Introduction to Lab 2

Programming in RTOS on LEGO Mindstorms

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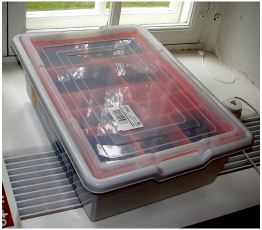
9 September 2015

Lab 2: Programming in RTOS using LEGO Mindstorms

- Lab goals:
  - Basic programming on an embedded device
  - Using the API of an RTOS for concurrent tasks
- Lab preparation:
  - Work in your groups
  - *Get LEGO box* (next slide), charge battery
  - Possibly refresh your C knowledge
  - Lab will be done on Wed, 16.9. and Mon, 21.9. (both in 1515)
  - Have a look at the lab homepage
    `http://www.it.uu.se/edu/course/homepage/realtid/ht15/lab2`
- Lab report:
  - OIL file and C code to all 3 parts, well commented
  - Descriptions of what you did and why
  - To submission page in studentportalen; *Deadline: Thu, 23.9. at 23:59*
- Further:
  - Demonstrate a working vehicle, participate in *car race on 24.9.*
  - Return all hardware you get to Karl (see next slide)

Lab 2: LEGO Mindstorms Boxes

- Each group gets one box



- All hardware issues are handled by *Karl Marklund*
- Office: 1440, mail: `karl.marklund@it.uu.se`
- Time schedule:

  Today at 12:00: Boxes handed out (after lecture)
  23.9. at 23:59: Report deadline (submit via studentportalen)
  24.9. at 10:15: Car presentation, *boxes handed back afterwords*

Lab 2: Working At Home

- You may work at home (using Windows/Linux/Mac?)
- Toolchain installation is non-trivial
  - *I can't give support for that*
  - Firmware upload, program compile, program upload
  - Windows: May need Cygwin
- Some hints at lab homepage
- *Default: Work in the Solaris lab (1515)*

LEGO Mindstorms

- Programmable LEGO brick with sensors and motors
- Comes in two generations:

RCX generation (1998)

NXT generation (2006)

- We will use the *NXT platform*

LEGO Mindstorms: Components

Package contents:

- NXT unit:
  - LCD matrix display
  - Sensor inputs 1 to 4
  - Motor outputs A, B, C
  - Speaker
  - USB, Bluetooth
- Three motors
- Sensors:
  - Light
  - Distance (Ultrasound)
  - Touch (2x)
  - Sound
  - (More from 3rd party vendors)

NXT Brick Internals:

- Atmel 32-bit ARM7 processor, 64k RAM, 256k Flash, 48MHz clock

RTOS: nxtOSEK

- We don't use the standard firmware
- Instead: *nxtOSEK*
  - Real-time operating system
  - Based on OSEK (industry standard for automotive embedded systems)
  - Implements highest OSEK conformance class ECC2
  - Provides C/C++ development environment
  - Support for (concurrent) tasks, priorities, semaphores, events
  - Comprehensive API for low-level I/O accesses
- Rest of this introduction: How to
  - Flash the custom firmware
  - Compile/upload programs
  - Write programs/use nxtOSEK API

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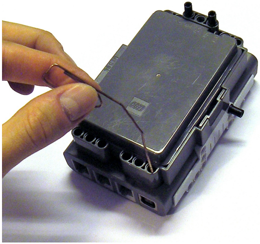
NXT Firmware Upload

1. Connect NXT unit to USB port (of SunRay)
2. Power up NXT unit
3. Put NXT into *reset mode*
4. Upload firmware:
    - Custom FW using `fwflash-jh`
    - Original FW using `fwflash-original`



Example Run: Firmware upload

```
$ /it/kurs/realtid/bin/fwflash-jh
...
Checking firmware... OK.
NXT device in reset mode located and opened.
Starting firmware flash procedure now...
Firmware flash complete.
New firmware started!
$
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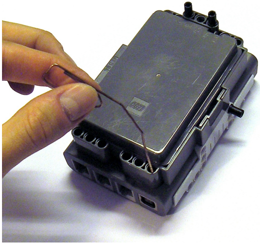

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nxtOSEK: Program Compile/Upload

1. Use and *adjust* provided `Makefile`
2. Compile program (OIL+C) using `make all`
3. Upload program using `nxjupload`
   - NXT needs to be running and idle
   - .. and connected via USB

Example Run: Program compile/upload

```
$ make all
Compiling /it/kurs/realtid/nxt/nxtosek/ecrobot/../...
...
Generating binary image file: helloworld.rxe
$ /it/kurs/realtid/bin/nxjupload helloworld.rxe
Found NXT: NXT 0016530915A7
leJOS NXJ> Connected to NXT
leJOS NXJ> Upload successful in 1750 milliseconds
$ make clean   # optional, but useful
...
$
```

nxtOSEK: Source Files

C Source File

```
#include <stdlib.h>
#include "kernel.h"
...

TASK(HelloWorld)
{
    display_string("Hello World!");
    ...
    TerminateTask();
}
```

OIL Source File

```
CPU ATMEL...
{
  ...
  TASK HelloWorld
  {
    ...
  };
};
```

Compilation, Linking, ...

