project	automatic	Ps [file]		?
show project informations		Pi [file]		?
Miscellaneous				
Dump byte char array	N/A	pc? (json, C, char, etc.)	Vppp	x/bc
options	option menu	e?	e	
search	search menu	/?	Select the zone with the cursor c then /	

Equivalent of "set-follow-fork-mode" gdb command

This can be done using 2 commands:

1. `dcf` - until a fork happen
2. then use `dp` to select what process you want to debug.

Common features

- r2 accepts FLIRT signatures
- r2 can connect to GDB, LLVM and WinDbg
- r2 can write/patch in place
- r2 have fortunes and [s]easter eggs[/s]balls of steel
- r2 can do basic loading of ELF core files from the box and MDMP (Windows minidumps)

Registers

The registers are part of a user area stored in the context structure used by the scheduler. This structure can be manipulated to get and set the values of those registers, and, for example, on Intel hosts, it is possible to directly manipulate DR0-DR7 hardware registers to set hardware breakpoints.

There are different commands to get values of registers. For the General Purpose ones use:

```
[0x4A13B8C0]> dr
r15 = 0x00000000
r14 = 0x00000000
r13 = 0x00000000
r12 = 0x00000000
rbp = 0x00000000
rbx = 0x00000000
r11 = 0x00000000
r10 = 0x00000000
r9 = 0x00000000
r8 = 0x00000000
rax = 0x00000000
rcx = 0x00000000
rdx = 0x00000000
rsi = 0x00000000
rdi = 0x00000000
oeax = 0x0000003b
rip = 0x7f20bf5df630
rsp = 0x7fff515923c0

[0x7f0f2dbae630]> dr rip ; get value of 'rip'
0x7f0f2dbae630

[0x4A13B8C0]> dr rip = esp ; set 'rip' as esp
```

Interaction between a plugin and the core is done by commands returning radare instructions. This is used, for example, to set flags in the core to set values of registers.

```
[0x7f0f2dbae630]> dr*      ; Appending '*' will show radare commands
f r15 1 0x0
f r14 1 0x0
f r13 1 0x0
f r12 1 0x0
f rbp 1 0x0
f rbx 1 0x0
f r11 1 0x0
f r10 1 0x0
f r9 1 0x0
f r8 1 0x0
f rax 1 0x0
f rcx 1 0x0
f rdx 1 0x0
f rsi 1 0x0
f rdi 1 0x0
f oeax 1 0x3b
f rip 1 0x7fff73557940
f rflags 1 0x200
f rsp 1 0x7fff73557940

[0x4A13B8C0]> .dr* ; include common register values in flags
```

An old copy of registers is stored all the time to keep track of the changes done during execution of a program being analyzed. This old copy can be accessed with `oregs`.

```
[0x7f1fab84c630]> dro
r15 = 0x00000000
r14 = 0x00000000
r13 = 0x00000000
r12 = 0x00000000
rbp = 0x00000000
rbx = 0x00000000
r11 = 0x00000000
r10 = 0x00000000
r9 = 0x00000000
r8 = 0x00000000
rax = 0x00000000
rcx = 0x00000000
rdx = 0x00000000
rsi = 0x00000000
rdi = 0x00000000
oeax = 0x0000003b
rip = 0x7f1fab84c630
rflags = 0x00000200
rsp = 0x7fff386b5080
```

Current state of registers

```
[0x7f1fab84c630]> dr
r15 = 0x00000000
r14 = 0x00000000
r13 = 0x00000000
r12 = 0x00000000
rbp = 0x00000000
rbx = 0x00000000
r11 = 0x00000000
r10 = 0x00000000
r9 = 0x00000000
r8 = 0x00000000
rax = 0x00000000
rcx = 0x00000000
rdx = 0x00000000
rsi = 0x00000000
rdi = 0x7fff386b5080
oeax = 0xfffffffffffffff
rip = 0x7f1fab84c633
rflags = 0x00000202
rsp = 0x7fff386b5080
```

Values stored in eax, oeax and eip have changed.

To store and restore register values you can just dump the output of 'dr*' command to disk and then re-interpret it again:

```
[0x4A13B8C0]> dr* > regs.saved ; save registers
[0x4A13B8C0]> drp regs.saved ; restore
```

EFLAGS can be similarly altered. E.g., setting selected flags:

```
[0x4A13B8C0]> dr eflags = pst
[0x4A13B8C0]> dr eflags = azsti
```

You can get a string which represents latest changes of registers using `drd` command (diff registers):

```
[0x4A13B8C0]> drd
oeax = 0x0000003b was 0x00000000 delta 59
rip = 0x7f00e71282d0 was 0x00000000 delta -418217264
rflags = 0x00000200 was 0x00000000 delta 512
rsp = 0x7ffe85a09c0 was 0x00000000 delta -396752448
```

Memory Maps

The ability to understand and manipulate the memory maps of a debugged program is important for many different Reverse Engineering tasks. radare2 offers a rich set of commands to handle memory maps in the binary. This includes listing the memory maps of the currently debugged binary, removing memory maps, handling loaded libraries and more.

First, let's see the help message for `dm`, the command which is responsible for handling memory maps:

```
[0x55f2104cf620]> dm?
| Usage: dm # Memory maps commands
| dm           List memory maps of target process
| dm addr size Allocate <size> bytes at <address> (anywhere if address is -1) in ch
|  ild process
| dm=          List memory maps of target process (ascii-art bars)
| dm.          Show map name of current address
| dm*          List memmaps in radare commands
| dm- address  Deallocate memory map of <address>
| dmd[a] [file] Dump current (all) debug map region to a file (from-to.dmp) (see Sd)
| dmh[?]       Show map of heap
| dmi.         List closest symbol to the current address
| dmiv        Show address of given symbol for given lib
| dmj          List memmaps in JSON format
| dml <file>   Load contents of file into the current map region (see S1)
| dmm[?][j*]    List modules (libraries, binaries loaded in memory)
| dmi [addr|libname] [symname] List symbols of target lib
| dmi* [addr|libname] [symname] List symbols of target lib in radare commands
| dmp[?] <address> <size> <perms> Change page at <address> with <size>, protection <p
|   rms> (rwx)
| dms[?] <id> <mapaddr>           Take memory snapshot
| dms- <id> <mapaddr>           Restore memory snapshot
| dmS [addr|libname] [sectname] List sections of target lib
| dmS* [addr|libname] [sectname] List sections of target lib in radare commands
```

In this chapter, we'll go over some of the most useful subcommands of `dm` using simple examples. For the following examples, we'll use a simple `helloworld` program for Linux but it'll be the same for every binary.

First things first - open a program in debugging mode:

```
$ r2 -d helloworld
Process with PID 20304 started...
= attach 20304 20304
bin.baddr 0x56136b475000
Using 0x56136b475000
asm.bits 64
[0x7f133f022fb0]>
```

Note that we passed "helloworld" to radare2 without "./". radare2 will try to find this program in the current directory and then in \$PATH, even if no "./" is passed. This is contradictory with UNIX systems, but makes the behaviour consistent for windows users

Let's use `dm` to print the memory maps of the binary we've just opened:

```
[0x7f133f022fb0]> dm
0x00000563a0113a000 - usr    4K s r-x /tmp/helloworld /tmp/helloworld ; map.tmp_helloworld.r_x
0x00000563a0133a000 - usr    8K s rw- /tmp/helloworld /tmp/helloworld ; map.tmp_helloworld.rw
0x000007f133f022000 * usr 148K s r-x /usr/lib/ld-2.27.so /usr/lib/ld-2.27.so ; map.usr_lib_ld_2.27.so.r_x
0x000007f133f246000 - usr    8K s rw- /usr/lib/ld-2.27.so /usr/lib/ld-2.27.so ; map.usr_lib_ld_2.27.so.rw
0x000007f133f248000 - usr    4K s rw- unk0 unk0 ; map.unk0.rw
0x000007ffffd25ce000 - usr 132K s rw- [stack] [stack] ; map.stack_.rw
0x000007ffffd25f6000 - usr   12K s r-- [vvar] [vvar] ; map.vvar_.r
0x000007ffffd25f9000 - usr    8K s r-x [vdso] [vdso] ; map.vdso_.r_x
0xfffffffffff600000 - usr    4K s r-x [vsyscall] [vsyscall] ; map.vsyscall_.r_x
```

For those of you who prefer a more visual way, you can use `dm=` to see the memory maps using an ASCII-art bars. This will be handy when you want to see how these maps are located in the memory.

If you want to know the memory-map you are currently in, use `dm.` :

```
[0x7f133f022fb0]> dm.
0x000007f947eed9000 # 0x000007f947eef000 * usr    148K s r-x /usr/lib/ld-2.27.so /usr/lib/ld-2.27.so ; map.usr_lib_ld_2.27.so.r_x
```

Using `dmm` we can "List modules (libraries, binaries loaded in memory)", this is quite a handy command to see which modules were loaded.

```
[0x7fa80a19dfb0]> dmm
0x55ca23a4a000 /tmp/helloworld
0x7fa80a19d000 /usr/lib/ld-2.27.so
```

Note that the output of `dm` subcommands, and `dmm` specifically, might be different in various systems and different binaries.

We can see that along with our `helloworld` binary itself, another library was loaded which is `ld-2.27.so`. We don't see `libc` yet and this is because radare2 breaks before `libc` is loaded to memory. Let's use `dcu` (`debug continue until`) to execute our program until the entry point of the program, which radare flags as `entry0`.

```
[0x7fa80a19dfb0]> dcu entry0
Continue until 0x55ca23a4a520 using 1 bpsize
hit breakpoint at: 55ca23a4a518
[0x55ca23a4a520]> dmm
0x55ca23a4a000 /tmp/helloworld
0x7fa809de1000 /usr/lib/libc-2.27.so
0x7fa80a19d000 /usr/lib/ld-2.27.so
```

Now we can see that `libc-2.27.so` was loaded as well, great!

Speaking of `libc`, a popular task for binary exploitation is to find the address of a specific symbol in a library. With this information in hand, you can build, for example, an exploit which uses ROP. This can be achieved using the `dmi` command. So if we want, for example, to find the address of `system()` in the loaded `libc`, we can simply execute the following command:

```
[0x55ca23a4a520]> dmi libc system
514 0x00000000 0x7fa809de1000 LOCAL FILE 0 system.c
515 0x00043750 0x7fa809e24750 LOCAL FUNC 1221 do_system
4468 0x001285a0 0x7fa809f095a0 LOCAL FUNC 100 svcerr_systemerr
5841 0x001285a0 0x7fa809f095a0 LOCAL FUNC 100 svcerr_systemerr
6427 0x00043d10 0x7fa809e24d10 WEAK FUNC 45 system
7094 0x00043d10 0x7fa809e24d10 GLBAL FUNC 45 system
7480 0x001285a0 0x7fa809f095a0 GLBAL FUNC 100 svcerr_systemerr
```

Similar to the `dm.` command, with `dmi.` you can see the closest symbol to the current address.

Another useful command is to list the sections of a specific library. In the following example we'll list the sections of `ld-2.27.so`:

```
[0x55a7ebf09520]> dmS ld-2.27
[Sections]
00 0x0000000000      0 0x0000000000      0 ---- ld-2.27.so.
01 0x0000001c8       36 0x4652d1c8       36 -r-- ld-2.27.so..note.gnu.build_id
02 0x0000001f0       352 0x4652d1f0      352 -r-- ld-2.27.so..hash
03 0x000000350       412 0x4652d350      412 -r-- ld-2.27.so..gnu.hash
04 0x0000004f0       816 0x4652d4f0      816 -r-- ld-2.27.so..dynsym
05 0x000000820       548 0x4652d820      548 -r-- ld-2.27.so..dynstr
06 0x000000a44       68 0x4652da44       68 -r-- ld-2.27.so..gnu.version
07 0x000000a88       164 0x4652da88      164 -r-- ld-2.27.so..gnu.version_d
08 0x000000b30      1152 0x4652db30     1152 -r-- ld-2.27.so..rela.dyn
09 0x000000fb0     11497 0x4652dfb0    11497 -r-x ld-2.27.so..text
10 0x0001d0e0      17760 0x4654a0e0    17760 -r-- ld-2.27.so..rodata
11 0x00021640      1716 0x4654e640     1716 -r-- ld-2.27.so..eh_frame_hdr
12 0x00021cf8      9876 0x4654ecf8     9876 -r-- ld-2.27.so..eh_frame
13 0x00024660     2020 0x46751660    2020 -rw- ld-2.27.so..data.rel.ro
14 0x00024e48      336 0x46751e48     336 -rw- ld-2.27.so..dynamic
15 0x00024f98      96 0x46751f98      96 -rw- ld-2.27.so..got
16 0x00025000     3960 0x46752000    3960 -rw- ld-2.27.so..data
17 0x00025f78        0 0x46752f80     376 -rw- ld-2.27.so..bss
18 0x00025f78        17 0x0000000000   17 ---- ld-2.27.so..comment
19 0x00025fa0        63 0x0000000000   63 ---- ld-2.27.so..gnu.warning.llseek
20 0x00025fe0     13272 0x0000000000 13272 ---- ld-2.27.so..symtab
21 0x000293b8      7101 0x0000000000  7101 ---- ld-2.27.so..strtab
22 0x0002af75      215 0x0000000000  215 ---- ld-2.27.so..shstrtab
```

Heap

radare2's `dm` subcommands can also display a map of the heap which is useful for those who are interesting in inspecting the heap and its content. Simply execute `dmh` to show a map of the heap:

```
[0x7fae46236ca6]> dmh
Malloc chunk @ 0x55a7ecbce250 [size: 0x411][allocated]
Top chunk @ 0x55a7ecbce660 - [brk_start: 0x55a7ecbce000, brk_end: 0x55a7ecbef000]
```

You can also see a graph layout of the heap:

```
[0x7fae46236ca6]> dmhg
Heap Layout
.
|   Malloc chunk @ 0x55a7ecbce000   |
| size: 0x251                      |
| fd: 0x0, bk: 0x0                 |
.
|
.
|   Malloc chunk @ 0x55a7ecbce250   |
| size: 0x411                      |
| fd: 0x57202c6f6c6c6548, bk: 0xa21646c726f |
.
|
.
|   Top chunk @ 0x55a7ecbce660   |
| [brk_start:0x55a7ecbce000, brk_end:0x55a7ecbef000] |
```

Another heap commands can be found under `dmh`, check `dmh?` for the full list.

```
[0x00000000]> dmh?
|Usage: dmh # Memory map heap
| dmh          List chunks in heap segment
| dmh [malloc_state] List heap chunks of a particular arena
| dmha         List all malloc_state instances in application
| dmhb         Display all parsed Double linked list of main_arena's bins instance
| dmhb [bin_num|bin_num:malloc_state]      Display parsed double linked list of bins instance from a particular arena
| dmhbg [bin_num]    Display double linked list graph of main_arena's bin [Under development]
| dmhc @[chunk_addr]  Display malloc_chunk struct for a given malloc chunk
| dmhf          Display all parsed fastbins of main_arena's fastbinY instance
| dmhf [fastbin_num|fastbin_num:malloc_state]  Display parsed single linked list in fastbinY instance from a particular arena
| dmhg          Display heap graph of heap segment
| dmhg [malloc_state] Display heap graph of a particular arena
| dmhi @[malloc_state]Display heap_info structure/structures for a given arena
| dmhm          List all elements of struct malloc_state of main thread (main_arena)
| dmhm [malloc_state] List all malloc_state instance of a particular arena
| dmht          Display all parsed tcache bins of main_arena's tcache instance
| dmh?          Show map heap help
```

Files

The radare2 debugger allows the user to list and manipulate the file descriptors from the target process.

