Robot Simulator, v180107

7th January, 2018

Contents

1 A Word of Caution

Simulators, by their very nature, are approximations of the real world. Various approximations are made to develop them and, as a result they do not model the world perfectly. Therefore, they should be treated as an *aid* to the development of your system. It does not replace working with the actual robotic platform.

2 Version History

- **160430**: Initial release
- **160505**: Include methods for custom setting of encoder ticks.
- **170108**: Significant rewrite of geometry handling to support collision of wheels with walls. Support wall material types. Added multiple IR sensor detection profiles which are chosen randomly. Inject random noise into robot movement. Approximate maximum acceleration constraints.
- **170123**: Added trails which robots can leave in the environment. Added macros to show if the code is being built in the simulator or not. Updated instructions to remove some errors.
- **180107**: Made configuration of IR sensors externally controllable through log files. Added ability to show sensor firing in the GUI.

3 Prerequisites

The simulator has been tested to work on Ubuntu Linux 16.04, macOS High Sierra and Windows 10, 64-bit edition but is likely to work on many other combinations of operating system and build environments. For example, it has been used in the Windows Subsystem for Linux. It uses standard software with no third party dependencies.

The project files consist of a large number of small programs which mostly communicate by writing messages to a console. Such programs tend to be very inefficiently managed using IDEs. Therefore, we do *not* recommend the use of any IDE such as Developer Studio or XCode but, rather, to use command line tools directly. In addition, command line is used quite often as a fallback in many, many systems, and having a familiarity with it is very useful in its own right.

- **Windows:** The recommended system to use is cygwin. The installer can be downloaded from `https://www.cygwin.com/`. You should install the cmake, make and g++ packages.
- **macOS:** The shell (bash) and the compiler (clang) come with the system (although you might have to install the Xcode command line tools). For package management, it is highly recommended that you use homebrew to install the basic system libraries (`http://brew.sh/`) together with cask (`https://caskroom.github.io/`) to manage installing applications.
- **Linux:** The command line tools are already provided, and only the below requirements need to be met.

To run the simulator, you will need:

- Java JRE 1.8 or above, `https://java.com/en/download/`.
- A C++11 or above compliant compiler, including gcc and clang.
- CMake, version 2.8.4 or above. This can be obtained from `https://cmake.org/download/`.

Optionally, you can install Eclipse (`https://eclipse.org/downloads/`) Neon (or above) to use the project files to build the simulator.

4 Package Structure

Uncompress the zip file to give the following directory structure:

```
robotsimulator
├── Client
│   ├── applications
│   ├── Examples
│   ├── include
│   ├── src
│   └── tests
├── Documentation
└── Simulator
    ├── bin
    ├── lib
    ├── maps
    ├── robot_params
    └── src
```

4.1 Simulator

This was built using Java in Eclipse. The full Eclipse project is included, but a precompiled, runnable jar file (`Simulator/bin/simulator.jar`) is shipped so that no building is required. Therefore, you should be able to double click on it to run. You might need to give it permission to act as a server in a firewall.

4.2 Client

Unlike the server, the client is in C / C++ code and must be built on the local operating system / build environment. The client consists of a library, `libclient`, which includes a networking library (`Client/src/Practical_Socket`), a library for linking with the simulation (`Client/src/Client`) and a port of a number of the standard Propeller IDE libraries (in `Client/src/Simple_Libraries`).

The meta-build system `cmake` (`https://cmake.org/`) is used. `cmake` uses high-level text files to specify a project. It can use these to generate build systems for a huge range of development platforms (including makefiles, Visual Studio solutions, nmake makefiles, Xcode projects, and eclipse workspaces) for a huge range of platforms (including OSX, Linux, Windows, and Cygwin under Windows).

4.2.1 Build Instructions

For all platforms, command line building is the recommended approach. The command is

```
cmake SOURCE_DIRECTORY
```

If you are compiling within the source directory, you would use:

```
cmake .
```

(Note the "." to mean current directory.)