```
NXTBINARY...
```

RXE Binary File

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nxtOSEK API

- You "program" two files:
  1. Systems description: *OIL Source File*
  2. Task implementations: *C Source File*
- OIL File:
  - Describe System: Scheduling and Task details
  - Counters, Alarms, Events, Resources, Task releases
- C File: Task implementations
  - Input/Output (orange Button/LCD)
  - Reading sensors (light/touch/distance/sound)
  - Controlling motors
  - Time functions (delay)
  - Generate/wait for events
  - Newlib (like libc, e.g., random numbers)
- Will do a short walk-through now
- *See "nxtOSEK C API Reference" and "Newlib Reference" manuals!*

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nxtOSEK API: I/O

- Input via orange button and sensors
  - Initialize sensors before use
- Output via LCD (strings, integers), sound and motors
- Sensor and motor access via ports: `NXT_PORT_S1`, ..., `NXT_PORT_A`, ..
- *See API reference!*

Example: I/O via button, LCD and motors

```
#define LIGHTSENSOR NXT_PORT_S3
#define MOTOR NXT_PORT_B
if (ecrobot_is_ENTER_button_pressed()) {  // Non-blocking
    display_clear(0);
    display_int(ecrobot_get_light_sensor(LIGHTSENSOR), 4);
    display_update();
    nxt_motor_set_speed(MOTOR, 100, 0); // full speed
}
```

nxtOSEK Tasks: Single Instance

OIL file

```
TASK RunOnce
{
  AUTOSTART = TRUE
  {
    APPMODE = appmode1;
  };
  PRIORITY = 1; /* Low */
  ACTIVATION = 1;
  SCHEDULE = FULL;
  STACKSIZE = 512;
};
```

C file

```
DeclareTask(RunOnce);
...
TASK(RunOnce)
{
    // This is executed
    // just *once*
    //
    // (Use a loop?)

    TerminateTask();
}
```

- Note the *declare* statement in the C source

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nxtOSEK Tasks: Periodic

- For periodic task releases every 100ms:
  1. Declare a *counter*
     - ⋆ Increased every ms
  2. Declare an *alarm*
     - ⋆ Activated when counter reaches specified value (100)
     - ⋆ Can release a task
  3. Declare and implement the *task*
     - ⋆ Execute some code
     - ⋆ Terminate cleanly with `TerminateTask()`
- Counter and Task declarations also in C file

nxtOSEK Tasks: Periodic (cont.)

OIL file: Counter declaration

```
COUNTER SysTimerCnt {
  MINCYCLE = 1;
  MAXALLOWEDVALUE = 10000;
  TICKSPERBASE = 1;
};
```

OIL file: Task declaration

```
TASK PeriodicTask {
  AUTOSTART = FALSE;
  PRIORITY = 1;
  ACTIVATION = 1;
  SCHEDULE = FULL;
  STACKSIZE = 512;
};
```

OIL file: Alarm declaration

```
ALARM cyclic_alarm {
  COUNTER = SysTimerCnt;
  ACTION = ACTIVATETASK
  {
      TASK = PeriodicTask;
  };
  AUTOSTART = TRUE
  {
      ALARMTIME = 1;
      CYCLETIME = 100;
      APPMODE = appmode1;
  };
};
```

nxtOSEK Tasks: Periodic (cont.)

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      CYCLETIME = 100;
      APPMODE = appmode1;
  };
};
```

nxtOSEK Tasks: Periodic (cont. 2)

C file: Periodic task

```c
...
DeclareCounter(SysTimerCnt);
DeclareTask(PeriodicTask);
...
void user_1ms_isr_type2(){ SignalCounter(SysTimerCnt); }
...
TASK(PeriodicTask) {

    // Executed just once
    //
    // DO NOT use an infinite loop!

    TerminateTask();
}
```

nxtOSEK: Synchronization Features

- Tasks can signal and wait for *events*
  - Declare in OIL file
  - .. and inside the Task in OIL file
  - .. and in the C file (using `DeclareEvent()`)
  - Implemented as a bitmask
  - More details in lab description
- Tasks can use semaphores, called *resources*
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  - .. and inside the Task in OIL file
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Lab Assignment

- Part 1: *Warm-Up*
  - Attach only light sensor
  - Write light values
  - Nothing fancy, just to get a soft start
- Part 2: *Event-driven Scheduling*
  - Use OSEK's event mechanism
  - Application: Four events with car on table
    1. Touch sensor is pressed/released
    2. Table edge is sensed (light sensor)
- Part 3: *Periodic Scheduling*
  - Define different periodic tasks
  - Application: Distance and touch sensor sensing
    1. Drive (back off) while sensor pressed
    2. Otherwise, keep distance constant
- Extra part: *LEGO Car Race*
  - Apply all you have learned
  - (See next slide)

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LEGO Car Race

- *Car demonstration* takes place on Thu, 24.9.
- Track looks roughly like this:

- Procedure for each team:

  1st phase: Follow another car in constant distance (20cm) for 1 lap

  2nd phase: Be fastest on the next lap

- Fastest team wins! (*Prize award included*)
- 3 tries per team (otherwise: assignment failed, fix car)
- Keep in mind: Demo conditions might differ (different light etc.)

Some Additional Pointers

- More information about NXT motors:
  http://www.philohome.com/nxtmotor/nxtmotor.htm
- Useful tutorials about line follower Lego Robot:
  http://www.nxtprograms.com/line_follower/steps.html
  http://www.inpharmix.com/jps/PID_Controller_For_Lego_Mindstorms_Robots.html

The End

Questions?