This is a useful feature, which is not found in other debuggers, the functionality is similar to the lsof command line tool.

But have extra subcommands to change the seek, close or duplicate them.

So, at any time in the debugging session you can replace the stdio file descriptors to use network sockets created by r2, or replace a network socket connection to hijack it.

This functionality is also available in r2frida by using the dd command prefixed with a backslash. In r2 you may want to see the output of dd? for proper details.

Reverse Debugging

Radare2 has reverse debugger, that can seek program counter backward. (e.g. reverse-next, reverse-continue in gdb) Firstly you need to save program state at the point that you want to start recording. The syntax for recording is:

```
[0x004028a0]> dts+
```

You can use `dts` commands for recording and managing program states. After recording the states, you can seek pc back and forth to any points after saved address. So after recording, you can try single step back:

```
[0x004028a0]> 2dso
[0x004028a0]> dr rip
0x004028ae
[0x004028a0]> dsb
continue until 0x004028a2
hit breakpoint at: 4028a2
[0x004028a0]> dr rip
0x004028a2
```

When you run `dsb`, reverse debugger restore previous recorded state and execute program from it until desired point.

Or you can also try continue back:

```
[0x004028a0]> db 0x004028a2
[0x004028a0]> 10dso
[0x004028a0]> dr rip
0x004028b9
[0x004028a0]> dcbs
[0x004028a0]> dr rip
0x004028a2
```

`dcbs` seeks program counter until hit the latest breakpoint. So once set a breakpoint, you can back to it any time.

You can see current recorded program states using `dts`:

```
[0x004028a0]> dts
session: 0    at:0x004028a0    ""
session: 1    at:0x004028c2    ""
```

NOTE: Program records can be saved at any moments. These are diff style format that save only different memory area from previous. It saves memory space rather than entire dump.

And also can add comment:

```
[0x004028c2]> dtsC 0 program start
[0x004028c2]> dtsC 1 decryption start
[0x004028c2]> dts
session: 0    at:0x004028a0    "program start"
session: 1    at:0x004028c2    "decryption start"
```

You can leave notes for each records to keep in your mind. `dsb` and `dcb` commands restore the program state from latest record if there are many records.

Program records can be exported to file and of course import it. Export/Import records to/from file:

```
[0x004028c2]> dtst records_for_test
Session saved in records_for_test.session and dump in records_for_test.dump
[0x004028c2]> dtsf records_for_test
session: 0, 0x4028a0 diffs: 0
session: 1, 0x4028c2 diffs: 0
```

Moreover, you can do reverse debugging in ESIL mode. In ESIL mode, program state can be managed by `aets` commands.

```
[0x00404870]> aets+
```

And step back by `aesb`:

```
[0x00404870]> aer rip
0x00404870
[0x00404870]> 5aes0
[0x00404870]> aer rip
0x0040487d
[0x00404870]> aesb
[0x00404870]> aer rip
0x00404879
```

Remote Access Capabilities

Radare can be run locally, or it can be started as a server process which is controlled by a local radare2 process. This is possible because everything uses radare's IO subsystem which abstracts access to system(), cmd() and all basic IO operations so to work over a network.

Help for commands useful for remote access to radare:

```
[0x00405a04]> =?  
|Usage:  =[!:!+-=hH] [...] # radare remote command execution protocol  
|  
rap commands:  
| =          list all open connections  
| =<[fd] cmd send output of local command to remote fd  
| =[fd] cmd  exec cmd at remote 'fd' (last open is default one)  
| != cmd    run command via r_io_system  
| += [proto://]host add host (default=rap://, tcp://, udp://)  
| -=[fd]    remove all hosts or host 'fd'  
| ==[fd]    open remote session with host 'fd', 'q' to quit  
| !==      disable remote cmd mode  
| !=!      enable remote cmd mode  
|  
rap server:  
| =:port    listen on given port using rap protocol (o rap://9999)  
| &:port    start rap server in background  
| =:host:port run 'cmd' command on remote server  
|  
other servers:  
| =h[?]    listen for http connections  
| =g[?]    using gdbserver
```

You can learn radare2 remote capabilities by displaying the list of supported IO plugins:

```
radare2 -L .
```

A little example should make this clearer. A typical remote session might look like this:

At the remote host1:

```
$ radare2 rap://:1234
```

At the remote host2:

```
$ radare2 rap://:1234
```

At localhost:

```
$ radare2 -
```

Add hosts

```
[0x004048c5]> =+ rap://<host1>:1234//bin/ls
Connected to: <host1> at port 1234
waiting... ok

[0x004048c5]> =
0 - rap://<host1>:1234//bin/ls
```

You can open remote files in debug mode (or using any IO plugin) specifying URI when adding hosts:

```
[0x004048c5]> =+ =+ rap://<host2>:1234/dbg:///bin/ls
Connected to: <host2> at port 1234
waiting... ok
0 - rap://<host1>:1234//bin/ls
1 - rap://<host2>:1234/dbg:///bin/ls
```

To execute commands on host1:

```
[0x004048c5]> =0 px
[0x004048c5]> = s 0x666
```

To open a session with host2:

```
[0x004048c5]> ==1
fd:6> pi 1
...
fd:6> q
```

To remove hosts (and close connections):

```
[0x004048c5]> =-
```

You can also redirect radare output to a TCP or UDP server (such as `nc -l`). First, Add the server with '`=+ tcp://`' or '`=+ udp://`', then you can redirect the output of a command to be sent to the server:

```
[0x004048c5]> =+ tcp://<host>:<port>/  
Connected to: <host> at port <port>  
5 - tcp://<host>:<port>/  
[0x004048c5]> =<5 cmd...
```

The `=<` command will send the output from the execution of `cmd` to the remote connection number N (or the last one used if no id specified).

Debugging with gdbserver

radare2 allows remote debugging over the gdb remote protocol. So you can run a gdbserver and connect to it with radare2 for remote debugging. The syntax for connecting is:

```
$ r2 -d gdb://<host>:<port>
```

Note that the following command does the same, r2 will use the debug plugin specified by the uri if found.

```
$ r2 -D gdb gdb://<host>:<port>
```

The debug plugin can be changed at runtime using the dL or Ld commands.

Or if the gdbserver is running in extended mode, you can attach to a process on the host with:

```
$ r2 -d gdb://<host>:<port>/<pid>
```

After connecting, you can use the standard r2 debug commands as normal.

radare2 does not yet load symbols from gdbserver, so it needs the binary to be locally present to load symbols from it. In case symbols are not loaded even if the binary is present, you can try specifying the path with `e dbg.exe.path`:

```
$ r2 -e dbg.exe.path=<path> -d gdb://<host>:<port>
```

If symbols are loaded at an incorrect base address, you can try specifying the base address too with `e bin.baddr`:

```
$ r2 -e bin.baddr=<baddr> -e dbg.exe.path=<path> -d gdb://<host>:<port>
```

Usually the gdbserver reports the maximum packet size it supports. Otherwise, radare2 resorts to sensible defaults. But you can specify the maximum packet size with the environment variable `R2_GDB_PKTSZ`. You can also check and set the max packet size during a session with the IO system, `=!`.

```
$ export R2_GDB_PKTSZ=512
$ r2 -d gdb://<host>:<port>
= attach <pid> <tid>
Assuming filepath <path/to/exe>
[0x7ff659d9fcc0]> =!pktsz
packet size: 512 bytes
[0x7ff659d9fcc0]> =!pktsz 64
[0x7ff659d9fcc0]> =!pktsz
packet size: 64 bytes
```

The gdb IO system provides useful commands which might not fit into any standard radare2 commands. You can get a list of these commands with `=!?`. (Remember, `=!` accesses the underlying IO plugin's `system()`).

```
[0x7ff659d9fcc0]> =!?
Usage: =!cmd args
=!pid           - show targeted pid
=!pkt s         - send packet 's'
=!monitor cmd   - hex-encode monitor command and pass to target interpreter
=!detach [pid]  - detach from remote/detach specific pid
=!inv.reg       - invalidate reg cache
=!=pktsz        - get max packet size used
=!=pktsz bytes  - set max. packet size as 'bytes' bytes
=!=exec_file [pid] - get file which was executed for current/specifed pid
```

radare2 also provides its own gdbserver implementation:

```
$ r2 -
[0x0000000000]> =g?
|Usage: =[g] [...] # gdb server
| gdbserver:
| =g port file [args]  listen on 'port' debugging 'file' using gdbserver
| =g! port file [args] same as above, but debug protocol messages (like gdbserver --r
emote-debug)
```

So you can start it as:

```
$ r2 -
[0x0000000000]> =g 8000 /bin/radare2 -
```

And then connect to it like you would to any gdbserver. For example, with radare2:

```
$ r2 -d gdb://localhost:8000
```


WinDBG

The WinDBG support for r2 allows you to attach to VM running Windows using a named socket file (will support more IOs in the future) to debug a windows box using the KD interface over serial port.

Bear in mind that WinDBG support is still work-in-progress, and this is just an initial implementation which will get better in time.

It is also possible to use the remote GDB interface to connect and debug Windows kernels without depending on Windows capabilities.

Enable WinDBG support on Windows Vista and higher like this:

```
bcdedit /debug on
bcdedit /dbgsettings serial debugport:1 baudrate:115200
```

Starting from Windows 8 there is no way to enforce debugging for every boot, but it is possible to always show the advanced boot options, which allows to enable kernel debugging:

```
bcdedit /set {globalsettings} advancedoptions true
```

Or like this for Windows XP: Open boot.ini and add /debug /debugport=COM1 /baudrate=115200:

```
[boot loader]
timeout=30
default=multi(0)disk(0)rdisk(0)partition(1)\WINDOWS
[operating systems]
multi(0)disk(0)rdisk(0)partition(1)\WINDOWS="Debugging with Cable" /fastdetect /debug
/debugport=COM1 /baudrate=57600
```

In case of VMWare

```
Virtual Machine Settings -> Add -> Serial Port
Device Status:
[v] Connect at power on
Connection:
[v] Use socket (named pipe)
[_/tmp/windbg.pipe_____]
From: Server To: Virtual Machine
```

Configure the VirtualBox Machine like this:

```
Preferences -> Serial Ports -> Port 1

[v] Enable Serial Port
Port Number: [_COM1_____][v]
Port Mode:   [_Host_Pipe__[v]]
[v] Create Pipe
Port/File Path: [/tmp/windbg.pipe____]
```

Or just spawn the VM with qemu like this:

```
$ qemu-system-x86_64 -chardev socket,id=serial0,\
path=/tmp/windbg.pipe,nowait,server \
-serial chardev:serial0 -hda Windows7-VM.vdi
```

Radare2 will use the 'windbg' io plugin to connect to a socket file created by virtualbox or qemu. Also, the 'windbg' debugger plugin and we should specify the x86-32 too. (32 and 64 bit debugging is supported)

```
$ r2 -a x86 -b 32 -D windbg windbg:///tmp/windbg.pipe
```

On Windows you should run the following line:

```
$ radare2 -D windbg windbg://\\.\pipe\com_1
```

At this point, we will get stuck here:

```
[0x828997b8]> pd 20
;-- eip:
0x828997b8 cc int3
0x828997b9 c20400 ret 4
0x828997bc cc int3
0x828997bd 90 nop
0x828997be c3 ret
0x828997bf 90 nop
```

In order to skip that trap we will need to change eip and run 'dc' twice:

```
dr eip=eip+1
dc
dr eip=eip+1
dc
```

Now the Windows VM will be interactive again. We will need to kill r2 and attach again to get back to control the kernel.

In addition, the `dp` command can be used to list all processes, and `dpa` or `dp=` to attach to the process. This will display the base address of the process in the physical memory layout.

Tools

Radare2 is not just the only tool provided by the radare2 project. All the functionalities provided by the different APIs and plugins have also different tools to allow to use them from the commandline and integrate them with shellscripts easily.

