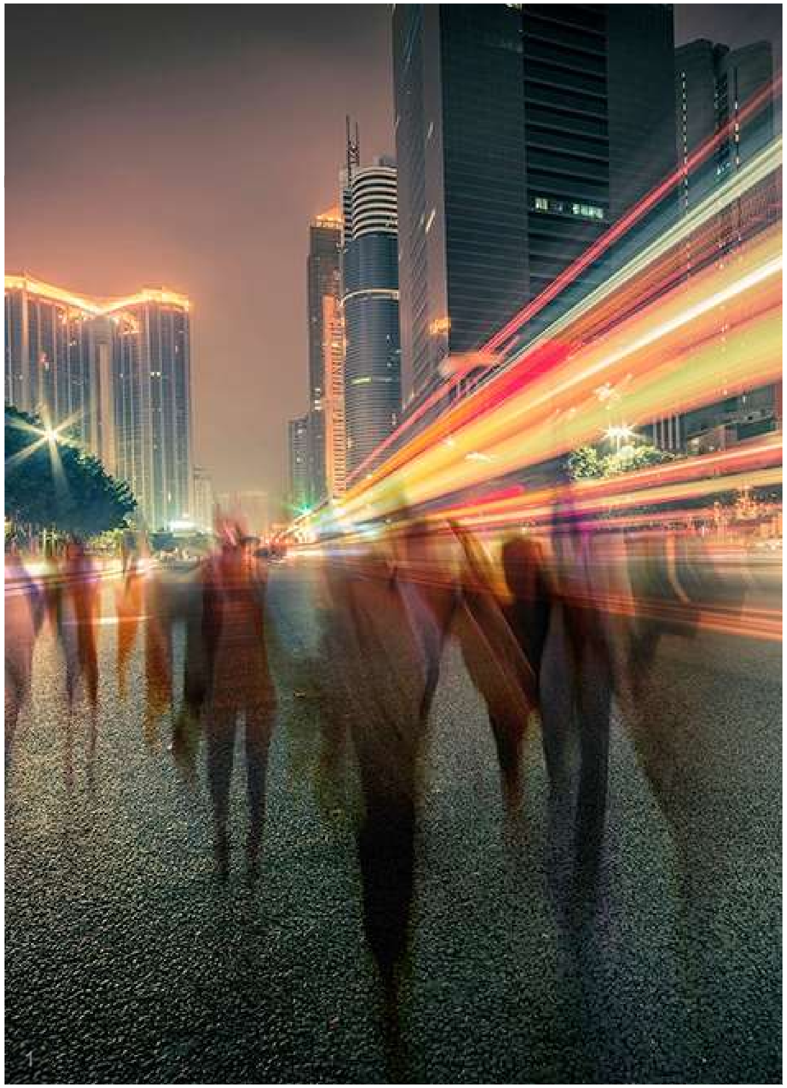

ivyscript reference

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The ivyscript programming language

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- Ivyscript is a programming language wrapper around the ivy engine control C++ API.
  - See "programming the ivy engine"
- Ivyscript – for scripting test workflow
  - The somewhat easier way for a human to operate ivy.
  - Similar to a subset of C/C++, with some minor differences.
  - Extensible - parser auto-generated from language grammar. (flex+bison)
- ivy engine REST API
  - Easier for programmers to integrate ivy into a wider framework.

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- Statements in the programming language end with a semi-colon, like C / C++ / Java.
- C style comments are supported
  - The part from /* to */ is ignored
- C++ style comments are supported
  - From // to the end of the line is ignored.
- # style comments are supported
  - From # to the end of the line is ignored.

Make .ivyscript programs executable

- So-called "sha-bang" lines work.
- A sha-bang line is when you start a script with a line that specifies a path to the program used to interpret the script.
- For example, as the first line of an .ivyscript program:

```
#!/path_to_ivy_executables/ivy
```

  (followed by remainder of ivyscript program)

- Then you can invoke the .ivyscript file as a program itself.