You should see the following. (Note that `Hnatt:Client ucacsjj$` is the command line prompt generated by my machine and shows the machine name, directory and user. Your prompt will be different.)

```
Hnatt:Client ucacsjj$ cmake .
-- Looking for pthread.h
-- Looking for pthread.h - found
-- Looking for pthread_create
-- Looking for pthread_create - found
-- Found Threads: TRUE
-- Configuring done
-- Generating done
-- Build files have been written to: /Users/ucacsjj/Proj/Simulator/Code/Trunk/Source/Client
```

The code can then be built using:

```
make
```

You should then see something like:

```
Hnatt:Client ucacsjj$ make
[  1%] Building CXX object src/CMakeFiles/client.dir/Practical_Socket/PracticalSocket.cpp.o
[  1%] Building CXX object src/CMakeFiles/client.dir/Client/Console.cpp.o
[  1%] Building CXX object src/CMakeFiles/client.dir/Client/ServerConnection.cpp.o
[  2%] Building CXX object src/CMakeFiles/client.dir/Client/launcher.cpp.o
[  2%] Building CXX object src/CMakeFiles/client.dir/Client/simulator.cpp.o
[  3%] Building CXX object src/CMakeFiles/client.dir/Simple_Libraries/Motor/libservo/servo.cpp.o
[  3%] Building CXX object src/CMakeFiles/client.dir/Simple_Libraries/PropellerGCC/cog.cpp.o
[  4%] Building CXX object src/CMakeFiles/client.dir/Simple_Libraries/PropellerGCC/CogManager.cpp.o

....
```

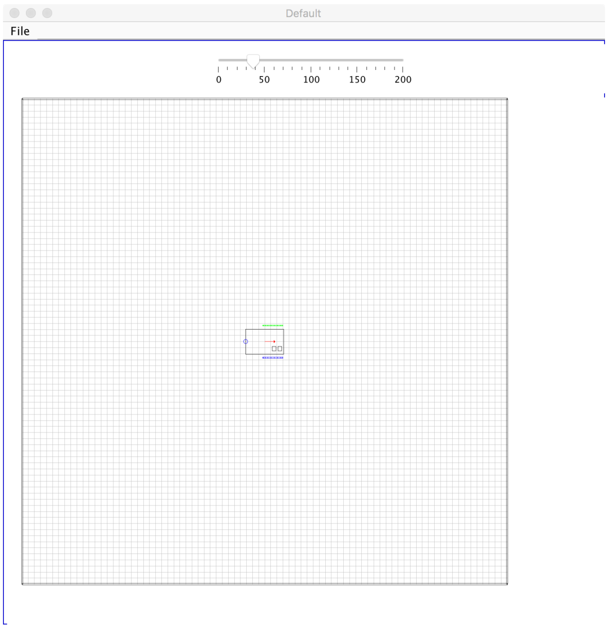
```
[100%] Linking CXX executable Cog_Info_Exchange
[100%] Built target Cog_Info_Exchange
[100%] Building C object applications/CMakeFiles/spinLeftRight.dir/spinLeftRight.c.o
[100%] Linking CXX executable spinLeftRight
```

You may see a number of warnings. These can be safely ignored. They occur because of the way in which the programs are wrapped so that they look the same both in the robot and in the simulator.

5 Usage

5.1 Simulator

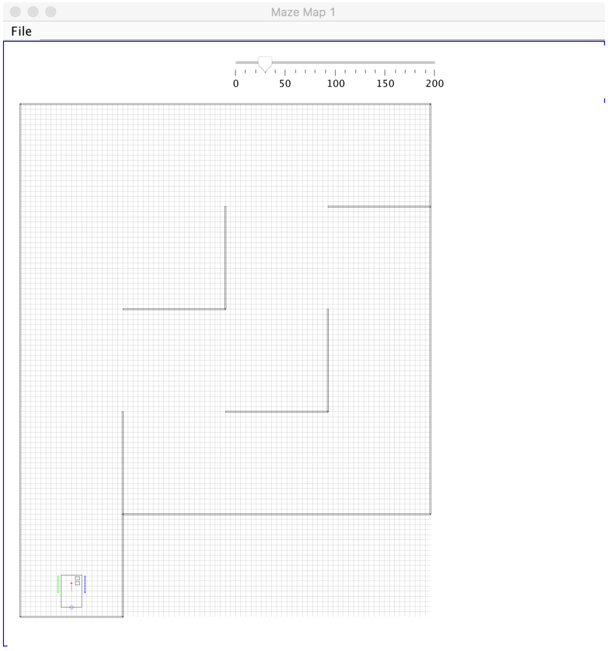
For the simulator, simply double click on the jar file to open. This should present you with the window:



The GUI options are (deliberately) very simple. The slider only changes the zoom setting (the mousewheel or equivalent can be used to zoom in and out).