Rax2

The `rax2` utility comes with the radare framework and aims to be a minimalistic expression evaluator for the shell. It is useful for making base conversions between floating point values, hexadecimal representations, hexpair strings to ascii, octal to integer. It supports endianness and can be used as a shell if no arguments are given.

```
$ rax2 -h
Usage: rax2 [options] [expr ...]
=[base]                                ; rax2 =10 0x46 -> output in base 10
int      -> hex                      ; rax2 10
hex      -> int                      ; rax2 0xa
-int     -> hex                      ; rax2 -77
-hex     -> int                      ; rax2 0xfffffffffb3
int      -> bin                      ; rax2 b30
int      -> ternary                  ; rax2 t42
bin      -> int                      ; rax2 1010d
ternary -> int                      ; rax2 1010dt
float    -> hex                      ; rax2 3.33f
hex      -> float                     ; rax2 Fx40551ed8
oct      -> hex                      ; rax2 35o
hex      -> oct                      ; rax2 0x12 (0 is a letter)
bin      -> hex                      ; rax2 1100011b
hex      -> bin                      ; rax2 Bx63
ternary -> hex                      ; rax2 212t
hex      -> ternary                  ; rax2 Tx23
raw      -> hex                      ; rax2 -S < /binfile
hex      -> raw                      ; rax2 -s 414141
-l                   ; append newline to output (for -E/-D/-r/..
-a      show ascii table             ; rax2 -a
-b      bin -> str                  ; rax2 -b 01000101 01110110
-B      str -> bin                  ; rax2 -B hello
-d      force integer               ; rax2 -d 3 -> 3 instead of 0x3
-e      swap endianness            ; rax2 -e 0x33
-D      base64 decode              ;
-E      base64 encode              ;
-f      floating point              ; rax2 -f 6.3+2.1
-F      stdin slurp code hex       ; rax2 -F < shellcode.[c/py/js]
-h      help                       ; rax2 -h
-i      dump as C byte array      ; rax2 -i < bytes
-k      keep base                 ; rax2 -k 33+3 -> 36
-K      randomart                 ; rax2 -K 0x34 1020304050
-L      bin -> hex(bignum)        ; rax2 -L 111111111 # 0x1ff
-n      binary number              ; rax2 -n 0x1234 # 34120000
-N      binary number              ; rax2 -N 0x1234 # \x34\x12\x00\x00
-r      r2 style output           ; rax2 -r 0x1234
-s      hexstr -> raw             ; rax2 -s 43 4a 50
-S      raw -> hexstr              ; rax2 -S < /bin/ls > ls.hex
-t      tstamp -> str              ; rax2 -t 1234567890
-x      hash string                ; rax2 -x linux osx
-u      units                      ; rax2 -u 389289238 # 317.0M
-w      signed word                ; rax2 -w 16 0xffff
-v      version                    ; rax2 -v
```

Some examples:

```
$ rax2 3+0x80  
0x83
```

```
$ rax2 0x80+3  
131
```

```
$ echo 0x80+3 | rax2  
131
```

```
$ rax2 -s 4142  
AB
```

```
$ rax2 -S AB  
4142
```

```
$ rax2 -S < bin.foo  
...
```

```
$ rax2 -e 33  
0x21000000
```

```
$ rax2 -e 0x21000000  
33
```

```
$ rax2 -K 90203010  
+--[0x10302090]---+  
|Eo. . . . . |  
| . . . . . |  
| . . . . . |  
| . . . . . |  
| . . . . . |  
| . . . . . |  
| . . . . . |  
| . . . . . |  
+-----+
```


rafind2

TODO

Rarun2

Rarun2 is a tool allowing to setup a specified execution environment - redefine stdin/stdout, pipes, change the environment variables and other settings useful to craft the boundary conditions you need to run a binary for debugging.

```
$ rarun2 -h
Usage: rarun2 -v|-t|script.rr2 [directive ..]
```

It takes the text file in key=value format to specify the execution environment. Rarun2 can be used as both separate tool or as a part of radare2. To load the rarun2 profile in radare2 you need to use either `-r` to load the profile from file or `-R` to specify the directive from string.

The format of the profile is very simple. Note the most important keys - `program` and `arg*`

One of the most common usage cases - redirect the output of debugged program in radare2. For this you need to use `stdio`, `stdout`, `stdin`, `input`, and a couple similar keys.

Here is the basic profile example:

```
program=/bin/ls
arg1=/bin
# arg2=hello
# arg3="hello\nworld"
# arg4=:048490184058104849
# arg5=:!ragg2 -p n50 -d 10:0x8048123
# arg6=@arg.txt
# arg7=@300@ABCD # 300 chars filled with ABCD pattern
# system=r2 -
# aslr=no
setenv=FOO=BAR
# unsetenv=FOO
# clearenv=true
# envfile=environ.txt
timeout=3
# timeoutsig=SIGTERM # or 15
# connect=localhost:8080
# listen=8080
# pty=false
# fork=true
# bits=32
# pid=0
# pidfile=/tmp/foo.pid
# #sleep=0
# #maxfd=0
# #execve=false
# #maxproc=0
# #maxstack=0
# #core=false
# #stdio=blah.txt
# #stderr=foo.txt
# stdout=foo.txt
# stdin=input.txt # or !program to redirect input from another program
# input=input.txt
# chdir=
# chroot=/mnt/chroot
# libpath=$PWD:/tmp/lib
# r2preload=yes
# preload=/lib/libfoo.so
# setuid=2000
# seteuid=2000
# setgid=2001
# setegid=2001
# nice=5
```

Rabin2 — Show Properties of a Binary

Under this bunny-arabic-like name, radare hides a powerful tool to handle binary files, to get information on imports, sections, headers and other data. Rabin2 can present it in several formats accepted by other tools, including radare2 itself. Rabin2 understands many file formats: Java CLASS, ELF, PE, Mach-O or any format supported by plugins, and it is able to obtain symbol import(exports), library dependencies, strings of data sections, xrefs, entrypoint address, sections, architecture type.

```
$ rabin2 -h
Usage: rabin2 [-AcdeEghHiIj1LMqrRsSvVxzz] [-@ at] [-a arch] [-b bits] [-B addr]
              [-C F:C:D] [-f str] [-m addr] [-n str] [-N m:M] [-P[-P] pdb]
              [-o str] [-O str] [-k query] [-D lang symname] | file

-@ [addr]      show section, symbol or import at addr
-A             list sub-binaries and their arch-bits pairs
-a [arch]       set arch (x86, arm, .. or <arch>_<bits>)
-b [bits]       set bits (32, 64 ...)
-B [addr]       override base address (pie bins)
-c             list classes
-C [fmt:C:D]   create [elf,mach0,pe] with Code and Data hexpairs (see -a)
-d             show debug/dwarf information
-D lang name   demangle symbol name (-D all for bin.demangle=true)
-e             entrypoint
-E             globally exportable symbols
-f [str]        select sub-bin named str
-F [binfmt]     force to use that bin plugin (ignore header check)
-g             same as -SMZIHVResizcld (show all info)
-G [addr]       load address . offset to header
-h             this help message
-H             header fields
-i             imports (symbols imported from libraries)
-I             binary info
-j             output in json
-k [sdb-query] run sdb query. for example: '*'
-K [algo]       calculate checksums (md5, sha1, ...)
-l             linked libraries
-L [plugin]    list supported bin plugins or plugin details
-m [addr]       show source line at addr
-M             main (show address of main symbol)
-n [str]        show section, symbol or import named str
-N [min:max]   force min:max number of chars per string (see -z and -zz)
-o [str]        output file/folder for write operations (out by default)
-O [str]        write/extract operations (-O help)
-p             show physical addresses
-P             show debug/pdb information
-PP            download pdb file for binary
-q             be quiet, just show fewer data
```

```
-qq           show less info (no offset/size for -z for ex.)  
-Q           show load address used by dlopen (non-aslr libs)  
-r           radare output  
-R           relocations  
-s           symbols  
-S           sections  
-u           unfiltered (no rename duplicated symbols/sections)  
-v           display version and quit  
-V           Show binary version information  
-x           extract bins contained in file  
-X [fmt] [f] .. package in fat or zip the given files and bins contained in file  
-z           strings (from data section)  
-zz          strings (from raw bins [e bin.rawstr=1])  
-zzz         dump raw strings to stdout (for huge files)  
-Z           guess size of binary program  
.....
```

File Properties Identification

File type identification is done using `-I`. With this option, rabin2 prints information on a binary type, like its encoding, endianness, class, operating system:

```
$ rabin2 -I /bin/ls
arch      x86
binsz    128456
bintype   elf
bits      64
canary    true
class     ELF64
crypto    false
endian   little
havecode  true
intrp    /lib64/ld-linux-x86-64.so.2
lang      c
linenum   false
lsyms    false
machine   AMD x86-64 architecture
maxopsz  16
minopsz  1
nx       true
os       linux
pcalign   0
pic      true
relocs   false
relro    partial
rpath    NONE
static   false
stripped true
subsys   linux
va       true
```

To make rabin2 output information in format that the main program, radare2, can understand, pass `-Ir` option to it:

```
$ rabin2 -Ir /bin/ls
e cfg.bigendian=false
e asm.bits=64
e asm.dwarf=true
e bin.lang=c
e file.type=elf
e asm.os=linux
e asm.arch=x86
e asm.pcalign=0
```


Code Entrypoints

The `-e` option passed to rabin2 will show entrypoints for given binary. Two examples:

```
$ rabin2 -e /bin/ls
[Entrypoints]
vaddr=0x00005310 paddr=0x00005310 baddr=0x00000000 laddr=0x00000000 haddr=0x00000018 type=program

1 entrypoints

$ rabin2 -er /bin/ls
fs symbols
f entry0 1 @ 0x00005310
f entry0_haddr 1 @ 0x000000018
s entry0
```

Imports

Rabin2 is able to find imported objects by an executable, as well as their offsets in its PLT. This information is useful, for example, to understand what external function is invoked by `call` instruction. Pass `-i` flag to rabin2 to get a list of imports. An example:

```
$ rabin2 -i /bin/ls
[Imports]
 1 0x0000032e0  GLOBAL  FUNC __ctype_toupper_loc
 2 0x0000032f0  GLOBAL  FUNC getenv
 3 0x000003300  GLOBAL  FUNC sigprocmask
 4 0x000003310  GLOBAL  FUNC __snprintf_chk
 5 0x000003320  GLOBAL  FUNC raise
 6 0x000000000  GLOBAL  FUNC free
 7 0x000003330  GLOBAL  FUNC abort
 8 0x000003340  GLOBAL  FUNC __errno_location
 9 0x000003350  GLOBAL  FUNC strncmp
10 0x000000000  WEAK   NOTYPE _ITM_deregisterTMCloneTable
11 0x000003360  GLOBAL  FUNC localtime_r
12 0x000003370  GLOBAL  FUNC _exit
13 0x000003380  GLOBAL  FUNC strcpy
14 0x000003390  GLOBAL  FUNC __fpending
15 0x0000033a0  GLOBAL  FUNC isatty
16 0x0000033b0  GLOBAL  FUNC sigaction
17 0x0000033c0  GLOBAL  FUNC iswcntrl
18 0x0000033d0  GLOBAL  FUNC wcswidth
19 0x0000033e0  GLOBAL  FUNC localeconv
20 0x0000033f0  GLOBAL  FUNC mbstowcs
21 0x000003400  GLOBAL  FUNC readlink
...
...
```

Exports

Rabin2 is able to find exports. For example:

```
$ rabin2 -E /usr/lib/libr_bin.so | head
[Exports]
210 0x000ae1f0 0x000ae1f0 GLOBAL  FUNC  200 r_bin_java_print_exceptions_attr_summary
211 0x000afc90 0x000afc90 GLOBAL  FUNC  135 r_bin_java_get_args
212 0x000b18e0 0x000b18e0 GLOBAL  FUNC   35 r_bin_java_get_item_desc_from_bin_cp_list
213 0x00022d90 0x00022d90 GLOBAL  FUNC  204 r_bin_class_add_method
214 0x000ae600 0x000ae600 GLOBAL  FUNC  175 r_bin_java_print_fieldref_cp_summary
215 0x000ad880 0x000ad880 GLOBAL  FUNC  144 r_bin_java_print_constant_value_attr_summary
216 0x000b7330 0x000b7330 GLOBAL  FUNC  679 r_bin_java_print_element_value_summary
217 0x000af170 0x000af170 GLOBAL  FUNC   65 r_bin_java_create_method_fq_str
218 0x00079b00 0x00079b00 GLOBAL  FUNC   15 LZ4_createStreamDecode
```

Symbols (Exports)

With rabin2, the generated symbols list format is similar to the imports list. Use the `-s` option to get it:

```
rabin2 -s /bin/ls | head
[Symbols]
110 0x0000150a0 0x0000150a0 GLOBAL FUNC 56 _obstack_allocated_p
111 0x00001f600 0x00021f600 GLOBAL OBJ 8 program_name
112 0x00001f620 0x00021f620 GLOBAL OBJ 8 stderr
113 0x000014f90 0x000014f90 GLOBAL FUNC 21 _obstack_begin_1
114 0x00001f600 0x00021f600 WEAK OBJ 8 program_invocation_name
115 0x00001f5c0 0x00021f5c0 GLOBAL OBJ 8 alloc_failed_handler
116 0x00001f5f8 0x00021f5f8 GLOBAL OBJ 8 optarg
117 0x00001f5e8 0x00021f5e8 GLOBAL OBJ 8 stdout
118 0x00001f5e0 0x00021f5e0 GLOBAL OBJ 8 program_short_name
```

With the `-sr` option rabin2 produces a radare2 script instead. It can later be passed to the core to automatically flag all symbols and to define corresponding byte ranges as functions and data blocks.

```
$ rabin2 -sr /bin/ls | head
fs symbols
f sym.obstack_allocated_p 56 0x0000150a0
f sym.program_invocation_name 8 0x00021f600
f sym.stderr 8 0x00021f620
f sym.obstack_begin_1 21 0x000014f90
f sym.program_invocation_name 8 0x00021f600
f sym.obstack_alloc_failed_handler 8 0x00021f5c0
f sym.optarg 8 0x00021f5f8
f sym.stdout 8 0x00021f5e8
f sym.program_invocation_short_name 8 0x00021f5e0
```

List Libraries

Rabin2 can list libraries used by a binary with the `-l` option:

```
$ rabin2 -l `which r2`  
[Linked libraries]  
libr_core.so  
libr_parse.so  
libr_search.so  
libr_cons.so  
libr_config.so  
libr_bin.so  
libr_debug.so  
libr_anal.so  
libr_reg.so  
libr_bp.so  
libr_io.so  
libr_fs.so  
libr_asm.so  
libr_syscall.so  
libr_hash.so  
libr_magic.so  
libr_flag.so  
libr_egg.so  
libr_crypto.so  
libr_util.so  
libpthread.so.0  
libc.so.6  
  
22 libraries
```

Lets check the output with `ldd` command:

```
$ ldd `which r2`  
linux-vdso.so.1 (0x00007ffffba38e000)  
libr_core.so => /usr/lib64/libr_core.so (0x00007f94b4678000)  
libr_parse.so => /usr/lib64/libr_parse.so (0x00007f94b4425000)  
libr_search.so => /usr/lib64/libr_search.so (0x00007f94b421f000)  
libr_cons.so => /usr/lib64/libr_cons.so (0x00007f94b4000000)  
libr_config.so => /usr/lib64/libr_config.so (0x00007f94b3dfa000)  
libr_bin.so => /usr/lib64/libr_bin.so (0x00007f94b3afd000)  
libr_debug.so => /usr/lib64/libr_debug.so (0x00007f94b38d2000)  
libr_anal.so => /usr/lib64/libr_anal.so (0x00007f94b2fdb000)  
libr_reg.so => /usr/lib64/libr_reg.so (0x00007f94b2db4000)  
libr_bp.so => /usr/lib64/libr_bp.so (0x00007f94b2baf000)  
libr_io.so => /usr/lib64/libr_io.so (0x00007f94b2944000)  
libr_fs.so => /usr/lib64/libr_fs.so (0x00007f94b270e000)  
libr_asm.so => /usr/lib64/libr_asm.so (0x00007f94b1c69000)  
libr_syscall.so => /usr/lib64/libr_syscall.so (0x00007f94b1a63000)  
libr_hash.so => /usr/lib64/libr_hash.so (0x00007f94b185a000)  
libr_magic.so => /usr/lib64/libr_magic.so (0x00007f94b164d000)  
libr_flag.so => /usr/lib64/libr_flag.so (0x00007f94b1446000)  
libr_egg.so => /usr/lib64/libr_egg.so (0x00007f94b1236000)  
libr_crypto.so => /usr/lib64/libr_crypto.so (0x00007f94b1016000)  
libr_util.so => /usr/lib64/libr_util.so (0x00007f94b0d35000)  
libpthread.so.0 => /lib64/libpthread.so.0 (0x00007f94b0b15000)  
libc.so.6 => /lib64/libc.so.6 (0x00007f94b074d000)  
libr_lang.so => /usr/lib64/libr_lang.so (0x00007f94b0546000)  
libr_socket.so => /usr/lib64/libr_socket.so (0x00007f94b0339000)  
libm.so.6 => /lib64/libm.so.6 (0x00007f94afffaf000)  
libdl.so.2 => /lib64/libdl.so.2 (0x00007f94afda0000)  
/lib64/ld-linux-x86-64.so.2 (0x00007f94b4c79000)  
libssl.so.1.0.0 => /usr/lib64/libssl.so.1.0.0 (0x00007f94afb3c000)  
libcrypto.so.1.0.0 => /usr/lib64/libcrypto.so.1.0.0 (0x00007f94af702000)  
libutil.so.1 => /lib64/libutil.so.1 (0x00007f94af4ff000)  
libz.so.1 => /lib64/libz.so.1 (0x00007f94af2e8000)
```

If you compare the outputs of `rabin2 -l` and `ldd`, you will notice that rabin2 lists fewer libraries than `ldd`. The reason is that rabin2 does not follow and does not show dependencies of libraries. Only direct binary dependencies are shown.

