Hi.
UPBOT: A Testbed for Cyber-Physical Systems

Tanya Crenshaw, assistant professor
Steven Beyer, senior EE undergraduate
University of Portland
CSET 2010
October 2006

http://varma.ece.cmu.edu/cps/
cyber physical systems are:
cyber physical systems are:

massively distributed
cyber physical systems are:

massively distributed  safety-critical
cyber physical systems are:

massively distributed safety-critical (sensor) networks
cyber physical systems are:

massively distributed safety-critical (sensor) networks and control systems
cyber physical systems are:

massively distributed safety-critical (sensor) networks and control systems and also embedded systems
cyber physical systems are:

massively distributed safety-critical (sensor) networks and control systems and also embedded systems built from off-the-shelf components
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massively distributed safety-critical (sensor) networks
and control systems and also embedded systems
built from off-the-shelf components
executing in open contexts
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massively distributed safety-critical (sensor) networks
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built from off-the-shelf components
executing in open contexts in real time
cyber physical systems are:

- massively distributed
- safety-critical
- (sensor) networks
- and control systems
- and also embedded systems
- built from off-the-shelf components
- executing in open contexts
- in real time
- monitoring or regulating the physical world
cyber physical systems are:

massively distributed safety-critical (sensor) networks and control systems and also embedded systems

built from off-the-shelf components executing in open contexts in real time

monitoring or regulating the physical world in unpredictable environments
cyber physical systems are: massively distributed (sensor) networks built from off-the-shelf components and embedded systems executing in open contexts monitoring or regulating the physical world
cyber physical systems are:

networked, component-based, real-time systems that control and monitor the physical world.
October 2006
doing cyber-physical systems research means you are at the mercy of really busy people working at Rockwell-Collins.
August 2008
is it possible to reproduce a cyber-physical system in a meaningful way?
2. what features would be necessary for testing security threats and defenses?
how can it be accessible to undergraduates and useful to researchers?
August 2010

the upbot testbed
let's begin with the first question.
is it possible to reproduce a cyber-physical system in a meaningful way?
key characteristics

1. networked control.

cyber-physical systems control the physical world, executing across multiple nodes.
2. enforceable physical properties.

cyber-physical systems interact with unpredictable environments, yet certain physical properties must remain invariant.
key characteristics

3. off-the-shelf-components.

cyber-physical systems are composed of heterogenous commodity parts with varying levels of criticality.
the upbot testbed
the upbot testbed

Desktop Machine

supervisor
issue commands; model the perceived world.

client
convey commands; obtain sensor data.

Software World

iRobot + gumstix platform

nervous system
creates two processes which i) communicate with the client and ii) communicate with the body.

brain
poll for external commands and convey to nerves; convey sensor data to supervisor.

nerves
translate high-level commands to iRobot commands; poll, format and convey sensor data.

<wireless socket communication>

<shared memory locations>

<serial communication>

Physical World

body
drive and sense.

<iRobot commands

<sensor data

<iRobot commands

client
convey commands; obtain sensor data.

Software World
1. networked control.

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issue commands; model the perceived world.

Client
convey commands; obtain sensor data.
2. enforceable physical properties.
3. off-the-shelf components.

The nervous system creates two processes which i) communicate with the client and ii) communicate with the body.

- **Brain**: Poll for external commands and convey to nerves; convey sensor data to supervisor.
- **Nerves**: Translate high-level commands to iRobot commands; poll, format and convey sensor data.

The software world involves:
- **Client**: Convey commands; obtain sensor data.
- **Supervisor**: Issue commands; model the perceived world.

The physical world involves:
- **Body**: Drive and sense.

Communication channels include:
- **Serial communication**
- **Wireless socket communication**
- **Shared memory locations**
2. what features would be necessary for testing security threats and defenses?
security characteristics

1. networked control.

→ provides multiple points of attack by which one may test against security threats.
security characteristics

2. enforceable physical properties.

⇒ simulations make assumptions that can hide physical issues. A testbed eliminates some of these.
security characteristics

3. off-the-shelf-components.

