Robotics Initiative at IIT

IPRO 316

Fall 2003

Faculty and Team Members

- Faculty Lead
  - Prof. Peter Lykos
- Student Members
  - Scorpion Group
    - ***Jacqueline Wegscheid (Scorpion Team Leader)***
    - ***Yuan Chen***
    - ***Ankur Sharma (IPRO Team Leader)***
  - Arm Group
    - ***Teng Chen (Arm Team Leader)***
    - ***Ju-Il Yum***
    - ***Keon Woo***
    - ***Deepti Yadlapalli***
    - ***Kitae Kim***
    - ***Dong Wook***
  - Robotics Initiative
    - ***Yuan Chen***

Objective of the IPRO

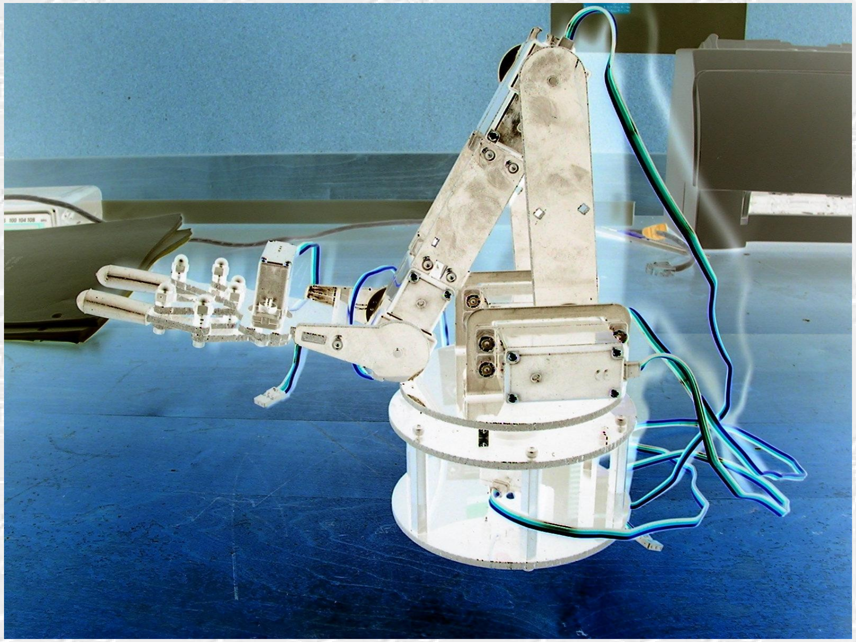
- Robotics initiative
  - Research into robotics program at other universities
  - introduce robotics as a major part of the academic curriculum
  - acquire knowledge and hands-on experience in constructing and understanding of robotic units via 4 main projects
    - Scorpion
    - Arm
    - Line Tracer
    - Hand Chaser / Repeller

Robotics Research

- Explore robotics programs at selective universities at undergraduate level
- Pioneers of Robotics
  - Stanford, MIT, Carnegie Mellon, Princeton
- Compare present courses in IIT and other universities
- Main idea - Introduce a minor/area of specialization in robotics at IIT