Strings

The `-z` option is used to list readable strings found in the `.rodata` section of ELF binaries, or the `.text` section of PE files. Example:

```
$ rabin2 -z /bin/ls | head
000 0x000160f8 0x000160f8 11 12 (.rodata) ascii dev_ino_pop
001 0x00016188 0x00016188 10 11 (.rodata) ascii sort_files
002 0x00016193 0x00016193 6 7 (.rodata) ascii posix-
003 0x0001619a 0x0001619a 4 5 (.rodata) ascii main
004 0x00016250 0x00016250 10 11 (.rodata) ascii ?pcdb-lswd
005 0x00016260 0x00016260 65 66 (.rodata) ascii # Configuration file for dircolors,
a utility to help you set the
006 0x000162a2 0x000162a2 72 73 (.rodata) ascii # LS_COLORS environment variable use
d by GNU ls with the --color option.
007 0x000162eb 0x000162eb 56 57 (.rodata) ascii # Copyright (C) 1996-2018 Free Softw
are Foundation, Inc.
008 0x00016324 0x00016324 70 71 (.rodata) ascii # Copying and distribution of this f
ile, with or without modification,
009 0x0001636b 0x0001636b 76 77 (.rodata) ascii # are permitted provided the copyrig
ht notice and this notice are preserved.
```

With the `-zr` option, this information is represented as a radare2 commands list. It can be used in a radare2 session to automatically create a flag space called "strings" pre-populated with flags for all strings found by rabin2. Furthermore, this script will mark corresponding byte ranges as strings instead of code.

```
$ rabin2 -zr /bin/ls | head
fs stringsf str.dev_ino_pop 12 @ 0x000160f8
Cs 12 @ 0x000160f8
f str.sort_files 11 @ 0x00016188
Cs 11 @ 0x00016188
f str.posix 7 @ 0x00016193
Cs 7 @ 0x00016193
f str.main 5 @ 0x0001619a
Cs 5 @ 0x0001619a
f str.pcdb_lswd 11 @ 0x00016250
Cs 11 @ 0x00016250
```

Program Sections

Rabin2 called with the `-s` option gives complete information about the sections of an executable. For each section the index, offset, size, alignment, type and permissions, are shown. The next example demonstrates this:

```
$ rabin2 -S /bin/ls
[Sections]
00 0x0000000000      0 0x0000000000      0 ----
01 0x000000238       28 0x000000238       28 -r-- .interp
02 0x000000254       32 0x000000254       32 -r-- .note.ABI_tag
03 0x000000278       176 0x000000278      176 -r-- .gnu.hash
04 0x000000328       3000 0x000000328      3000 -r-- .dynsym
05 0x000000ee0       1412 0x000000ee0      1412 -r-- .dynstr
06 0x000001464       250 0x000001464      250 -r-- .gnu.version
07 0x000001560       112 0x000001560      112 -r-- .gnu.version_r
08 0x0000015d0       4944 0x0000015d0      4944 -r-- .rela.dyn
09 0x000002920       2448 0x000002920      2448 -r-- .rela.plt
10 0x0000032b0       23 0x0000032b0       23 -r-x .init
11 0x0000032d0       1648 0x0000032d0      1648 -r-x .plt
12 0x000003940       24 0x000003940      24 -r-x .plt.got
13 0x000003960     73931 0x000003960     73931 -r-x .text
14 0x00015a2c        9 0x00015a2c        9 -r-x .fini
15 0x00015a40     20201 0x00015a40     20201 -r-- .rodata
16 0x0001a92c      2164 0x0001a92c      2164 -r-- .eh_frame_hdr
17 0x0001b1a0     11384 0x0001b1a0     11384 -r-- .eh_frame
18 0x0001e390        8 0x0021e390        8 -rw- .init_array
19 0x0001e398        8 0x0021e398        8 -rw- .fini_array
20 0x0001e3a0     2616 0x0021e3a0     2616 -rw- .data.rel.ro
21 0x0001edd8      480 0x0021edd8      480 -rw- .dynamic
22 0x0001efb8       56 0x0021efb8       56 -rw- .got
23 0x0001f000      840 0x0021f000      840 -rw- .got.plt
24 0x0001f360      616 0x0021f360      616 -rw- .data
25 0x0001f5c8        0 0x0021f5e0     4824 -rw- .bss
26 0x0001f5c8      232 0x00000000      232 ---- .shstrtab
```

With the `-sr` option, rabin2 will flag the start/end of every section, and will pass the rest of information as a comment.

```
$ rabin2 -Sr /bin/ls | head
fs sections
S 0x00000000 0x00000000 0x00000000 0x00000000 0
f section. 0 0x00000000
f section_end. 1 0x00000000
CC section 0 va=0x00000000 pa=0x00000000 sz=0 vsz=0 rwx=---- @ 0x00000000
S 0x00000238 0x00000238 0x0000001c 0x0000001c .interp 4
f section..interp 28 0x00000238
f section_end..interp 1 0x00000254
CC section 1 va=0x00000238 pa=0x00000238 sz=28 vsz=28 rwx=-r-- .interp @ 0x00000238
S 0x00000254 0x00000254 0x00000020 0x00000020 .note.ABI_tag 4
```

Radiff2

Radiff2 is a tool designed to compare binary files, similar to how regular `diff` compares text files.

```
$ radiff2 -h
Usage: radiff2 [-abBcCdjrsp0xuUvV] [-A[A]] [-g sym] [-t %] [file] [file]
  -a [arch]  specify architecture plugin to use (x86, arm, ...)
  -A [-A]    run aaa or aaaa after loading each binary (see -C)
  -b [bits]  specify register size for arch (16 (thumb), 32, 64, ...)
  -B        output in binary diff (GDIFF)
  -c        count of changes
  -C        graphdiff code (columns: off-A, match-ratio, off-B) (see -A)
  -d        use delta diffing
  -D        show disasm instead of hexpairs
  -e [k=v]   set eval config var value for all RCore instances
  -g [sym|off1,off2]  graph diff of given symbol, or between two offsets
  -G [cmd]   run an r2 command on every RCore instance created
  -i        diff imports of target files (see -u, -U and -z)
  -j        output in json format
  -n        print bare addresses only (diff.bare=1)
  -o        code diffing with opcode bytes only
  -p        use physical addressing (io.va=0)
  -q        quiet mode (disable colors, reduce output)
  -r        output in radare commands
  -s        compute edit distance (no substitution, Eugene W. Myers' O(ND) diff algorithm)
  -ss       compute Levenshtein edit distance (substitution is allowed, O(N^2))
  -S [name]  sort code diff (name, namelen, addr, size, type, dist) (only for -C or -g )
  -t [0-100] set threshold for code diff (default is 70%)
  -x        show two column hexdump diffing
  -u        unified output (---+++)
  -U        unified output using system 'diff'
  -v        show version information
  -V        be verbose (current only for -s)
  -z        diff on extracted strings
```

Binary Diffing

This section is based on the <http://radare.today> article "binary diffing"

Without any parameters, `radiff2` by default shows what bytes are changed and their corresponding offsets:

```
$ radiff2 genuine cracked
0x0000081e0 85c00f94c0 => 9090909090 0x000081e0
0x0007c805 85c00f84c0 => 9090909090 0x0007c805

$ rasm2 -d 85c00f94c0
test eax, eax
sete al
```

Notice how the two jumps are nop'ed.

For bulk processing, you may want to have a higher-level overview of differences. This is why radare2 is able to compute the distance and the percentage of similarity between two files with the `-s` option:

```
$ radiff2 -s /bin/true /bin/false
similarity: 0.97
distance: 743
```

If you want more concrete data, it's also possible to count the differences, with the `-c` option:

```
$ radiff2 -c genuine cracked
2
```

If you are unsure whether you are dealing with similar binaries, with `-c` flag you can check there are matching functions. In this mode, it will give you three columns for all functions: "First file offset", "Percentage of matching" and "Second file offset".

```
$ radiff2 -C /bin/false /bin>true
entry0 0x4013e8 | MATCH (0.904762) | 0x4013e2 entry0
sym.imp.__libc_start_main 0x401190 | MATCH (1.000000) | 0x401190 sym.imp.__libc_start_main
fcn.00401196 0x401196 | MATCH (1.000000) | 0x401196 fcn.00401196
fcn.0040103c 0x40103c | MATCH (1.000000) | 0x40103c fcn.0040103c
fcn.00401046 0x401046 | MATCH (1.000000) | 0x401046 fcn.00401046
fcn.000045e0 24 0x45e0 | UNMATCH (0.916667) | 0x45f0 24 fcn.000045f0
...
```

Moreover, we can ask radiff2 to perform analysis first - adding `-A` option will run `aaa` on the binaries. And we can specify binaries architecture for this analysis too using

```
$ radiff2 -AC -a x86 /bin>true /bin>false | grep UNMATCH
[x] Analyze all flags starting with sym. and entry0 (aa)
[x] Analyze len bytes of instructions for references (aar)
[x] Analyze function calls (aac)
[ ] [*] Use -AA or aaaa to perform additional experimental analysis.
[x] Constructing a function name for fcn.* and sym.func.* functions (aan))
[x] Analyze all flags starting with sym. and entry0 (aa)
[x] Analyze len bytes of instructions for references (aar)
[x] Analyze function calls (aac)
[ ] [*] Use -AA or aaaa to perform additional experimental analysis.
[x] Constructing a function name for fcn.* and sym.func.* functions (aan))
      sub.fileno_500 86 0x4500 | UNMATCH (0.965116) | 0x4510 8
6 sub.fileno_510
      sub.__freading_4c0 59 0x44c0 | UNMATCH (0.949153) | 0x44d0 5
9 sub.__freading_4d0
      sub.fileno_440 120 0x4440 | UNMATCH (0.200000) | 0x4450 12
0 sub.fileno_450
      sub.setlocale_fa0 64 0x3fa0 | UNMATCH (0.104651) | 0x3fb0 6
4 sub.setlocale_fb0
      fcn.00003a50 120 0x3a50 | UNMATCH (0.125000) | 0x3a60 12
0 fcn.00003a60
```

And now a cool feature : radare2 supports graph-differencing, à la [DarunGrim](#), with the `-g` option. You can either give it a symbol name, or specify two offsets, if the function you want to diff is named differently in compared files. For example, `radiff2 -g main /bin>true /bin>false | xdot -` will show differences in `main()` function of Unix `true` and `false` programs. You can compare it to `radiff2 -g main /bin>false /bin>true` (Notice the order of the arguments) to get the two versions. This is the result:



Parts in yellow indicate that some offsets do not match. The grey piece means a perfect match. The red one highlights a strong difference. If you look closely, you will see that the left part of the picture has `mov edi, 0x1; call sym.imp.exit`, while the right one has `xor`

```
edi, edi; call sym.imp.exit .
```

Binary diffing is an important feature for reverse engineering. It can be used to analyze [security updates](#), infected binaries, firmware changes and more...

We have only shown the code analysis diffing functionality, but radare2 supports additional types of diffing between two binaries: at byte level, deltified similarities, and more to come.

We have plans to implement more kinds of bindiffing algorithms into r2, and why not, add support for ASCII art graph diffing and better integration with the rest of the toolkit.