Nested blocks

- Anywhere you can put a statement, you can put a nested block, which starts with "`{`" and ends with "`}`".
- Any variable or function declarations made inside a nested block are not "visible" to code outside the nested block.
- Nested blocks are typically used in `if` statements, looping constructs, etc.

Types

- There are 3 types: `int`, `double`, and `string`.

- Examples of constants, also called literals:

```
int:       0        -5      12345
double:    5.       .5      5.5       5E-2      5%   5.5%
string:    "house"          ""
```

  – There is also a hex form of `int` literal (constant)
    – `0x0` to `0x7FFFFFFF`
    – The hex form of `int` literal only supports non-negative values
  – `5%` means the same thing as `0.05`.

More on string literals

- To include a double quote character in a string constant, escape it with a backslash:
  - `"the word \"house\" is double-quoted"`
- Other escaped characters: `\r, \n, \t`
- An escaped octal character value has 3 digits, e.g. `\001`
- An escaped hex character value has one or two digits, e.g. `\xf` or `\x0f`
- Raw strings start with << and end with >>. Use this for JSON and you won't need to escape the double-quote characters.

```
<< { "port" : "1A", "LDEV" : "00:FF" } >>
```

Identifiers

- "identifiers" are eligible to serve as the name of a variable or function.
- An identifier begins with an alphabetic character (a letter) or a Japanese hiragana, katakana, or Kanji character, and continues with letters, Japanese hiragana, katakana, or Kanji characters, digits, and underscore _ characters.

Statement – variable declaration

- <type> <list of identifiers <with optional = initializer expression>>;
- Examples:
- ```
  int i, j;
  int k = -1;
  double c;
  double d = 1.5;
  string s;
  string name = "bert";
  ```
  ```

Expressions

- A constant (a literal of one of the types) is an expression
  - e.g. `"constant"`
- A variable reference is an expression
  - e.g. `x`
- Expressions may be combined together with operators, which operate the same as in C/C++:
  - +, -, *, /, %, >, <, >=, <=, ==, !=, =, |, &, ^, &&, ||
- Expressions have a type, `int`, `double`, or `string`

Converting an expression to a different type

- int(<expression>)
  double(<expression>)
  string(<expression>)
- Some times called a "cast".
- The expression is evaluated and the result is converted to the target type.
- Can result in a run time error
  - E.g. evaluating `int("cow")` would cause a run-time error.

Operators - arithmetic

- + plus – for numbers, adds, for strings, concatenates
  - minus
  * multiply
  / divide
  % remainder from integer division

Logical operators - comparison

- $>$ greater than
  $<$ less than
  $>=$ greater than or equal to
  $<=$ less than or equal to
  $==$ equal to
  $!=$ not equal to

- There is no true/false type. Logical operators evaluate to an integer value just like the old C language before there was a `bool` type.
  – An `int` or a `double` value used as a logical expression means "false" if the numeric value is zero, and means "true" for any non-zero value.
  – Use of `int` logical values is transparent – it works the way you expect it to.

Bitwise or, bitwise and, bitwise exclusive or

- The bitwise operators operate on the individual bits in an `int` value, exactly like in C/C++.
- | bitwise or
  & bitwise and
  ^ bitwise exclusive or

Logical or, and, not

- These operate on logical expressions, which evaluate to an `int` interpreted to mean "false" if the `int` value is zero, "true" otherwise.
  - Like in C/C++ the second expression after the operator is not evaluated if the result is known from evaluating the first expression before the operator.
- || logical or
  - Evaluates the first expression, and if true, returns true. Otherwise, it evaluates the second expression and returns its true/false value.
- && logical and
  - Evaluates the first expression, and if false, returns false. Otherwise it evaluates the second expression and returns its true/false value.
- ! not
  - Evaluates a logical expression and returns the opposite.

Assignment expression

- <identifier> = <expression>
- The identifier is looked up in the symbol table at compile time, and if it's valid, at execution the expression is evaluated and the variable is set to that value.
- If the expression is not of the same type as the variable, the value may be coerced / converted, or in some cases a compile time error occurs.

Function call expression

- <identifier> (<comma separated list of zero or more expressions>)
  - E.g. `sin(.5)`
- Identifier and parameter list signature are looked up at compile time to and if valid, a function call is built.
- At run time, the expressions are evaluated and the resulting parameter values are passed to the function, the function is executed, and the result is returned.

Operator precedence

- Same as C/C++
  - `if ( 3*4+5*6 == fred || ! Person == Nancy = 4)`
  - Means
  - `if ((((3*4)+(5*6))==fred)||(!(Person==(Nancy=4))))`
- If you are not sure, group with parentheses ().

User-defined functions

- E.g.
  - ```
    int add_three( int i )
    {
        return i+3;
    };
    ```