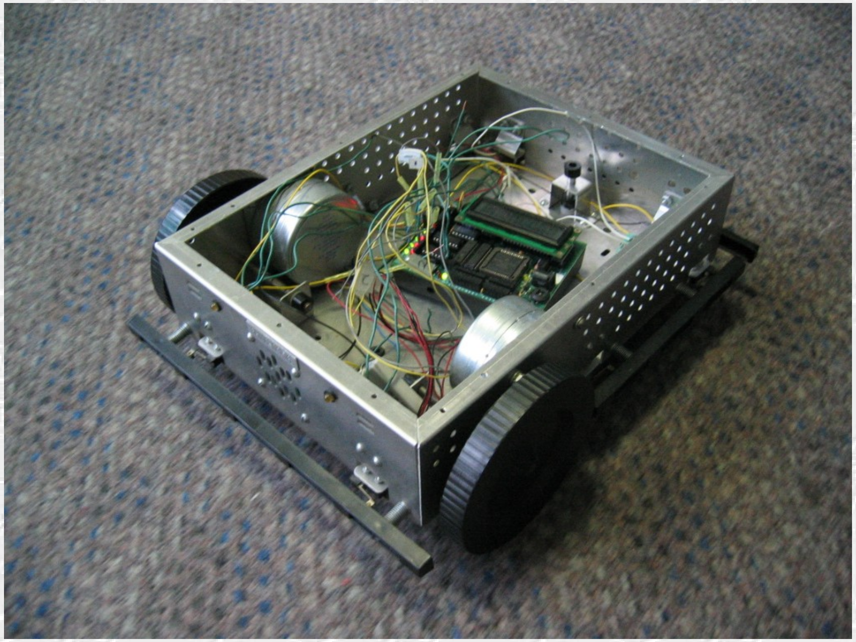
Arm Unit

- Assembled from kit
- Designed to pick up and move objects
- Controller circuits made by the students
- MATLAB – simulation
- Hanoi Tower



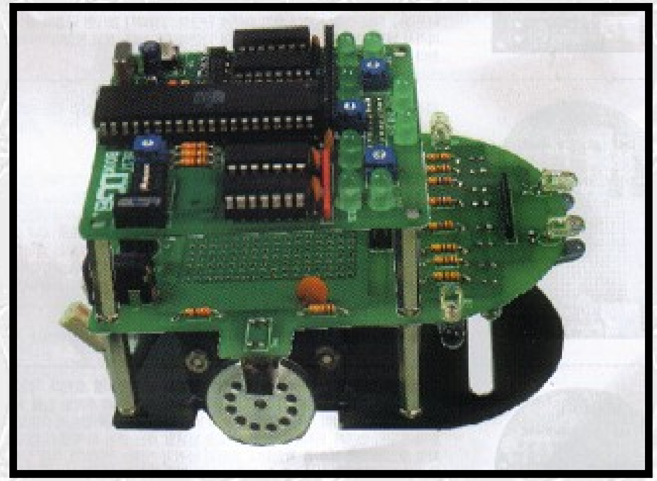
Scorpion Unit

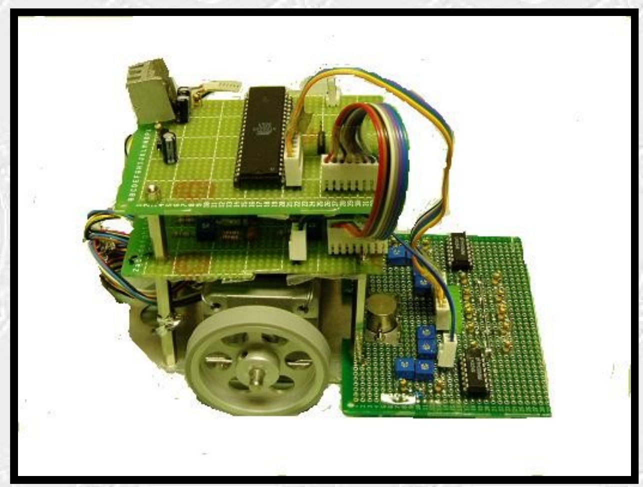
- Restore an obsolete scorpion unit
- Controller Board
- Use Interactive C for programming