Rasm2

`rasm2` is an inline assembler/disassembler. Initially, `rasm` tool was designed to be used for binary patching. Its main function is to get bytes corresponding to given machine instruction opcode.

```
$ rasm2 -h
Usage: rasm2 [-ACdDehLBvw] [-a arch] [-b bits] [-o addr] [-s syntax]
              [-f file] [-F fil:ter] [-i skip] [-l len] 'code'|hex|-
-a [arch]      Set architecture to assemble/disassemble (see -L)
-A             Show Analysis information from given hexpairs
-b [bits]       Set cpu register size (8, 16, 32, 64) (RASM2_BITS)
-B             Binary input/output (-l is mandatory for binary input)
-c [cpu]        Select specific CPU (depends on arch)
-C             Output in C format
-d, -D         Disassemble from hexpair bytes (-D show hexpairs)
-e             Use big endian instead of little endian
-E             Display ESIL expression (same input as in -d)
-f [file]       Read data from file
-F [in:out]     Specify input and/or output filters (att2intel, x86.pseudo, ...)
-h, -hh        Show this help, -hh for long
-i [len]        ignore/skip N bytes of the input buffer
-j             output in json format
-k [kernel]    Select operating system (linux, windows, darwin, ...)
-l [len]        Input/Output length
-L             List Asm plugins: (a=asm, d=disasm, A=analyze, e=ESIL)
-o [offset]    Set start address for code (default 0)
-o [file]       Output file name (rasm2 -Bf a.asm -o a)
-p             Run SPP over input for assembly
-q             quiet mode
-r             output in radare commands
-s [syntax]    Select syntax (intel, att)
-v             Show version information
-w             What's this instruction for? describe opcode
If '-l' value is greater than output length, output is padded with nops
If the last argument is '-' reads from stdin
Environment:
RASM2_NOPLUGINS do not load shared plugins (speedup loading)
RASM2_ARCH      same as rasm2 -a
RASM2_BITS      same as rasm2 -b
R_DEBUG         if defined, show error messages and crash signal
```

Plugins for supported target architectures can be listed with the `-L` option. Knowing a plugin name, you can use it by specifying its name to the `-a` option

```
$ rasm2 -L
```

_dAe	8 16	6502	LGPL3	6502/NES/C64/Tamagotchi/T-1000 CPU
_dAe	8	8051	PD	8051 Intel CPU
dA	16 32	arc	GPL3	Argonaut RISC Core
a__	16 32 64	arm.as	LGPL3	as ARM Assembler (use ARM_AS environment)
adAe	16 32 64	arm	BSD	Capstone ARM disassembler
dA	16 32 64	arm.gnu	GPL3	Acorn RISC Machine CPU
d	16 32	arm.winedbg	LGPL2	WineDBG's ARM disassembler
adAe	8 16	avr	GPL	AVR Atmel
adAe	16 32 64	bf	LGPL3	Brainfuck (by pancake, nibble) v4.0.0
dA	32	chip8	LGPL3	Chip8 disassembler
dA	16	cr16	LGPL3	cr16 disassembly plugin
dA	32	cris	GPL3	Axis Communications 32-bit embedded processor
ada_	32 64	dalvik	LGPL3	AndroidVM Dalvik
ad_	16	dcpu16	PD	Mojang's DCPU-16
dA	32 64	ebc	LGPL3	EFI Bytecode
adAe	16	gb	LGPL3	GameBoy(TM) (z80-like)
_dAe	16	h8300	LGPL3	H8/300 disassembly plugin
_dAe	32	hexagon	LGPL3	Qualcomm Hexagon (QDSP6) V6
d	32	hppa	GPL3	HP PA-RISC
_dAe		i4004	LGPL3	Intel 4004 microprocessor
dA	8	i8080	BSD	Intel 8080 CPU
adA_	32	java	Apache	Java bytecode
d	32	lanai	GPL3	LANAI
d	8	lh5801	LGPL3	SHARP LH5801 disassembler
d	32	lm32	BSD	disassembly plugin for Lattice Micro 32 ISA
dA	16 32	m68k	BSD	Capstone M68K disassembler
dA	32	malbolge	LGPL3	Malbolge Ternary VM
d	16	mcs96	LGPL3	condrets car
adAe	16 32 64	mips	BSD	Capstone MIPS disassembler
adAe	32 64	mips.gnu	GPL3	MIPS CPU
dA	16	msp430	LGPL3	msp430 disassembly plugin
dA	32	nios2	GPL3	NIOS II Embedded Processor
_dAe	8	pic	LGPL3	PIC disassembler
_dAe	32 64	ppc	BSD	Capstone PowerPC disassembler
dA	32 64	ppc.gnu	GPL3	PowerPC
d	32	propeller	LGPL3	propeller disassembly plugin
dA	32 64	riscv	GPL	RISC-V
_dAe	32	rsp	LGPL3	Reality Signal Processor
_dAe	32	sh	GPL3	SuperH-4 CPU
dA	8 16	snes	LGPL3	SuperNES CPU
_dAe	32 64	sparc	BSD	Capstone SPARC disassembler
dA	32 64	sparc.gnu	GPL3	Scalable Processor Architecture
d	16	spc700	LGPL3	spc700, snes' sound-chip
d	32	sysz	BSD	SystemZ CPU disassembler
dA	32	tms320	LGPLv3	TMS320 DSP family (c54x,c55x,c55x+,c64x)
d	32	tricore	GPL3	Siemens TriCore CPU
_dAe	32	v810	LGPL3	v810 disassembly plugin
_dAe	32	v850	LGPL3	v850 disassembly plugin
_dAe	8 32	vax	GPL	VAX
ada_	32	wasm	MIT	WebAssembly (by cgvwzq) v0.1.0
dA	32	ws	LGPL3	Whitespace esoteric VM
a__	16 32 64	x86.as	LGPL3	Intel X86 GNU Assembler
_dAe	16 32 64	x86	BSD	Capstone X86 disassembler

a___	16 32 64	x86.nasm	LGPL3	X86 nasm assembler
a___	16 32 64	x86.nz	LGPL3	x86 handmade assembler
dA	16	xap	PD	XAP4 RISC (CSR)
dA	32	xcore	BSD	Capstone XCore disassembler
_dAe	32	xtensa	GPL3	XTensa CPU
adA_	8	z80	GPL	Zilog Z80

Note that "ad" in the first column means both assembler and disassembler are offered by a corresponding plugin. "*d*" indicates disassembler, "a" means only assembler is available.

Assembler

Assembling is the action to take a computer instruction in human readable form (using mnemonics) and convert that into a bunch of bytes that can be executed by a machine.

In radare2, the assembler and disassembler logic is implemented in the `rasm*` API, and can be used with the `pa` and `pad` commands from the commandline as well as using `rasm2`.

Rasm2 can be used to quickly copy-paste hexpairs that represent a given machine instruction. The following line is assembling this mov instruction for x86/32.

```
$ rasm2 -a x86 -b 32 'mov eax, 33'  
b821000000
```

Apart from specifying the input as an argument, you can also pipe it to rasm2:

```
$ echo 'push eax;nop;nop' | rasm2 -f -  
5090
```

As you have seen, rasm2 can assemble one or many instructions. In line by separating them with a semicolon `;`, but can also read that from a file, using generic nasm/gas/.. syntax and directives. You can check the rasm2 manpage for more details on this.

The `pa` and `pad` are subcommands of `print`, what means they will only print assembly or disassembly. In case you want to actually write the instruction it is required to use `wa` or `wx` commands with the assembly string or bytes appended.

The assembler understands the following input languages and their flavors: `x86` (Intel and AT&T variants), `olly` (OllyDBG syntax), `powerpc` (PowerPC), `arm` and `java`. For Intel syntax, rasm2 tries to mimic NASM or GAS.

There are several examples in the rasm2 source code directory. Consult them to understand how you can assemble a raw binary file from a rasm2 description.

Lets create an assembly file called `selfstop.rasm`:

```

;
; Self-Stop shellcode written in rasm for x86
;
; --pancake
;

.arch x86
.equ base 0x8048000
.org 0x8048000 ; the offset where we inject the 5 byte jmp

selfstop:
    push 0x8048000
    pusha
    mov eax, 20
    int 0x80

    mov ebx, eax
    mov ecx, 19
    mov eax, 37
    int 0x80
    popa
    ret
;
; The call injection
;

    ret

```

Now we can assemble it in place:

```

[0x00000000]> e asm.bits = 32
[0x00000000]> wx `!rasm2 -f a.rasm`
[0x00000000]> pd 20
    0x00000000  6800800408  push 0x8048000 ; 0x08048000
    0x00000005  60          pushad
    0x00000006  b814000000  mov eax, 0x14 ; 0x00000014
    0x0000000b  cd80        int 0x80
        syscall[0x80][0]=?
    0x0000000d  89c3        mov ebx, eax
    0x0000000f  b913000000  mov ecx, 0x13 ; 0x00000013
    0x00000014  b825000000  mov eax, 0x25 ; 0x00000025
    0x00000019  cd80        int 0x80
        syscall[0x80][0]=?
    0x0000001b  61          popad
    0x0000001c  c3          ret
    0x0000001d  c3          ret

```

Visual mode

Assembling also is accessible in radare2 visual mode through pressing `A` key to insert the assembly in the current offset.

The cool thing of writing assembly using the visual assembler interface that the changes are done in memory until you press enter.

So you can check the size of the code and which instructions is overlapping before committing the changes.

Disassembler

Disassembling is the inverse action of assembling. Rasm2 takes hexpair as an input (but can also take a file in binary form) and show the human readable form.

To do this we can use the `-d` option of rasm2 like this:

```
$ rasm2 -a x86 -b 32 -d '90'  
nop
```

Rasm2 also have the `-D` flag to show the disassembly like `-d` does, but includes offset and bytes.

In radare2 there are many commands to perform a disassembly from a specific place in memory.

You might be interested in trying if you want different outputs for later parsing with your scripts, or just grep to find what you are looking for:

pd N

Disassemble N instructions

pD N

Disassemble N bytes

pda

Disassemble all instructions (seeking 1 byte, or the minimum alignment instruction size), which can be useful for ROP

pi, pl

Same as `pd` and `pD`, but using a simpler output.

Disassembler Configuration

The assembler and disassembler have many small switches to tweak the output.

Those configurations are available through the `e` command. Here there are the most common ones:

- `asm.bytes` - show/hide bytes
- `asm.offset` - show/hide offset
- `asm.lines` - show/hide lines
- `asm.ucase` - show disasm in uppercase
- ...

Use the `e??asm.` for more details.

Purpose

ragg2 stands for `radare2 egg`, this is the basic block to construct relocatable snippets of code to be used for injection in target processes when doing exploiting.

ragg2 compiles programs written in a simple high-level language into tiny binaries for x86, x86-64, and ARM.

By default it will compile its own `ragg2` language, but you can also compile C code using GCC or Clang shellcodes depending on the file extension. Lets create C file called `a.c`:

```
int main() {
    write(1, "Hello World\n", 13);
    return 0;
}
```

```
$ ragg2 -a x86 -b32 a.c
e900000000488d3516000000bf01000000b80400000248c7c20d0000000f0531c0c348656c6c6f20576f72
6c640a00

$ rasm2 -a x86 -b 32 -D e900000000488d3516000000bf01000000b80400000248c7c20d0000000f05
31c0c348656c6c6f20576f726c640a00
0x00000000      5          e900000000  jmp 5
0x00000005      1          48 dec eax
0x00000006      6          8d3516000000 lea esi, [0x16]
0x0000000c      5          bf01000000 mov edi, 1
0x00000011      5          b804000002 mov eax, 0x2000004
0x00000016      1          48 dec eax
0x00000017      6          c7c20d000000 mov edx, 0xd
0x0000001d      2          0f05 syscall
0x0000001f      2          31c0 xor eax, eax
0x00000021      1          c3 ret
0x00000022      1          48 dec eax
0x00000023      2          656c insb byte es:[edi], dx
0x00000025      1          6c insb byte es:[edi], dx
0x00000026      1          6f outsd dx, dword [esi]
0x00000027      3          20576f and byte [edi + 0x6f], dl
0x0000002a      2          726c jb 0x98
0x0000002c      3          640a00 or al, byte fs:[eax]
```

Compiling ragg2 example

```
$ cat hello.r
exit@syscall(1);

main@global() {
    exit(2);
}

$ ragg2 -a x86 -b 64 hello.r
48c7c00200000050488b3c2448c7c0010000000f054883c408c3
0x00000000 1          48 dec eax
0x00000001 6          c7c002000000 mov eax, 2
0x00000007 1          50 push eax
0x00000008 1          48 dec eax
0x00000009 3          8b3c24 mov edi, dword [esp]
0x0000000c 1          48 dec eax
0x0000000d 6          c7c001000000 mov eax, 1
0x00000013 2          0f05 syscall
0x00000015 1          48 dec eax
0x00000016 3          83c408 add esp, 8
0x00000019 1          c3 ret

$ rasm2 -a x86 -b 64 -D 48c7c00200000050488b3c2448c7c0010000000f054883c408c3
0x00000000 7          48c7c002000000 mov rax, 2
0x00000007 1          50 push rax
0x00000008 4          488b3c24 mov rdi, qword [rsp]
0x0000000c 7          48c7c001000000 mov rax, 1
0x00000013 2          0f05 syscall
0x00000015 4          4883c408 add rsp, 8
0x00000019 1          c3 ret
```

Tiny binaries

You can create them using the `-F` flag in ragg2, or the `-c` in rabin2.

Syntax of the language

The code of r_egg is compiled as in a flow. It is a one-pass compiler; this means that you have to define the proper stackframe size at the beginning of the function, and you have to define the functions in order to avoid getting compilation errors.

The compiler generates assembly code for x86-{32,64} and arm. But it aims to support more platforms. This code is then compiled with r_asm and injected into a tiny binary with r_bin.

You may like to use r_egg to create standalone binaries, position-independent raw eggs to be injected on running processes or to patch on-disk binaries.

The generated code is not yet optimized, but it's safe to be executed at any place in the code.

Preprocessor

Aliases

Sometimes you just need to replace at compile time a single entity on multiple places. Aliases are translated into 'equ' statements in assembly language. This is just an assembler-level keyword redefinition.

```
AF_INET@alias(2);  
printf@alias(0x8053940);
```

Includes

Use `cat(1)` or the preprocessor to concatenate multiple files to be compiled.

```
INCDIR@alias("/usr/include/ragg2");  
sys-osx.r@include(INCDIR);
```

Hashbang

eggs can use a hashbang to make them executable.

```
$ head -n1 hello.r  
#!/usr/bin/ragg2 -X  
  
$ ./hello.r  
  
Hello World!
```

Main

The execution of the code is done as in a flow. The first function to be defined will be the first one to be executed. If you want to run main() just do like this:

```
#!/usr/bin/ragg2 -X  
  
main();  
  
...  
  
main@global(128,64) {  
  
...
```

Function definition

You may like to split up your code into several code blocks. Those blocks are bound to a label followed by root brackets '{ ... }'

Function signatures

```
name@type(stackframesize,staticframesize) { body }  
  
name : name of the function to define  
  
type : see function types below  
  
stackframesize : get space from stack to store local variables  
  
staticframesize : get space from stack to store static variables (strings)  
  
body : code of the function
```

Function types

```
alias ; Used to create aliases
```

```
data ; the body of the block is defined in .data
```

```
inline ; the function body is inlined when called
```

```
global ; make the symbol global
```

```
fastcall ; function that is called using the fast calling convention
```

```
syscall ; define syscall calling convention signature
```

Syscalls

r_egg offers a syntax sugar for defining syscalls. The syntax is like this:

```
exit@syscall(1);  
  
@syscall() {  
  
` : mov eax, .arg``  
  
: int 0x80  
  
}  
  
main@global() {  
  
exit (0);  
  
}
```

Libraries

At the moment there is no support for linking r_egg programs to system libraries. but if you inject the code into a program (disk/memory) you can define the address of each function using the @alias syntax.

Core library

There's a work-in-progress libc-like library written completely in r_egg

Variables

```
.arg
```

```
.arg0
```

```
.arg1
```

```
.arg2  
.var0  
.var2  
.fix  
.ret ; eax for x86, r0 for arm  
.bp  
.pc  
.sp
```

Attention: All the numbers after `.var` and `.arg` mean the offset with the top of stack, not variable symbols.

Arrays

Supported as raw pointers. TODO: enhance this feature

Tracing

Sometimes r_egg programs will break or just not work as expected. Use the 'trace' architecture to get a arch-backend call trace:

```
$ ragg2 -a trace -s yourprogram.r
```

Pointers

TODO: Theorically `**` is used to get contents of a memory pointer.