Semicolon needed for function definitions, unlike in C / C++

- Functions have a type, which is the type of the object they return to the caller.
- Functions can be "declared" without being defined yet:
  ```
  int add_three(int i);
  ```
  ```

Library of user defined functions

- As in most programming languages you can "include" or "import" a copy of some ivyscript code from a library.
- In ivyscript, you say:

```
inklude port_scalability_test.ivyscript
```

- Just be advised that the initial implementation of this feature allows infinite loops.
  - Need to consider use cases – in some cases it could be valid to be importing multiple copies, but from different and separate places.
  - Maybe default to #pragma once behaviour, requiring specific override.

Function overloading

- It's OK to have different functions with the same name as long as the sequence of types of the parameters is different so the compiler can tell them apart.
- ```
  int    addtwo(int i)    { return i+2;}
  string addtwo(string s) { return s + "two";}
  ```
  ```

`ivy_engine_get("thing")` `ivy_engine_set("thing","value")`

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- `"thing"` must be an identifier starting with a letter and continuing with letters, digits, and underscores
  - `"thing"` names are normalized before examination by removing underscores and translating to lower case, that is, `"outputFolderRoot"`, `"output_Folder_Root"`, and `"output_folder_root"` are equivalent.
- `ivy_engine_get("summary_csv")` gets the `"all=all"` summary csv filename
- `ivy_engine_get("outputFolderRoot")` from `[OutputFolderRoot]` statement – default `"."`
- `ivy_engine_get("testName")` root part of ivyscript file without `.ivyscript` suffix
- `ivy_engine_get("masterlogfile")` gets the filename
- `ivy_engine_set("masterlogfile","message")` writes a timestamp and `"message"` to the log
- `ivy_engine_get("testFolder")` root folder for output from this run
- `ivy_engine_get("stepNNNN")` from most recent [Go!], e.g. step0002
- `ivy_engine_get("stepName")` from most recent [Go]
- `ivy_engine_get("stepFolder")` subfolder for most recent [Go] within testFolder()
- `ivy_engine_get("last_result")` for most recent [Go], returns `"success"` or `"failure"`
- `ivy_engine_get("rollup_structure")` gets type / instance / workload thread hierarchy.

Deprecated ivyscript ivy engine accessor builtins

- The following ivyscript builtin functions still work, but users are encouraged to switch over to using the equivalent calls to `ivy_engine_get(“thing”)` and `ivy_engine_set(“thing”, “value”)`
- `string outputFolderRoot();` from `[OutputFolderRoot]` statement – default "`.`"
- `string testName();` root part of ivyscript file without `.ivyscript` suffix
- `string masterlogfile();` ivy master log filename
- `string testFolder();` root folder for output from this run
- `string stepNNNN();` from most recent [Go!], e.g. step0002
- `string stepName();` from most recent [Go]
- `string stepFolder();` subfolder for most recent [go] within testFolder()
- `string last_result();` for most recent [Go], returns "`success`" or "`failure`"
- `string show_rollup_structure();` shows type / instance / workload thread hierarchy.