Hand Chaser & Line Tracer

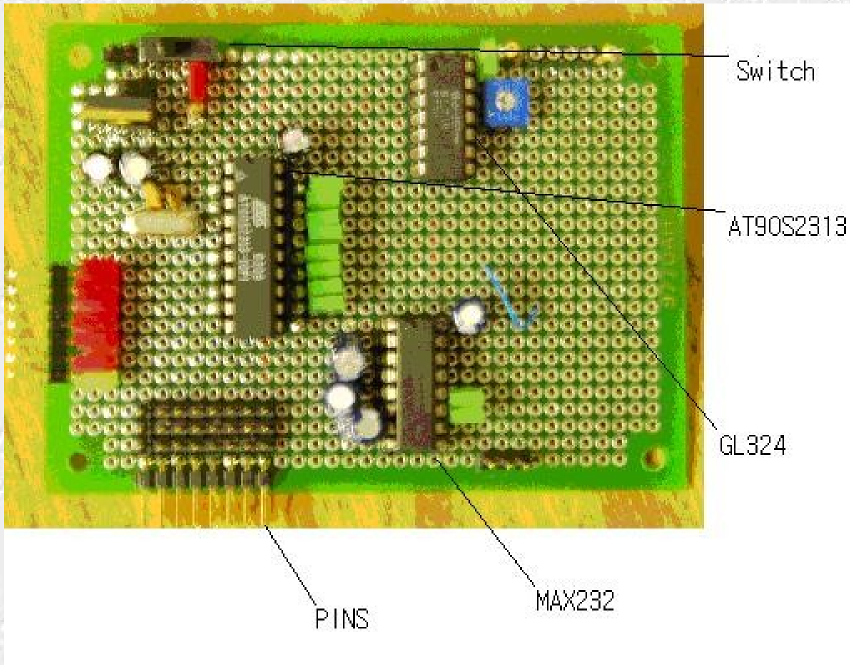
- **Hand Chaser**
  - Following, Escaping, Line tracer, Micro mouse
- **Line Tracer**
  - Follows white line