Virtual registers

TODO: a0, a1, a2, a3, sp, fp, bp, pc

Math operations

Ragg2 supports local variables assignment by math operating, including the following operators:

```
+ - * / & | ^
```

Return values

The return value is stored in the a0 register, this register is set when calling a function or when typing a variable name without assignment.

```
$ cat test.r
add@global(4) {
    .var0 = .arg0 + .arg1;
    .var0;
}

main@global() {
    add (3,4);
}

$ ragg2 -F -o test test.r
$ ./test
$ echo $?
7
```

Traps

Each architecture have a different instruction to break the execution of the program. REgg language captures calls to 'break()' to run the emit_trap callback of the selected arch. The

```
break(); --> compiles into 'int3' on x86
break; --> compiles into 'int3' on x86
```

Inline assembly

Lines prefixed with ':' char are just inlined in the output assembly.

```
: jmp 0x8048400
: .byte 33,44
```

Labels

You can define labels using the `:` keyword like this:

```
:label_name:
/* loop forever */
goto(label_name)
```

Control flow

```
goto (addr) -- branch execution  
while (cond)  
if (cond)  
if (cond) { body } else { body }  
break () -- executes a trap instruction
```

Comments

Supported syntax for comments are:

```
/* multiline comment */  
// single line comment  
# single line comment
```

rahash2

The rahash2 tool can be used to compute checksums of files, disk devices or strings. By block or entirely using many different hash algorithms.

This tool is also capable of doing some encoding/decoding operations like base64 and xor encryption.

This is an example usage:

```
$ rahash2 -a md5 -s "hello world"
```

Note that rahash2 also permits to read from stdin in a stream, so you don't need 4GB of ram to compute the hash of a 4GB file.

Hashing by blocks

When doing forensics, it is useful to compute partial checksums. The reason for that is because you may want to split a huge file into small portions that are easier to identify by contents or regions in the disk.

This will spot the same hash for blocks containing the same contents. For example, if filled by zeros.

But also, it can be used to find which blocks have changed between more than one sample dump.

This can be useful when analyzing ram dumps from a virtual machine for example. Use this command for this:

```
$ rahash2 -B 1M -b -a sha256 /bin/ls
```

Hashing with rabin2

The rabin2 tool parses the binary headers of the files, but it also have the ability to use the rhash plugins to compute checksum of sections in the binary.

```
$ rabin2 -K md5 -S /bin/ls
```

Obtaining hashes within radare2 session

To calculate a checksum of current block when running radare2, use the `ph` command. Pass an algorithm name to it as a parameter. An example session:

```
$ radare2 /bin/ls  
[0x08049790]> bf entry0  
[0x08049790]> ph md5  
d2994c75adaa58392f953a448de5fba7
```

You can use all hashing algorithms supported by `rahash2`:

```
[0x00000000]> ph?
md5
sha1
sha256
sha384
sha512
md4
xor
xorpair
parity
entropy
hamdist
pcprint
mod255
xxhash
adler32
luhn
crc8smbus
crc15can
crc16
crc16hdlc
crc16usb
crc16citt
crc24
crc32
crc32c
crc32ecma267
crc32bzip2
crc32d
crc32mpeg2
crc32posix
crc32q
crc32jamcrc
crc32xfer
crc64
crc64ecma
crc64we
crc64xz
crc64iso
```

The `ph` command accepts an optional numeric argument to specify length of byte range to be hashed, instead of default block size. For example:

```
[0x08049A80]> ph md5 32
9b9012b00ef7a94b5824105b7aaad83b
[0x08049A80]> ph md5 64
a71b087d8166c99869c9781e2edcf183
[0x08049A80]> ph md5 1024
a933cc94cd705f09a41ecc80c0041def
```


Rahash2

The rahash2 tool can be used to calculate checksums and has functions of byte streams, files, text strings.

```
$ rahash2 -h
Usage: rahash2 [-rBhLkv] [-b S] [-a A] [-c H] [-E A] [-s S] [-f O] [-t O] [file] ...
-a algo      comma separated list of algorithms (default is 'sha256')
-b bsize     specify the size of the block (instead of full file)
-B           show per-block hash
-c hash      compare with this hash
-e           swap endian (use little endian)
-E algo      encrypt. Use -S to set key and -I to set IV
-D algo      decrypt. Use -S to set key and -I to set IV
-f from     start hashing at given address
-i num       repeat hash N iterations
-I iv        use give initialization vector (IV) (hexa or s:string)
-S seed      use given seed (hexa or s:string) use ^ to prefix (key for -E)
             (- will slurp the key from stdin, the @ prefix points to a file
-k           show hash using the openssh's randomkey algorithm
-q           run in quiet mode (-qq to show only the hash)
-L           list all available algorithms (see -a)
-r           output radare commands
-s string    hash this string instead of files
-t to        stop hashing at given address
-x hexstr   hash this hexpair string instead of files
-v           show version information
```

To obtain an MD5 hash value of a text string, use the `-s` option:

```
$ rahash2 -q -a md5 -s 'hello world'
5eb63bbbe01eeed093cb22bb8f5acdc3
```

It is possible to calculate hash values for contents of files. But do not attempt to do it for very large files because rahash2 buffers the whole input in memory before computing the hash.

To apply all algorithms known to rahash2, use `all` as an algorithm name:

```
$ rahash2 -a all /bin/ls
/bin/ls: 0x00000000-0x000268c7 md5: 767f0fff116bc6584dbfc1af6fd48fc7
/bin/ls: 0x00000000-0x000268c7 sha1: 404303f3960f196f42f8c2c12970ab0d49e28971
/bin/ls: 0x00000000-0x000268c7 sha256: 74ea05150acf311484bddd19c608aa02e6bf3332a0f0805
a4deb278e17396354
/bin/ls: 0x00000000-0x000268c7 sha384: c6f811287514ceeeaaabe73b5b2f54545036d6fd3a192ea5
d6a1fc494d46151df4117e1c62de0884cbc174c8db008ed1
/bin/ls: 0x00000000-0x000268c7 sha512: 53e4950a150f06d7922a2ed732060e291bf0e1c2ac20bc7
2a41b9303e1f2837d50643761030d8b918ed05d12993d9515e1ac46676bc0d15ac94d93d8e446fa09
/bin/ls: 0x00000000-0x000268c7 md4: fdfe7c7118a57c1ff8c88a51b16fc78c
/bin/ls: 0x00000000-0x000268c7 xor: 42
/bin/ls: 0x00000000-0x000268c7 xorpair: d391
/bin/ls: 0x00000000-0x000268c7 parity: 00
/bin/ls: 0x00000000-0x000268c7 entropy: 5.95471783
/bin/ls: 0x00000000-0x000268c7 hamdist: 00
/bin/ls: 0x00000000-0x000268c7 pcprint: 22
/bin/ls: 0x00000000-0x000268c7 mod255: ef
/bin/ls: 0x00000000-0x000268c7 xxhash: 76554666
/bin/ls: 0x00000000-0x000268c7 adler32: 7704fe60
/bin/ls: 0x00000000-0x000268c7 luhn: 01
/bin/ls: 0x00000000-0x000268c7 crc8smbus: 8d
/bin/ls: 0x00000000-0x000268c7 crc15can: 1cd5
/bin/ls: 0x00000000-0x000268c7 crc16: d940
/bin/ls: 0x00000000-0x000268c7 crc16hdlc: 7847
/bin/ls: 0x00000000-0x000268c7 crc16usb: 17bb
/bin/ls: 0x00000000-0x000268c7 crc16citt: 67f7
/bin/ls: 0x00000000-0x000268c7 crc24: 3e7053
/bin/ls: 0x00000000-0x000268c7 crc32: c713f78f
/bin/ls: 0x00000000-0x000268c7 crc32c: 6cfba67c
/bin/ls: 0x00000000-0x000268c7 crc32ecma267: b4c809d6
/bin/ls: 0x00000000-0x000268c7 crc32bzip2: a1884a09
/bin/ls: 0x00000000-0x000268c7 crc32d: d1a9533c
/bin/ls: 0x00000000-0x000268c7 crc32mpeg2: 5e77b5f6
/bin/ls: 0x00000000-0x000268c7 crc32posix: 6ba0dec3
/bin/ls: 0x00000000-0x000268c7 crc32q: 3166085c
/bin/ls: 0x00000000-0x000268c7 crc32jamcrc: 38ec0870
/bin/ls: 0x00000000-0x000268c7 crc32xfer: 7504089d
/bin/ls: 0x00000000-0x000268c7 crc64: b6471d3093d94241
/bin/ls: 0x00000000-0x000268c7 crc64ecma: b6471d3093d94241
/bin/ls: 0x00000000-0x000268c7 crc64we: 8fe37d44a47157bd
/bin/ls: 0x00000000-0x000268c7 crc64xz: ea83e12c719e0d79
/bin/ls: 0x00000000-0x000268c7 crc64iso: d243106d9853221c
```

Plugins

radare2 is implemented on top of a bunch of libraries, almost every of those libraries support plugins to extend the capabilities of the library or add support for different targets.

This section aims to explain what are the plugins, how to write them and use them

Types of plugins

```
$ ls libr/*/p | grep : | awk -F / '{ print $2 }'  
anal      # analysis plugins  
asm       # assembler/disassembler plugins  
bin       # binary format parsing plugins  
bp        # breakpoint plugins  
core      # core plugins (implement new commands)  
crypto    # encrypt/decrypt/hash/...  
debug     # debugger backends  
egg       # shellcode encoders, etc  
fs        # filesystems and partition tables  
io        # io plugins  
lang      # embedded scripting languages  
parse     # disassembler parsing plugins  
reg       # arch register logic
```

Listing plugins

Some r2 tools have the `-L` flag to list all the plugins associated to the functionality.

```
rasm2 -L    # list asm plugins  
r2 -L      # list io plugins  
rabin2 -L   # list bin plugins  
rahash2 -L  # list hash/crypto/encoding plugins
```

There are more plugins in r2land, we can list them from inside r2, and this is done by using the `L` suffix.

Those are some of the commands:

```
L      # list core plugins
iL     # list bin plugins
dL     # list debug plugins
mL     # list fs plugins
ph     # print support hash algoriths
```

But also using the `? value` in the associated eval vars.

```
e asm.arch=? # list assembler/disassembler plugins
e anal.arch=? # list analysis plugins
```

Notes

Note there are some inconsistencies that most likely will be fixed in the future radare2 versions.

IO plugins

All access to files, network, debugger and all input/output in general is wrapped by an IO abstraction layer that allows radare to treat all data as if it were just a file.

IO plugins are the ones used to wrap the open, read, write and 'system' on virtual file systems. You can make radare understand anything as a plain file. E.g. a socket connection, a remote radare session, a file, a process, a device, a gdb session.

So, when radare reads a block of bytes, it is the task of an IO plugin to get these bytes from any place and put them into internal buffer. An IO plugin is chosen by a file's URI to be opened. Some examples:

- Debugging URIs

```
$ r2 dbg:///bin/ls<br />
$ r2 pid://1927
```

- Remote sessions

```
$ r2 rap://:1234<br />
$ r2 rap://<host>:1234//bin/ls
```

- Virtual buffers

```
$ r2 malloc://512<br />
shortcut for
$ r2 -
```

You can get a list of the radare IO plugins by typing `radare2 -L` :

```
$ r2 -L
rw_ ar          Open ar/lib files [ar|lib]://[file//path] (LGPL3)
rw_ bfdbs      BrainFuck Debugger (bfdbs://path/to/file) (LGPL3)
rwd bochs       Attach to a BOCHS debugger (LGPL3)
r_d debug       Native debugger (dbg:///bin/ls dbg://1388 pidof:// waitfor://) (LGPL
3) v0.2.0 pancake
rw_ default     open local files using def_mmap:// (LGPL3)
rwd gdb         Attach to gdbserver, 'qemu -s', gdb://localhost:1234 (LGPL3)
rw_ gprobe      open gprobe connection using gprobe:// (LGPL3)
rw_ gzip        read/write gzipped files (LGPL3)
rw_ http        http get (http://rada.re/) (LGPL3)
rw_ ihex        Intel HEX file (ihex://eeproms.hex) (LGPL)
r_ mach         mach debug io (unsupported in this platform) (LGPL)
rw_ malloc      memory allocation (malloc://1024 hex://cd8090) (LGPL3)
rw_ mmap        open file using mmap:// (LGPL3)
rw_ null        null-plugin (null://23) (LGPL3)
rw_ procpid    /proc/pid/mem io (LGPL3)
rwd ptrace     ptrace and /proc/pid/mem (if available) io (LGPL3)
rwd qnx        Attach to QNX pdebug instance, qnx://host:1234 (LGPL3)
rw_ r2k         kernel access API io (r2k://) (LGPL3)
rw_ r2pipe     r2pipe io plugin (MIT)
rw_ r2web      r2web io client (r2web://cloud.rada.re/cmd/) (LGPL3)
rw_ rap         radare network protocol (rap://:port rap://host:port/file) (LGPL3)
rw_ rbuf        RBuffer IO plugin: rbuf:// (LGPL)
rw_ self        read memory from myself using 'self://' (LGPL3)
rw_ shm         shared memory resources (shm://key) (LGPL3)
rw_ sparse      sparse buffer allocation (sparse://1024 sparse://) (LGPL3)
rw_ tcp         load files via TCP (listen or connect) (LGPL3)
rwd windbg     Attach to a KD debugger (windbg://socket) (LGPL3)
rwd winedbg    Wine-dbg io and debug.io plugin for r2 (MIT)
rw_ zip         Open zip files [apk|ipa|zip|zipall]://[file//path] (BSD)
```

Implementing a new disassembly plugin

Radare2 has modular architecture, thus adding support for a new architecture is very easy, if you are fluent in C. For various reasons it might be easier to implement it out of the tree. For this we will need to create single C file, called `asm_mycpu.c` and makefile for it.