Math builtin functions – same as C/C++

- `double sin(double), double cos(double), double tan(double)`
- `double sinh(double), double cosh(double), double tanh(double)`
- `double asin(double), double acos(double),`
  `double atan(double), double atan2(double,double)`
- `double log(double), log10(double),`
  `double exp(double), double pow(double,double)`
- `double sqrt(double)`
- `int abs(int)` - absolute value
- `double pi(), double e()`

String builtin functions

- `string substring(string s, int begin_index_from_zero, int number_of_chars);`
- `string left(string s, int n);` like in BASIC, gives you leftmost / rightmost characters
  `string right(string s, int n);`
- `string trim(string s);` removes leading / trailing whitespace
- `string to_lower(string s);`
  `string to_upper(string s);`
- `int stringCaseInsensitiveEquality(string s1, string s2);`
- `string int_to_ldev(int n);` `int_to_ldev(0xFF)` returns `"00:FF"`
- `string to_string_with_decimal_places(double x, int n);`
  `to_string_decimal_places(3.1415,2)` returns `"3.14"`

regex builtin functions

- ivy uses the default flavour of C++ std::regex, which I think uses the ECMAscript dialect
- `int regex_match(std::string s, string regex);`
  E.g. `if ( regex_match("horse","(horse)|(cow)") ) then print("animal\n");`
- `int regex_sub_match_count(string s, string regex);`
- `string regex_sub_match(string s, string regex, int n);`
  `n` must be less than `regex_sub_match_count(s, regex)`
- `int matches_digits(string s);`
  `int matches_float_number(string s);`
  `int matches_float_number_optional_trailing_percent(string s);`
  some ivy parameters can be set to these
  `int matches_identifier(string s);`
  alphabetic, continued with alphanumeric and underscores _
  `int matches_IPv4_dotted_quad(string s);`

Accessing csv files – row and column

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Header row is row -1

Row 0 is test step 0 or subinterval 0

Use column number from 0, or say "Overall IOPS"

Test step csv files (not shown) have one line per subinterval (both host & subsystem data)

Summary csv files like this one have one line per test step.

	A	B	C	Q	R	S	AW	AX			
1	Test Name	Step Number	Step Name	iogenerator type	blocksize	maxTags	Overall IOPS	Overall Decimal MB/s	Overall Average Blocksize (KiB)	Overall Little's Law Avg Q	Overall Average Service Time (ms)
2	demo9	step0000	iops_max	random_independent	4 KiB	32	2597.16	10.638	4	64.0024	24.6432
3	demo9	step0001	baseline_service_time	random_independent	4 KiB	32	25.81	0.105718	4	0.164588	6.37691
4	demo9	step0002	1.125_x_baseline	random_independent	4 KiB	32	555.849	2.27676	4	4.08014	7.34037
5	demo9	step0003	1.25_x_baseline	random_independent	4 KiB	32	1097.86	4.49682	4	8.74646	7.96686
6	demo9	step0004	1.5_x_baseline	random_independent	4 KiB	32	1486.01	6.08671	4	14.2187	9.56836
7	demo9	step0005	1.75_x_baseline	random_independent	4 KiB	32	1722.35	7.05476	4	19.2298	11.1649
8	demo9	step0006	2_x_baseline	random_independent	4 KiB	32	1898.07	7.77448	4	24.2199	12.7603
9	demo9	step0007	3_x_baseline	random_independent	4 KiB	32	2353.68	9.64067	4	45.0346	19.1337
10	demo9	step0008	4_x_baseline	random_independent	4 KiB	32	2602.77	10.6609	4	63.9994	24.589
11	demo9	step0009	5_x_baseline	random_independent	4 KiB	32	2601.7	10.6566	4	63.9962	24.5978

Csv file builtin functions 1/3 – overall size

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- These csv functions are the same as the standalone ivy companion csv file command line utilities
- `int csv_rows(string filename);`
  - Number of rows following the header row.
  - Returns -1 if invalid file or file empty. Returns 0 if there was only a header row.
- `int csv_columns_in_row(string filename, int row);`
- `int csv_header_columns(string filename);`
  - Same as `csv_columns_in_row(filename, -1)`