The `File` menu supports loading a map from file, refreshing a map (which reloads a previous specified map) or exiting.

The maps are all in the `Simulator/maps` directory. The figure below shows the map obtained from loading Maze 02:



The map files are stored using a JSON format. The format should be "self-explanatory" but, if people are interested, documentation on it can be provided.

The graphics will show, in real time, the firing of the sensors as well. The ping sensor is shown as a ray which faces towards the front, and the IR sensors are rays to the left and right.

5.2 Client

Any program you build will be linked into a command line application. You should be able to build most applications "out of the box" without any modification. (The only requirement is that `simpletools.h` *must* be included by the file which includes the declaration of the `main` function.)

For example, consider the contents of `Client/tests/testDriveSpeed.c`:

```
#include <stdio.h>
#include <stdlib.h>
#include <time.h>

#include "abdrive.h"
#include "simpletext.h"
#include "simpletools.h"
#include "ping.h"

int main(int argc, const char* argv[])
{
  // Drive ahead nice and slow
  drive_speed(16, 16);

  struct timeval tv;

  gettimeofday(&tv, NULL);

  long int startSecs = tv.tv_sec;

  while(ping_cm(8) > 8)
    {
      pause(100);
```

```
      struct timeval now;
      gettimeofday(&now, NULL);
      if (now.tv_sec != tv.tv_sec)
        {
          int left, right;
          drive_getTicks(&left, &right);
          printf("%ld %d %d\n", now.tv_sec-startSecs, left, right);
          tv.tv_sec = now.tv_sec;
        }
    }
}
```

This program sets up the drive speed so that the robot slowly trundles forwards and, once per second, prints out the drive ticks (the encoder values in the wheels which say how far a wheel has turned).

The client library can issue messages. These are formatted as `[library] method(line): <<MESSAGE>>`.

If the client cannot connect to the server, you'll see a message like:

```
Hnatt:Client ucacsjj$ ./tests/testDriveSpeed
[PropGCC] start(28): start: Initialised with 8 available cogs
[libsimpletools] LibSimpleToolsStarter(19): Time ticks setup
[libsimpletools] LibSimpleToolsStarter(20): ms=80000
[libsimpletools] LibSimpleToolsStarter(21): us=80
[libsimpletools] LibSimpleToolsStarter(22): st_iodt=80
[libsimpletools] LibSimpleToolsStarter(23): st_pauseTicks=80000
[libsimpletools] LibSimpleToolsStarter(24): st_timeout=20000000
[libsimpletool] eepromStart(15): eepromStart: Setting up EEPROM with 65536 bytes
[libsimpletool] eepromStart(16): eepromStart: EEPROM is simulated using an in memory buffer
 and is not persistent
[simpletext] LibSimpleTextStarter(30): Started with stdio stubs for the simpleterm
[ServerConnection] open(57): Could not open connection with the simulator - is it running?
[PropGCC] stop(14): stop: Joining all cog threads; might hang
```

If the connection is successful, the output will be:

```
[PropGCC] start(28): start: Initialised with 8 available cogs
[libsimpletools] LibSimpleToolsStarter(19): Time ticks setup
[libsimpletools] LibSimpleToolsStarter(20): ms=80000
[libsimpletools] LibSimpleToolsStarter(21): us=80
[libsimpletools] LibSimpleToolsStarter(22): st_iodt=80
[libsimpletools] LibSimpleToolsStarter(23): st_pauseTicks=80000
[libsimpletools] LibSimpleToolsStarter(24): st_timeout=20000000
[libsimpletool] eepromStart(15): eepromStart: Setting up EEPROM with 65536 bytes
[libsimpletool] eepromStart(16): eepromStart: EEPROM is simulated using an in memory buffer
 and is not persistent
[simpletext] LibSimpleTextStarter(30): Started with stdio stubs for the simpleterm
[ServerConnection] getRobotHandle(92): The robot handle is 0
[simulator] simulator_showRobotConfiguration(110): simulator_showRobotConfiguration The returned rob
...
```

The robot configuration specifies details about how the robot is set up. If there are problems — for example with the IR sensors not working properly — you should make a note of this information when talking with the TAs.