The key thing of RAsm plugin is a structure

```
RAsmPlugin r_asm_plugin_mycpu = {  
    .name = "mycpu",  
    .license = "LGPL3",  
    .desc = "MYCPU disassembly plugin",  
    .arch = "mycpu",  
    .bits = 32,  
    .endian = R_SYS_ENDIAN_LITTLE,  
    .disassemble = &disassemble  
};
```

where `.disassemble` is a pointer to disassembly function, which accepts the bytes buffer and length:

```
static int disassemble(RAsm *a, RAsmOp *op, const ut8 *buf, int len)
```

Makefile

```
NAME=asm_snes
R2_PLUGIN_PATH=$(shell r2 -H|grep USER_PLUGINS|awk '{print $$2}')
CFLAGS=-g -fPIC $(shell pkg-config --cflags r_anal)
LDFLAGS=-shared $(shell pkg-config --libs r_anal)
OBJS=$(NAME).o
SO_EXT=$(shell uname|grep -q Darwin && echo dylib || echo so)
LIB=$(NAME).$(SO_EXT)

all: $(LIB)

clean:
    rm -f $(LIB) $(OBJS)

$(LIB): $(OBJS)
    $(CC) $(CFLAGS) $(LDFLAGS) $(OBJS) -o $(LIB)

install:
    cp -f asm_mycpu.$(SO_EXT) $(R2_PLUGIN_PATH)

uninstall:
    rm -f $(R2_PLUGIN_PATH)/asm_mycpu.$(SO_EXT)
```

asm_mycpu.c

```

/* radare - LGPL - Copyright 2018 - user */

#include <stdio.h>
#include <string.h>
#include <r_types.h>
#include <r_lib.h>
#include <r_asm.h>

static int disassemble(RAsm *a, RAsmOp *op, const ut8 *buf, int len) {
    struct op_cmd cmd = {
        .instr = "",
        .operands = ""
    };
    if (len < 2) return -1;
    int ret = decode_opcode (buf, len, &cmd);
    if (ret > 0) {
        sprintf (op->buf_asm, R_ASM_BUFSIZE, "%s %s",
            cmd.instr, cmd.operands);
    }
    return op->size = ret;
}

RAsmPlugin r_asm_plugin_mycpu = {
    .name = "mycpu",
    .license = "LGPL3",
    .desc = "MYCPU disassembly plugin",
    .arch = "mycpu",
    .bits = 32,
    .endian = R_SYS_ENDIAN_LITTLE,
    .disassemble = &disassemble
};

#ifndef CORELIB
RLibStruct radare_plugin = {
    .type = R_LIB_TYPE_ASM,
    .data = &r_asm_plugin_mycpu,
    .version = R2_VERSION
};
#endif

```

After compiling radare2 will list this plugin in the output:

_d__	_8_32	mycpu	LGPL3	MYCPU
------	-------	-------	-------	-------

Moving plugin into the tree

Pushing a new architecture into the main branch of r2 requires to modify several files in order to make it fit into the way the rest of plugins are built.

List of affected files:

- `plugins.def.cfg` : add the `asm.mycpu` plugin name string in there
- `libr/asm/p/mycpu.mk` : build instructions
- `libr/asm/p/asm_mycpu.c` : implementation
- `libr/include/r_asm.h` : add the struct definition in there

Check out how the NIOS II CPU disassembly plugin was implemented by reading those commits:

Implement RAsm plugin:
<https://github.com/radare/radare2/commit/933dc0ef6ddfe44c88bbb261165bf8f8b531476b>

Implement RAnal plugin:
<https://github.com/radare/radare2/commit/ad430f0d52fbe933e0830c49ee607e9b0e4ac8f2>

Implementing a new analysis plugin

After implementing disassembly plugin, you might have noticed that output is far from being good - no proper highlighting, no reference lines and so on. This is because radare2 requires every architecture plugin to provide also analysis information about every opcode. At the moment the implementation of disassembly and opcodes analysis is separated between two modules - RAsm and RAnal. Thus we need to write an analysis plugin too. The principle is very similar - you just need to create a C file and corresponding Makefile.

The structure of RAnal plugin looks like

```
RAnalPlugin r_anal_plugin_v810 = {
    .name = "mycpu",
    .desc = "MYCPU code analysis plugin",
    .license = "LGPL3",
    .arch = "mycpu",
    .bits = 32,
    .op = mycpu_op,
    .esil = true,
    .set_reg_profile = set_reg_profile,
};
```

Like with disassembly plugin there is a key function - `mycpu_op` which scans the opcode and builds RAnalOp structure. On the other hand, in this example analysis plugins also performs uplifting to ESIL, which is enabled in `.esil = true` statement. Thus, `mycpu_op` obliged to fill the corresponding RAnalOp ESIL field for the opcodes. Second important thing for ESIL uplifting and emulation - register profile, like in debugger, which is set within `set_reg_profile` function.

Makefile

```
NAME=anal_snes
R2_PLUGIN_PATH=$(shell r2 -H|grep USER_PLUGINS|awk '{print $$2}')
CFLAGS=-g -fPIC $(shell pkg-config --cflags r_anal)
LDFLAGS=-shared $(shell pkg-config --libs r_anal)
OBJS=$(NAME).o
SO_EXT=$(shell uname|grep -q Darwin && echo dylib || echo so)
LIB=$(NAME).$(SO_EXT)

all: $(LIB)

clean:
    rm -f $(LIB) $(OBJS)

$(LIB): $(OBJS)
    $(CC) $(CFLAGS) $(LDFLAGS) $(OBJS) -o $(LIB)

install:
    cp -f anal_snes.$(SO_EXT) $(R2_PLUGIN_PATH)

uninstall:
    rm -f $(R2_PLUGIN_PATH)/anal_snes.$(SO_EXT)
```

anal_snes.c:

```

/* radare - LGPL - Copyright 2015 - condret */

#include <string.h>
#include <r_types.h>
#include <r_lib.h>
#include <r_asm.h>
#include <r_anal.h>
#include "snes_op_table.h"

static int snes_anop(RAnal *anal, RAnalOp *op, ut64 addr, const ut8 *data, int len) {
    memset (op, '\0', sizeof (RAnalOp));
    op->size = snes_op[data[0]].len;
    op->addr = addr;
    op->type = R_ANAL_OP_TYPE_UNK;
    switch (data[0]) {
        case 0xea:
            op->type = R_ANAL_OP_TYPE_NOP;
            break;
    }
    return op->size;
}

struct r_anal_plugin_t r_anal_plugin_snes = {
    .name = "snes",
    .desc = "SNES analysis plugin",
    .license = "LGPL3",
    .arch = R_SYS_ARCH_NONE,
    .bits = 16,
    .init = NULL,
    .fini = NULL,
    .op = &snes_anop,
    .set_reg_profile = NULL,
    .fingerprint_bb = NULL,
    .fingerprint_fcn = NULL,
    .diff_bb = NULL,
    .diff_fcn = NULL,
    .diff_eval = NULL
};

#ifndef CORELIB
struct r_lib_struct_t radare_plugin = {
    .type = R_LIB_TYPE_ANAL,
    .data = &r_anal_plugin_snes,
    .version = R2_VERSION
};
#endif

```

After compiling radare2 will list this plugin in the output:

dA	_8_16	snes	LGPL3	SuperNES CPU
------	-------	------	-------	--------------

snes_op_table.h:

https://github.com/radare/radare2/blob/master/libr/asm/arch/snes/snes_op_table.h

Example:

- **6502:**

<https://github.com/radare/radare2/commit/64636e9505f9ca8b408958d3c01ac8e3ce254a9b>

- **SNES:**

<https://github.com/radare/radare2/commit/60d6e5a1b9d244c7085b22ae8985d00027624b49>

Implementing a new format

To enable virtual addressing

In `info add et->has_va = 1;` and `ptr->srxw` with the `R_BIN_SCN_MAP;` attribute

Create a folder with file format name in libr/bin/format

Makefile:

```

NAME=bin_nes
R2_PLUGIN_PATH=$(shell r2 -hh|grep LIBR_PLUGINS|awk '{print $$2}')
CFLAGS=-g -fPIC $(shell pkg-config --cflags r_bin)
LDFLAGS=-shared $(shell pkg-config --libs r_bin)
OBJS=$(NAME).o
SO_EXT=$(shell uname|grep -q Darwin && echo dylib || echo so)
LIB=$(NAME).$(SO_EXT)

all: $(LIB)

clean:
    rm -f $(LIB) $(OBJS)

$(LIB): $(OBJS)
    $(CC) $(CFLAGS) $(LDFLAGS) $(OBJS) -o $(LIB)

install:
    cp -f $(NAME).$(SO_EXT) $(R2_PLUGIN_PATH)

uninstall:
    rm -f $(R2_PLUGIN_PATH)/$(NAME).$(SO_EXT)

```

bin_nes.c:

```

#include <r_bin.h>

static int check(RBinFile *arch);
static int check_bytes(const ut8 *buf, ut64 length);

static void * load_bytes(RBinFile *arch, const ut8 *buf, ut64 sz, ut64 loadaddr, Sdb *
sdb){
    check_bytes (buf, sz);
    return R_NONNULL;
}

```

```

static int check(RBinFile *arch) {
    const ut8 \*bytes = arch ? r_buf_buffer (arch->buf) : NULL;
    ut64 sz = arch ? r_buf_size (arch->buf): 0;
    return check_bytes (bytes, sz);
}

static int check_bytes(const ut8 *buf, ut64 length) {
    if (!buf || length < 4) return false;
    return (!memcmp (buf, "\x4E\x45\x53\x1A", 4));
}

static RBinInfo* info(RBinFile *arch) {
    RBinInfo \*ret = R_NEW0 (RBinInfo);
    if (!ret) return NULL;

    if (!arch || !arch->buf) {
        free (ret);
        return NULL;
    }
    ret->file = strdup (arch->file);
    ret->type = strdup ("ROM");
    ret->machine = strdup ("Nintendo NES");
    ret->os = strdup ("nes");
    ret->arch = strdup ("6502");
    ret->bits = 8;

    return ret;
}

struct r_bin_plugin_t r_bin_plugin_nes = {
    .name = "nes",
    .desc = "NES",
    .license = "BSD",
    .init = NULL,
    .fini = NULL,
    .get_sdb = NULL,
    .load = NULL,
    .load_bytes = &load_bytes,
    .check = &check,
    .baddr = NULL,
    .check_bytes = &check_bytes,
    .entries = NULL,
    .sections = NULL,
    .info = &info,
};

#ifndef CORELIB
struct r_lib_struct_t radare_plugin = {
    .type = R_LIB_TYPE_BIN,
    .data = &r_bin_plugin_nes,
    .version = R2_VERSION

```

```
};  
#endif
```

Some Examples

- XBE - <https://github.com/radare/radare2/pull/972>
- COFF - <https://github.com/radare/radare2/pull/645>
- TE - <https://github.com/radare/radare2/pull/61>
- Zimgz
 - <https://github.com/radare/radare2/commit/d1351cf836df3e2e63043a6dc728e880316f00eb>
- OMF
 - <https://github.com/radare/radare2/commit/44fd8b2555a0446ea759901a94c06f20566bbc40>

Write a debugger plugin

- Adding the debugger registers profile into the shlr/gdb/src/core.c
- Adding the registers profile and architecture support in the libr/debug/p/debug_native.c and libr/debug/p/debug_gdb.c
- Add the code to apply the profiles into the function `r_debug_gdb_attach(RDebug *dbg, int pid)`

If you want to add support for the gdb, you can see the register profile in the active gdb session using command `maint print registers`.

More to come..

- Related article: <http://radare.today/posts/extending-r2-with-new-plugins/>

Some commits related to "Implementing a new architecture"

- Extensa: <https://github.com/radare/radare2/commit/6f1655c49160fe9a287020537afe0fb8049085d7>
- Malbolge: <https://github.com/radare/radare2/pull/579>
- 6502: <https://github.com/radare/radare2/pull/656>
- h8300: <https://github.com/radare/radare2/pull/664>
- GBA: <https://github.com/radare/radare2/pull/702>
- CR16: <https://github.com/radare/radare2/pull/721/> && 726
- XCore: <https://github.com/radare/radare2/commit/bb16d1737ca5a471142f16ccfa7d444d2713a54d>
- SharpLH5801: <https://github.com/neuschaefer/radare2/commit/f4993cca634161ce6f82a64596fce45fe6b818e7>
- MSP430: <https://github.com/radare/radare2/pull/1426>
- HP-PA-RISC: <https://github.com/radare/radare2/commit/f8384feb6ba019b91229adb8fd6e0314b0656f7b>
- V810: <https://github.com/radare/radare2/pull/2899>
- TMS320: <https://github.com/radare/radare2/pull/596>

Implementing a new pseudo architecture

This is an simple plugin for z80 that you may use as example:

<https://github.com/radare/radare2/commit/8ff6a92f65331cf8ad74cd0f44a60c258b137a06>

Python plugins

At first, to be able to write a plugins in Python for radare2 you need to install r2lang plugin. If you're going to use Python 2, then use `r2pm -i lang-python2`, otherwise (and recommended) - install the Python 3 version: `r2pm -i lang-python3`. Note - in the following examples there are missing functions of the actual decoding for the sake of readability!

For this you need to do this:

1. `import r2lang and from r2lang import R` (for constants)
2. Make a function with 2 subfunctions - `assemble` and `disassemble` and returning plugin structure - for RAsm plugin

```
def mycpu(a):
    def assemble(s):
        return [1, 2, 3, 4]

    def disassemble(buf):
        try:
            opcode = get_opcode(buf)
            opstr = optbl[opcode][1]
            return [4, opstr]
        except:
            return [4, "unknown"]
```

3. This structure should contain a pointers to these 2 functions - `assemble` and `disassemble`

```
return {
    "name" : "mycpu",
    "arch" : "mycpu",
    "bits" : 32,
    "endian" : "little",
    "license" : "GPL",
    "desc" : "MYCPU disasm",
    "assemble" : assemble,
    "disassemble" : disassemble,
}
```

1. Make a function with 2 subfunctions - `set_reg_profile` and `op` and returning plugin structure - for RAnal plugin

```

def mycpu_anal(a):
    def set_reg_profile():
        profile = "=PC      pc\n" + \
                  "=SP      sp\n" + \
                  "gpr    r0      .32    0      0\n" + \
                  "gpr    r1      .32    4      0\n" + \
                  "gpr    r2      .32    8      0\n" + \
                  "gpr    r3      .32   12      0\n" + \
                  "gpr    r4      .32   16      0\n" + \
                  "gpr    r5      .32   20      0\n" + \
                  "gpr    sp      .32   24      0\n" + \
                  "gpr    pc      .32   28      0"
        return profile

    def op(addr, buf):
        analop = {
            "type" : R.R_ANAL_OP_TYPE_NULL,
            "cycles" : 0,
            "stackop" : 0,
            "stackptr" : 0,
            "ptr" : -1,
            "jump" : -1,
            "addr" : 0,
            "eob" : False,
            "esil" : ""
        }
        try:
            opcode = get_opcode(buf)
            esilstr = optbl[opcode][2]
            if optbl[opcode][0] == "J": # it's jump
                analop["type"] = R.R_ANAL_OP_TYPE JMP
                analop["jump"] = decode_jump(opcode, j_mask)
                esilstr = jump_esil(esilstr, opcode, j_mask)

        except:
            result = analop
        # Don't forget to return proper instruction size!
        return [4, result]

```

1. This structure should contain a pointers to these 2 functions - `set_reg_profile` and `op`

```
return {
    "name" : "mycpu",
    "arch" : "mycpu",
    "bits" : 32,
    "license" : "GPL",
    "desc" : "MYCPU anal",
    "esil" : 1,
    "set_reg_profile" : set_reg_profile,
    "op" : op,
}
```

1. Then register those using `r2lang.plugin("asm")` and `r2lang.plugin("anal")` respectively

```
print("Registering MYCPU disasm plugin...")
print(r2lang.plugin("asm", mycpu))
print("Registering MYCPU analysis plugin...")
print(r2lang.plugin("anal", mycpu_anal))
```

You can combine everything in one file and load it using `-i` option:

```
r2 -I mycpu.py some_file.bin
```

Or you can load it from the r2 shell: `#!python mycpu.py`

See also:

- [Python](#)
- [Javascript](#)

Implementing new format plugin in Python

Note - in the following examples there are missing functions of the actual decoding for the sake of readability!