Csv file builtin functions 2/3 – individual cells

- ```
  string csv_cell_value(string filename, int row, int column);
  string csv_cell_value(string filename, int row, string column_header_text);
  ```
  - You can refer to a column using an int, the column index from zero.
  - You can refer to a column using a string, the column header text.
- ```
  string csv_raw_cell_value(string filename, int row, int column);
  string csv_raw_cell_value(string filename,
                                           int row, string column_header_text);
  ```
  - ivy "wraps" text fields as a formula with a string constant, e.g. `="horse"`
    - This stops Excel from interpreting 1-1 as January 1st, and 00:00 from interpreting as a time.
  - The csv file functions normally "unwrap" csv column values, removing this kind of wrapper or removing simple double quotes surrounding a value, to treat `="horse", "horse"` and `horse` the same
  - Retrieving the raw value give you exactly what was between the commas in the csv file.

Csv file builtin functions 3/3 – headers & slices

- `int csv_lookup_column(string filename, string column_header);`
  - Gives you the column number for a column title string.
- `string csv_column_header(string filename, int col);`
  - Give you the text of the column header for a column number from zero.
- ```
  string csv_column(string filename, int col);
  string csv_column(string filename, string column_header);
  ```
  - Gives you a "column slice" of the spreadsheet showing "raw" values.
  - E.g. `"IOPS,55,66,55,44"`
  - Demo number 8 shows iterating through the column slices to write out the transpose of a csv file.
- `string csvfile_row(string filename, int row);`
  - Gives you a "row slice" of the spreadsheet showing the "raw" values.
  - E.g. `="random_independent",="4 KiB",32,2601.7`
  ```

utility functions

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- `string print(string), double print(double), int print(int)`
  - Prints the specified value to stdout and then returns that value.
- `int fileappend(string filename, string s)`
  - One way to write output. Does not append a newline to `s`.
- `int log(string s)`
  - Writes to the ivy master log file, adding a timestamp prefix before the string, and adds terminating newline if the last line in `s` doesn't already have one.
- `trace_evaluate(int)`
  - Turns execution tracing on/off. Zero means off, otherwise on.

Builtin functions – `shell_command`

- `string shell_command(string)`
  or equivalently `string system(string)`
  - Executes the shell command and returns its output.
    - Runs as **`root`**. You have been warned.
    - Ivy runs as `root` in our lab because ivy uses ssh to fire up ivydriver and ivy_cmddev on test hosts, and "`root`" has been set up to not require a password to ssh. Ivy may also need to run as `root` to do I/O to raw LUNs – not sure.
    - The only ivy component that definitely requires to run as `root` is the SCSI Inquiry tool, which has the executable that issues "SCSI Inquiry" marked `setuid` as `root`, and thus works for any user.
  - Use `shell_command()` to do almost anything
    - `grep` in an ivy output folder to find a csv file name
    - Get a time or date stamp

Builtin functions – `exit()`

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– As in

```
– if ( last_result() != "success" )
  {
     print "timed out without making a valid measurement.\n";
     exit();
  }
```

Statements: expression statement

- <expression> ;
- Executes the expression and discards the result.

Statements – if / then / else

- `if ( <logical expression> ) <statement>`
- `if ( <logical expression> ) <statement> else <statement>`
- <statement> can be a single statement, or it can be a nested block starting with { and ending with }.
- ```
  int x = 1;

  if ( x >= 0 ) print( "x is greater than or equal to zero.\n");
  else          print( "x is less than zero.\n");

  if ( x >= 0 ) { print( "x is greater than or equal to zero.\n"); x = x + 1; }
  else          { print( "x is less than zero.\n");                x = x - 1; }
  ```
  ```

Statements – traditional C style for loop

- `for (` <initializer expression> `;` <logical expression>`;` <epilogue expression> `)`
  <loop body statement>
- The initializer expression is run.
- Then the logical expression is evaluated, if false, execution of the statement is complete.
- Otherwise, the loop body statement is run, then the epilogue expression is run, then we loop back to where we will evaluate the logical expression.