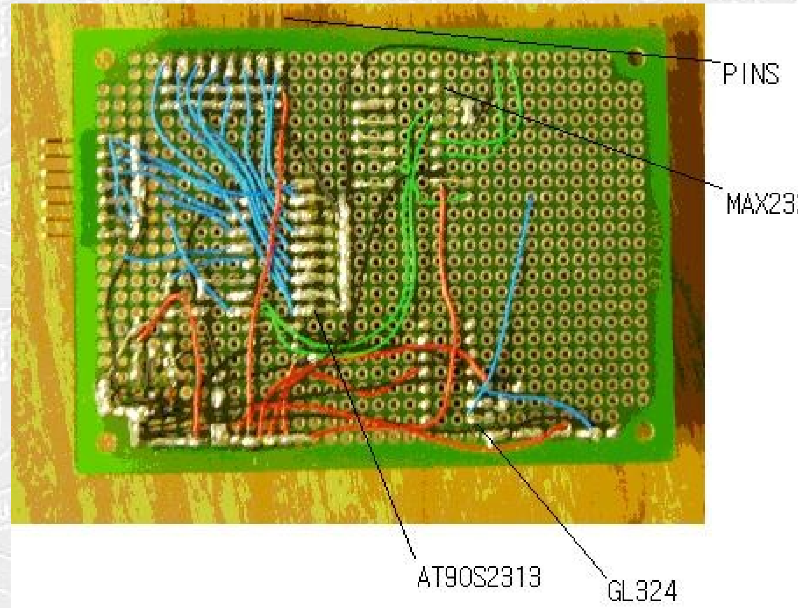


About the ARM: Hardware and Software

ARM Hardware

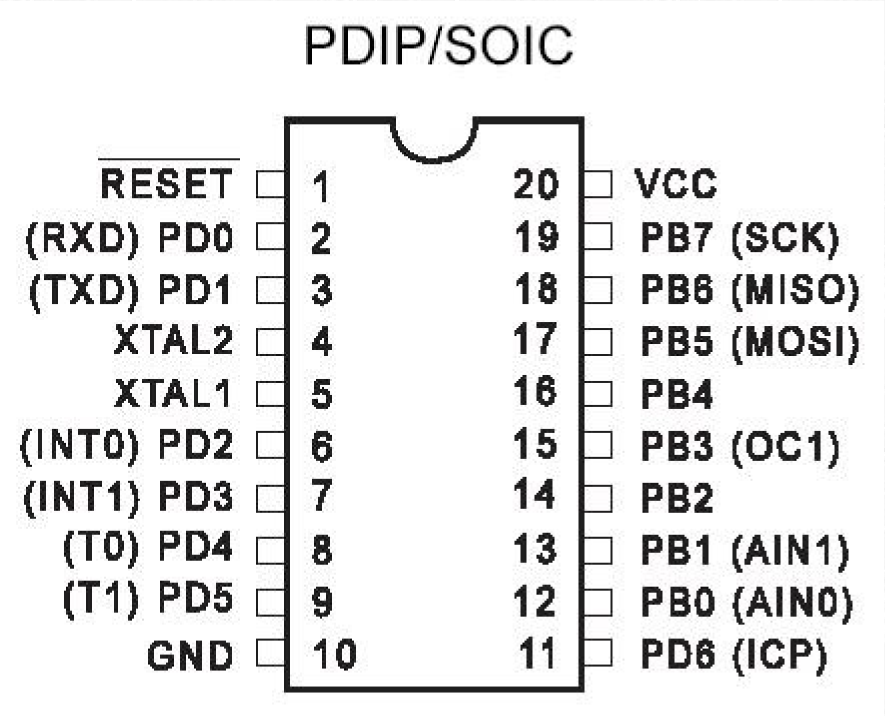


The Front



The Back

AT90S2313

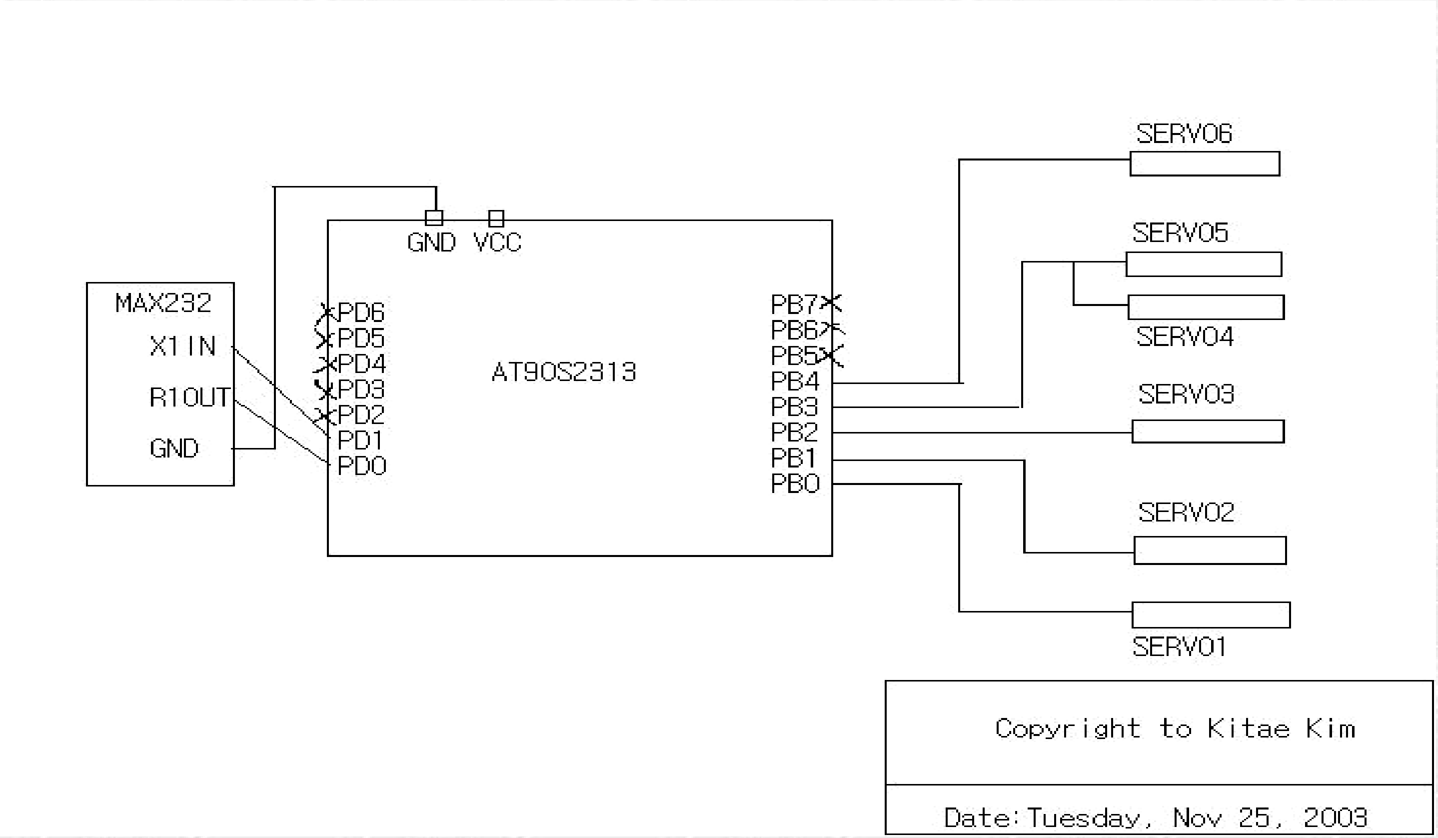


1. *This chip has 2Kbyte memory to program.*