Note that not all functions have been implemented. One example is the function `dac_ctr_stop()`, which does nothing in the simulator. If you call it, you will see a message of the form:

```
[abdrive] dac_ctr_stop(43): dac_ctr_stop stub implementation
```

5.3 Writing Your Own Applications

There are two issues to consider:

1. Creating a new directory for applications.
2. Creating a new application in an existing directory.

These are slightly different because when you create a new directory, `cmake` has to be made aware that the directory is there.

5.3.1 Creating a New Directory

Suppose you want to create a new directory `Task1` in the `applications` subdirectory. There are four steps:

1. Create the directory `Task1` in `applications`
2. Modify the CMakeLists.txt file in `applications` and add the line

   ```
   ADD_SUBDIRECTORY(Task1)
   ```

3. Create a CMakeLists.txt file in `Task1`. See the second below on how to declare a new application.
4. Run cmake *once* from the `applications` directory.

When this happens, cmake notices that `CMakeLists.txt` has changed, and loads the new version. It then sees that there is a new directory (`Task1`) and stores that this directory needs to be checked in the future. It also loads `Task1/CMakeLists.txt` and does whatever processing is required.

After this, it is sufficient to just cd into the `Task1` directory and run `make`. The dependency system will now pick up if, for example, you create a new application and will update everything automatically.

5.3.2 Creating a New Application in an Existing Directory

If the directory has been registered, you create a new application by adding a line of the form `DECLARE_APP(appName sourc`
For example, suppose you wanted to build an application called `testDrive` and it had one source file called `my_test_drive_code.c`. The syntax would be:

```
DECLARE_APP(testDrive my_test_drive_code.c)
```

If you have several files — for example a common library file. These are just added as well. For example, if in this example we also had the file `my_common_tools.c`, then the declaration would be changed to:

```
DECLARE_APP(testDrive my_test_drive_code.c my_common_tools.c)
```

5.3.3 Writing Code Which is Only Used in the Simulator

The simulator provides a few special "extended" commands such as drawing trails and rescaling the resolution of the encoders. These are *not* available in the ActivityBot API — if you use these directly your code will not compile. To prevent this from happening, the simulator defines the C macro `BUILDING_IN_SIMULATOR`. An example usage is as follows. This includes the file `simulator.h` and runs the start trail command on the simulator.

```
#include "abdrive.h"
#include "simpletext.h"
#include "simpletools.h"

#ifdef BUILDING_IN_SIMULATOR
```

```
#include "simulator.h"
#endif

int main(int argc, const char* argv[])
{
#ifdef BUILDING_IN_SIMULATOR
  simulator_startNewSmokeTrail();
#endif
 drive_goto(100, 100);
#ifdef BUILDING_IN_SIMULATOR
  simulator_stopSmokeTrail();
#endif
  return 0;
}
```

5.4 Interesting Facts and Limitations

1. **Simulation Time vs. Real Time:** The simulator attempts to accurately simulate the temporal sequence of activites. For example, the pause in the return of a measurement from a `ping` request depends on how far a target is from the robot. To model this timing accurately, the simulator has its own simulation time. This typically runs at half real-time but, in some operations can be slower. This will be obvious as the robot appearing to "speed up" and "slow down" in the GUI. However, all method associated with reporting system time will report the simulation time and so these effects should not be evident.

2. **EEPROM:** The Propeller Board has an EEPROM which can act as a persistent store. Data can be written to — and read from — this store. It is often used to store wheel calibration data. The simulator simulates the EEPROM but the storage is not persistent. If the program exits, the data stored in EEPROM is lost as well. If you wish the simulator to simulate persistency in the EEPROM, let us know and we will attempt to implement it.

3. **Cogs:** The Propeller Board has a set of eight "cores" or "cogs" which can run separately and in parallel. The simulator emulates these using threadings. However, there are two important limitations. First, in the simulator, only a single thread can query the simulation server at a time. Therefore, asynchronous operation cannot be supported. Second, cogs have termination semantics different from threads. The cog termination routines when translated to C++ thread termination semantics cause programs to abort. Therefore, use of cogs in the simulator is highly discouraged.