Example of traditional for loop

- ```
  int i;
  for ( i=0; i<10; i=i+1 )
  {
          print( "i = " + string(i) + "\n");
  }
  ```

- Note that it's not `for (int i=0; i<10; i++)`

  1. The initializer is an expression, not a statement, so can't declare `i` to be an `int`.

  2. There is no increment operator ++ as in C++.
  ```

Statement – list-style for loop

- For <identifier> = { <list of expressions> } statement
- E.g.

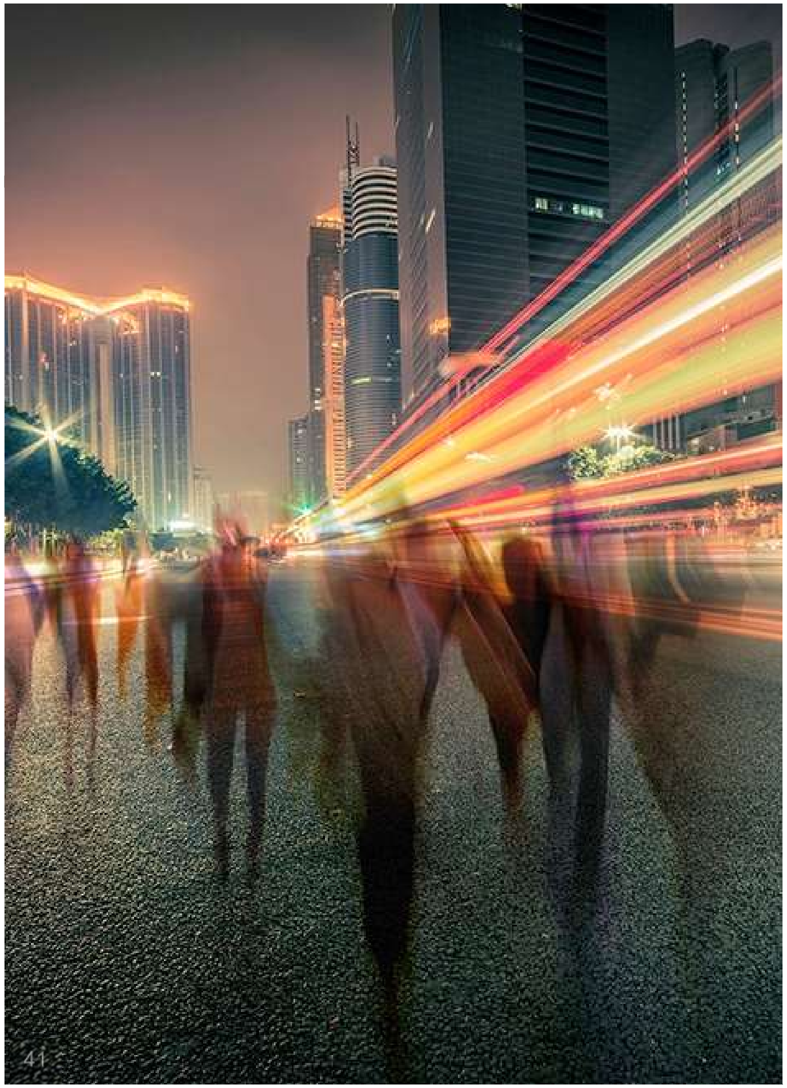
```
int i;
for i = { 0, 1, 2 }
    print("i = " + string(i) + "\n");

string s;
for s = { "cat", "dog", "mouse" }
{
    print ( "A " + s + " has four legs.\n");
}
```

Statement – while loop

- `while` (<logical expression>) <loop body statement>
- The logical expression is evaluated, and if false, execution of the statement is complete.
- Otherwise, the loop body statement is executed and then we loop back to evaluating the logical expression again.

Statement – do - while loop

- `do` <loop body statement> `while` (<logical expression>) ;
- The loop body statement is executed, and then the logical expression is evaluated, and if the result was "false", execution of the statement is complete.
- Otherwise, and then we loop back to running the loop body statement again.



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