For this you need to do this:

1. `import r2lang`
2. Make a function with subfunctions:

- `load`
- `load_bytes`
- `destroy`
- `check_bytes`
- `baddr`

- o `entries`
- o `sections`
- o `imports`
- o `relocs`
- o `binsym`
- o `info`

and returning plugin structure - for RAsm plugin

```
def le_format(a):
def load(binf):
    return [0]

def check_bytes(buf):
    try:
        if buf[0] == 77 and buf[1] == 90:
            lx_off, = struct.unpack("<I", buf[0x3c:0x40])
            if buf[lx_off] == 76 and buf[lx_off+1] == 88:
                return [1]
            return [0]
    except:
        return [0]
```

and so on. Please be sure of the parameters for each function and format of returns. Note, that functions `entries`, `sections`, `imports`, `relocs` returns a list of special formed dictionaries - each with a different type. Other functions return just a list of numerical values, even if single element one. There is a special function, which returns information about the file - `info`:

```
def info(binf):
    return [
        "type" : "le",
        "bclass" : "le",
        "rclass" : "le",
        "os" : "OS/2",
        "subsystem" : "CLI",
        "machine" : "IBM",
        "arch" : "x86",
        "has_va" : 0,
        "bits" : 32,
        "big_endian" : 0,
        "dbg_info" : 0,
    ]
```

3. This structure should contain a pointers to the most important functions like `check_bytes`, `load` and `load_bytes`, `entries`, `relocs`, `imports`.

```
return {
    "name" : "le",
    "desc" : "OS/2 LE/LX format",
    "license" : "GPL",
    "load" : load,
    "load_bytes" : load_bytes,
    "destroy" : destroy,
    "check_bytes" : check_bytes,
    "baddr" : baddr,
    "entries" : entries,
    "sections" : sections,
    "imports" : imports,
    "symbols" : symbols,
    "relocs" : relocs,
    "binsym" : binsym,
    "info" : info,
}
```

1. Then you need to register it as a file format plugin:

```
print("Registering OS/2 LE/LX plugin...")
print(r2lang.plugin("bin", le_format))
```

Debugging

It is common to have issues when you write a plugin, especially if you do this for the first time. This is why debugging them is very important. The first step for debugging is to set an environment variable when running radare2 instance:

```
R_DEBUG=yes r2 /bin/ls
Loading /usr/local/lib/radare2/2.2.0-git//bin_xtr_dyldcache.so
Cannot find symbol 'radare_plugin' in library '/usr/local/lib/radare2/2.2.0-git//bin_xtr_dyldcache.so'
Cannot open /usr/local/lib/radare2/2.2.0-git//2.2.0-git
Loading /home/user/.config/radare2/plugins/asm_mips_ks.so
PLUGIN OK 0x55b205ea6070 fcn 0x7f298de08762
Loading /home/user/.config/radare2/plugins/asm_sparc_ks.so
PLUGIN OK 0x55b205ea6070 fcn 0x7f298de08762
Cannot open /home/user/.config/radare2/plugins/pimp
Cannot open /home/user/.config/radare2/plugins/yara
Loading /home/user/.config/radare2/plugins/asm_arm_ks.so
PLUGIN OK 0x55b205ea6070 fcn 0x7f298de08762
Loading /home/user/.config/radare2/plugins/core_yara.so
Module version mismatch /home/user/.config/radare2/plugins/core_yara.so (2.1.0) vs (2.2.0-git)
Loading /home/user/.config/radare2/plugins/asm_ppc_ks.so
PLUGIN OK 0x55b205ea6070 fcn 0x7f298de08762
Loading /home/user/.config/radare2/plugins/lang_python3.so
PLUGIN OK 0x55b205ea5ed0 fcn 0x7f298de08692
Loading /usr/local/lib/radare2/2.2.0-git/bin_xtr_dyldcache.so
Cannot find symbol 'radare_plugin' in library '/usr/local/lib/radare2/2.2.0-git/bin_xtr_dyldcache.so'
Cannot open /usr/local/lib/radare2/2.2.0-git/2.2.0-git
Cannot open directory '/usr/local/lib/radare2-extras/2.2.0-git'
Cannot open directory '/usr/local/lib/radare2-bindings/2.2.0-git'
USER CONFIG loaded from /home/user/.config/radare2/radare2rc
-- In visual mode press 'c' to toggle the cursor mode. Use tab to navigate
[0x000005520]>
```

Testing the plugin

This plugin is used by rasm2 and r2. You can verify that the plugin is properly loaded with this command:

```
$ rasm2 -L | grep mycpu
_d  mycpu      My CPU disassembler  (LGPL3)
```

Let's open an empty file using the 'mycpu' arch and write some random code there.

```
$ r2 -
-- I endians swap
[0x00000000]> e asm.arch=mycpu
[0x00000000]> woR
[0x00000000]> pd 10
0x00000000  888e      mov r8, 14
0x00000002  b2a5      ifnot r10, r5
0x00000004  3f67      ret
0x00000006  7ef6      bl r15, r6
0x00000008  2701      xor r0, 1
0x0000000a  9826      mov r2, 6
0x0000000c  478d      xor r8, 13
0x0000000e  6b6b      store r6, 11
0x00000010  1382      add r8, r2
0x00000012  7f15      ret
```

Yay! it works.. and the mandatory oneliner too!

```
r2 -nqamycpu -cwoR -cpd' 10' -
```

Packaging plugin

As you remember radare2 has its own [packaging manager](#) and we can easily add newly written plugin for everyone to access.

All packages are located in [radare2-pm](#) repository, and have very simple text format.

```
R2PM_BEGIN

R2PM_GIT "https://github.com/user/mycpu"
R2PM_DESC "[r2-arch] MYCPU disassembler and analyzer plugins"

R2PM_INSTALL() {
    ${MAKE} clean
    ${MAKE} all || exit 1
    ${MAKE} install R2PM_PLUGDIR="${R2PM_PLUGDIR}"
}

R2PM_UNINSTALL() {
    rm -f "${R2PM_PLUGDIR}/asm_mycpu.*"
    rm -f "${R2PM_PLUGDIR}/anal_mycpu.*"
}

R2PM_END
```

Then add it in the `/db` directory of [radare2-pm](#) repository and send a pull request to the mainline.

Radare2 Reference Card

This chapter is based on the Radare 2 reference card by Thanat0s, which is under the GNU GPL. Original license is as follows:

This card may be freely distributed under the terms of the GNU general public licence – Copyright by Thanat0s - v0.1 -

Survival Guide

Those are the basic commands you will want to know and use for moving around a binary and getting information about it.

Command	Description
s (tab)	Seek to a different place
x [nbytes]	Hexdump of nbytes, \$b by default
aa	Auto analyze
pdf@fcn(Tab)	Disassemble function
f fcn(Tab)	List functions
f str(Tab)	List strings
fr [flagname] [newname]	Rename flag
psz [offset]~grep	Print strings and grep for one
arf [flag]	Find cross reference for a flag

Flags

Flags are like bookmarks, but they carry some extra information like size, tags or associated flagspace. Use the `f` command to list, set, get them.

Command	Description
f	List flags
fd \$\$	Describe an offset
fj	Display flags in JSON
fl	Show flag length
fx	Show hexdump of flag
fC [name] [comment]	Set flag comment

Flagspaces

Flags are created into a flagspace, by default none is selected, and listing flags will list them all. To display a subset of flags you can use the `fs` command to restrict it.

Command	Description
fs	Display flagspaces
fs *	Select all flagspaces
fs [sections]	Select one flagspace

Information

Binary files have information stored inside the headers. The `i` command uses the RBin api and allows us to do the same things rabin2 do. Those are the most common ones.

Command	Description
ii	Information on imports
il	Info on binary
ie	Display entrypoint
iS	Display sections
ir	Display relocations
iz	List strings (izz, izzz)

Print string

There are different ways to represent a string in memory. The `ps` command allows us to print it in utf-16, pascal, zero terminated, .. formats.

Command	Description
<code>psz [offset]</code>	Print zero terminated string
<code>psb [offset]</code>	Print strings in current block
<code>psx [offset]</code>	Show string with scaped chars
<code>psp [offset]</code>	Print pascal string
<code>psw [offset]</code>	Print wide string

Visual mode

The visual mode is the standard interactive interface of radare2.

To enter in visual mode use the `v` or `V` command, and then you'll only have to press keys to get the actions happen instead of commands.

Command	Description
<code>V</code>	Enter visual mode
<code>p/P</code>	Rotate modes (hex, disasm, debug, words, buf)
<code>c</code>	Toggle (c)ursor
<code>q</code>	Back to Radare shell
<code>hjkl</code>	Move around (or HJKL) (left-down-up-right)
<code>Enter</code>	Follow address of jump/call
<code>sS</code>	Step/step over
<code>o</code>	Go/seek to given offset
<code>.</code>	Seek to program counter
<code>/</code>	In cursor mode, search in current block
<code>:cmd</code>	Run radare command
<code>;[-]cmt</code>	Add/remove comment
<code>x+-[]</code>	Change block size, [] = resize hex.cols
<code>> <</code>	Seek aligned to block size
<code>i/a/A</code>	(i)nsert hex, (a)ssemble code, visual (A)ssembler
<code>b/B</code>	Toggle breakpoint / automatic block size

d[f?]	Define function, data, code, ..
D	Enter visual diff mode (set diff.from/to)
e	Edit eval configuration variables
f/F	Set/unset flag
gG	Go seek to begin and end of file (0-\$s)
mK'K	Mark/go to Key (any key)
M	Walk the mounted filesystems
n/N	Seek next/prev function/flag/hit (scr.nkey)
o	Go/seek to given offset
C	Toggle (C)olors
R	Randomize color palette (ecr)
t	Track flags (browse symbols, functions..)
T	Browse anal info and comments
v	Visual code analysis menu
V/W	(V)iew graph (agv?), open (W)ebUI
uU	Undo/redo seek
x	Show xrefs to seek between them
yY	Copy and paste selection
z	Toggle zoom mode

Searching

There are many situations where we need to find a value inside a binary or in some specific regions. Use the `e search.in=?` command to choose where the `/` command may search for the given value.

Command	Description
/ foo\00	Search for string 'foo\0'
/b	Search backwards
//	Repeat last search
/w foo	Search for wide string 'f\0o\0o\0'
/wi foo	Search for wide string ignoring case
!/ ff	Search for first occurrence not matching
/i foo	Search for string 'foo' ignoring case
/e /E.F/i	Match regular expression
/x ff0.23	Search for hex string
/x ff..33	Search for hex string ignoring some nibbles
/x ff43 ffd0	Search for hexpair with mask
/d 101112	Search for a deltified sequence of bytes
!/x 00	Inverse hexa search (find first byte != 0x00)
/c jmp [esp]	Search for asm code (see search.asmstr)
/a jmp eax	Assemble opcode and search its bytes
/A	Search for AES expanded keys
/r sym.printf	Analyze opcode reference an offset
/R	Search for ROP gadgets
/P	Show offset of previous instruction
/m magicfile	Search for matching magic file
/p patternsize	Search for pattern of given size
/z min max	Search for strings of given size
/v[?248] num	Look for a asm.bigendian 32bit value

Saving

By default, when you open a file in write mode (`r2 -w`) all changes will be written directly into the file. No undo history is saved by default.

Use `e io.cache.write=true` and the `wc` command to manage the *write cache* history changes. To undo, redo, commit them to write the changes on the file..

But, if we want to save the analysis information, comments, flags and other user-created metadata, we may want to use projects with `r2 -p` and the `P` command.

Command	Description
<code>Po [file]</code>	Open project
<code>Ps [file]</code>	Save project
<code>Pi [file]</code>	Show project information

Usable variables in expression

The `?$?` command will display the variables that can be used in any math operation inside the r2 shell. For example, using the `? $$` command to evaluate a number or `?v` to just the value in one format.

All commands in r2 that accept a number supports the use of those variables.

Command	Description
<code>\$\$</code>	here (current virtual seek)
<code>\$\$\$</code>	current non-temporary virtual seek
<code>\$?</code>	last comparison value
<code>\$alias=value</code>	alias commands (simple macros)
<code>\$b</code>	block size
<code>\$B</code>	base address (aligned lowest map address)
<code>\$f</code>	jump fail address (e.g. <code>jz 0x10 => next instruction</code>)
<code>\$fl</code>	flag length (size) at current address (<code>fla; pD \$I @ entry0</code>)
<code>\$F</code>	current function size
<code>\$FB</code>	begin of function
<code>\$Fb</code>	address of the current basic block
<code>\$Fs</code>	size of the current basic block
<code>\$FE</code>	end of function
<code>\$FS</code>	function size
<code>\$Fj</code>	function jump destination
<code>\$Ff</code>	function false destination
<code>\$FI</code>	function instructions
<code>\$c,\$r</code>	get width and height of terminal

\$Cn	get nth call of function
\$Dn	get nth data reference in function
\$D	current debug map base address ?v \$D @ rsp
\$DD	current debug map size
\$e	1 if end of block, else 0
\$j	jump address (e.g. jmp 0x10, jz 0x10 => 0x10)
\$Ja	get nth jump of function
\$Xn	get nth xref of function
\$I	opcode length
\$m	opcode memory reference (e.g. mov eax,[0x10] => 0x10)
\$M	map address (lowest map address)
\$o	here (current disk io offset)
\$p	getpid()
\$P	pid of children (only in debug)
\$s	file size
\$S	section offset
\$SS	section size
\$v	opcode immediate value (e.g. lui a0,0x8010 => 0x8010)
\$w	get word size, 4 if asm.bits=32, 8 if 64, ...
\${ev}	get value of eval config variable
\${r{reg}}	get value of named register
\${k{kv}}	get value of an sdb query value
\${s{flag}}	get size of flag
RNum	variables usable in math expressions

Authors & Contributors

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The radare2 book

This book was started by maijin as a new version of the original radare book written by pancake.

- Old radare1 book <http://www.radare.org/get/radare.pdf>

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