⇒ defensive and fault-tolerant measures must be built into software solutions.
3. how can it be accessible to undergraduates and useful to researchers?
undergraduate opportunities
course modules
senior design project
5 undergraduate research projects
research opportunities
iRobot + gumstix platform

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Desktop Machine

Software World

Physical World

iRobot commands

format and convey sensor data

<serial communication>

<wireless socket communication>

<shared memory locations>

body
drive and sense.

high-level commands

formatted sensor data

nerves

brain

client

supervisor

iRobot + gumstix platform

Software World

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iRobot + gumstix platform

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Client
convey commands; obtain sensor data.

Desktop Machine

Physical World

body
drive and sense.

Physical World

Software World

client
convey commands; obtain sensor data.

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**Communication Channels**:
- High-level commands
- Formatted sensor data
- Shared memory locations
- Wireless socket communication
- Serial communication

**Software World**
- **Supervisor**: issue commands; model the perceived world.
- **Client**: convey commands; obtain sensor data.

**Physical World**
- **Body**: drive and sense.

**iRobot + Gumstix Platform**
- Sensory data
- iRobot commands

**Andrew Nuxoll**
Research Question 1 (ongoing):
How successful is the episodic memory-based supervisor at learning how to navigate the robot through a simple maze?
1. Drive forward 630 mm.
2. Turn right 90 degrees.
3. Turn left 90 degrees.
4. Turn right 10 degrees.
5. Turn left 10 degrees.
Research Question 2 (future work):
Given that the supervisor has already learned a maze, how successful is the supervisor at navigating the same maze in a threatening environment?
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Physical World

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Desktop Machine

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malicious commands

fake sensor data

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Tanya L. Crenshaw  Assistant Professor at the University of Portland

RoboDocs
Welcome to RoboDocs, documentation for developing and interfacing gumstix motherboards to the iRobot Create platforms. Major topics for these RoboDocs include:

**Getting Started.** The list of materials necessary to build the iRobot Create + gumstix platform, ten steps to building an iRobot + gumstix mobile robot, upbot testbed datasheet.

**Gumstix Hardware.** Powering the devices, gumstix connex processor, gumstix verdex processor, how to re-flash the gumstix with the factory image.

**Interfacing.** Pinout for the mini DIN-7 serial port on the iRobot Create, setting up a terminal emulator to communicate with a gumstix, setting up the wifistix to communicate wirelessly with the gumstix, configuring the gumstix UART to communicate with the iRobot Create.

**Development.** A sample program that blinks the LEDs on the iRobot Create, the public code repository for the upbot testbed.

Contributors. Steven Beyer, Tanya L. Crenshaw.

http://kaju.dreamhosters.com
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RoRoDocs
Welcome to RoRoDocs, documentation for developing and interfacing gumstix motherboards to the iRobot Create platforms. Major topics for these RoRoDocs include:

Getting Started. The list of materials necessary to build the iRobot Create + gumstix platform, ten steps to building an iRobot + gumstix mobile robot, upbot testbed datasheet.

Gumstix Hardware. Powering the devices, gumstix connex processor, gumstix verdex processor, how to re-flash the gumstix with the factory image.

Interfacing. Pinout for the mini DIN-7 serial port on the iRobot Create, setting up a terminal emulator to communicate with a gumstix, setting up the wifistix to communicate wirelessly with the gumstix, configuring the gumstix UART to communicate with the iRobot Create.

Development. A sample program that blinks the LEDs on the iRobot Create, the public code repository for the upbot testbed.

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From its DB-25 serial port, the iRobot Create has multiple pins which supply +15V @ 1.5A when the iRobot is powered on. These are pins 10, 11, and 12. Powering the gumstix motherboards from the iRobot battery requires stepping down this +15V supply to +5V. To do so, build a simple step-down circuit using an L7805, a +5 Positive Voltage Regulator.

I have not been successful at powering the gumstix from a single iRobot Create DB-25 pin. Instead, I power the gumstix motherboard and the gumstix wifistix separately from pin 10 and pin 11 using two L7805’s, as shown in the circuit diagram below:
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questions and collaborators welcome!
I do not think a bunch of dorky robots compare to an F-22.
I do think the upbot testbed offers a low barrier to entry for undergraduates and researchers in cyber-physical system security.
thank you
university of portland: http://up.edu

robodocs: http://kaju.dreamhosters.com

public code repository: http://code.google.com/p/upbot/