Robo-Kit: A Low Cost Kit for Robotics Research

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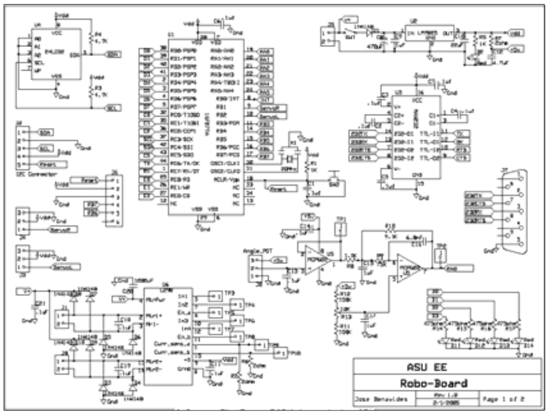
Research Question How can we develop a robotics kit "Robo-Kit" that provides a suitable trade of between performance, cost, and ease-of-use so that participation in advanced robotics research is significantly enhanced?

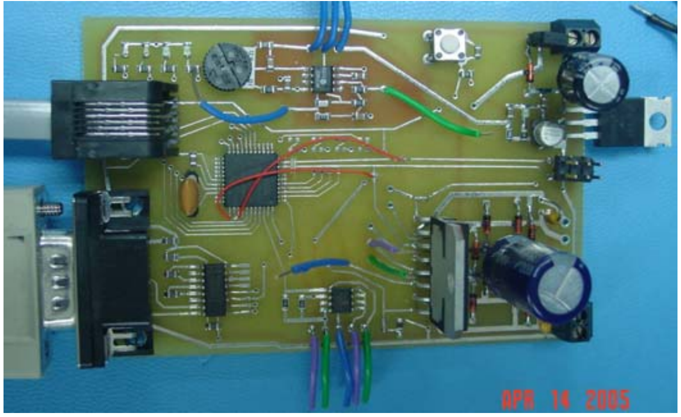
Background and Objectives

- Undergraduate level kits:
  - -inflexible, low-performance, low-cost, difficult-to-use
- Graduate level kits:
  - -flexible, high-performance, high-cost, easy-to-use
- Objective:
  - -find best tradeoff between flexibility/performance, cost, and ease-of-use in comparison to existing kits

Board Schematic



Robo-Kit (prototype)



Robo-Kit Features:

Flexible & High Performing

- Expandable (33 accessible i/o pins)
- Fast (5 MIPS)
- On board DC motor control
- Analog sensor interface (LPF & A/D)

Low-Cost

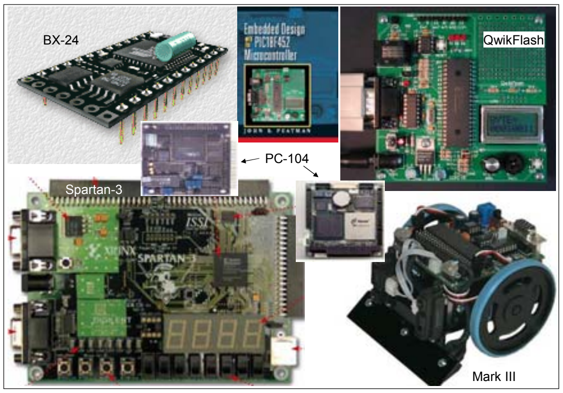
- Affordable (target price $50)
- 1/2 cost of typical undergraduate robotics kit

Easy-to-Use

- Quick and easy programming interface
- Finger operated wiring terminals
- Detailed documentation describing possible design projects

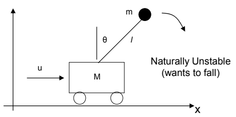
Analysis: A Comparative Study

Comparison to other "Kit Technologies"	Current ECE100 kit	Robo-Kit	Mark III	Xilinx Spartin-3 starter board	PC104	QwikFlash
Controller	BX24	16F877	16F877	Spartin III	AMD GX1	18F452
i/o pins	21	33	33	173	32	40
EEPROM	32 KBytes	16 KBytes	16 KBytes	1Mbit PROM	N/A	256 Bytes
RAM	400 Bytes	368 Bytes	368 Bytes	1Mbytes SRAM	128 MB	1.5 Kbytes
Program Flash	8K instructions	8K instructions	8K instructions	200 K gates	128 MB CF	16K instructions
ADC	8ch 10bit 6ksps	8ch 10bit 30 ksps	8ch 10bit 30 ksps	N/A	16ch 12bit 100 ksps	8ch 10bit 30 ksps
serial	RS232, SPI	RS232, SPI, I2C	RS232, SPI, I2C, PSP	Configurable	2 RS232, IrDA, USB	RS232, SPI, I2C, PSP
serially programmable	Yes	Yes	Yes	Yes	Yes	Yes
PWM	No	Yes (2)	Yes (2)	Yes	No	Yes (2)
Speed	0.065 MIPS	5 MIPS	5 MIPS	50 MHz	300 MHz	10 MIPS
Programming Language	BasicX	Assembler, Jal, C	Assembler, Jal, C	HDL	C, C++	Assembler
Board	Breadboard	Custom PCB	Custom PCB	Custom PCB	Custom PCB	Custom PCB
Support circuitry	Bag of passive components (Capacitors, Resisters, wires)	Reset button	Reset button	Reset button	Reset button	Reset button
		DB9 RS232 port	DB9 RS232	DB9 RS232	DB9 RS232	DB9 RS232
		4 LED's, 1 Pwr LED	2 Pwr LED	8 LED's, 1 Pwr LED		3 LED's, 2 Pwr LED
		5 volt regulator	5v reg. w/ LV detection	3.3v,2.4v,1.2v reg.		5 volt regulator
		(2) servo connectors	(2) servo connectors	VGA, PS2 connectors	VGA, PS2, Ethernet	16 char LCD
		3 POT's		(4) 8-seg LED's		2 POT's
		H-bridge motor driver		8 Switches		Dual 8-bit DAC
		Adjustable LP Filter		4 buttons		1 button
Power	9 V Battery	AC adapter, 9 V Bat	9 V & 4AA batteries	AC adapter	AC adapter	AC adapter
Sensors	2 bump sensors	2 bump sensors	2 IR, 3 line sensors	N/A	N/A	temperature sensor
Actuators	2 servos motors	2 DC motors	2 servos motors	N/A	N/A	N/A
Cost	$100	$50	$92	$99	$915	$119



Representative Application of Robo-Kit to Classical Cart Inverted Pendulum Balancing Problem

Schematic



Dynamical Model

Nonlinear

$$(M+m)\ddot{x} = u + ml\left[\sin\theta\,\dot{\theta}^2 - \cos\theta\,\ddot{\theta}\right]$$
$$\ddot{x}\cos\theta + l\ddot{\theta} = g\sin\theta$$

Linear

$$Ml\ddot{\theta} = (M+m)g\theta - u$$
$$M\ddot{x} = u - mg\theta$$

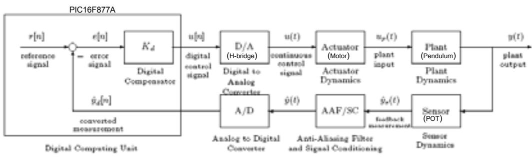
$$P = \frac{x}{u} = \frac{\frac{1}{M}}{s^2}\left[\frac{s^2 - \frac{g}{l}}{s^2 - (1+\frac{m}{M})\frac{g}{l}}\right]$$

Nominal Parameter Values

M = 0.455 kg
m = 0.21 kg
l = 0.609 meters

Motor model not given above

Fixed-Rate Sampled Data Negative Feedback System



Control Law: $U = g_1(r - x) + g_2\dot{x} + g_3\theta + g_4\dot{\theta}$

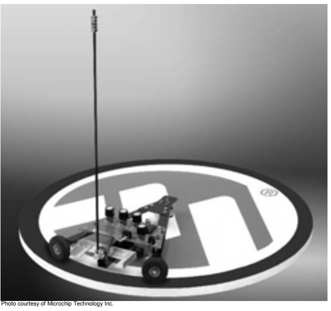
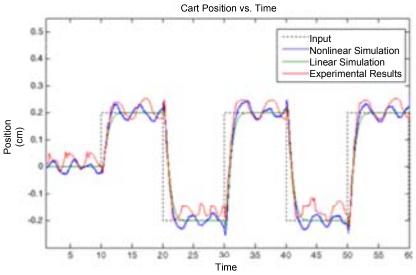
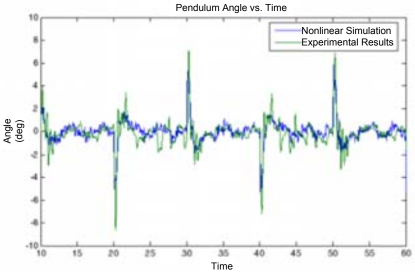


Photo courtesy of Microchip Technology Inc.





Summary

- Robo-Kit - flexible, high performance, low-cost, easy-to-use

Directions for Further Research

- Continued improvement of development interface
- Develop detailed documentation including project descriptions

Other Possible Applications: General vehicle and robotic system position/speed control

FURI: Undergraduate Student Research Program

ASU Ira A. Fulton school of engineering