2. *It is possible to program up to 1000 times.*
3. *15 I/O ports controlled by programming.*

Reference:

YongSu Song, Sungjun Bae. AVR BIBLE (2002), bogdoo publishing company.

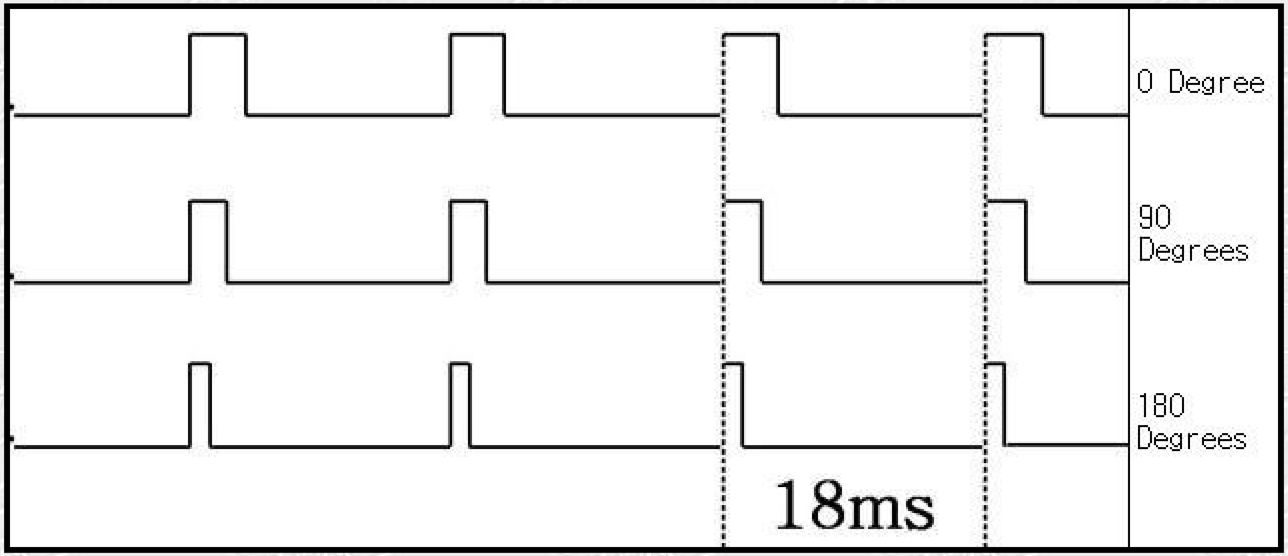
A Circuit Diagram for ARM



ARM Software

Servo Motor

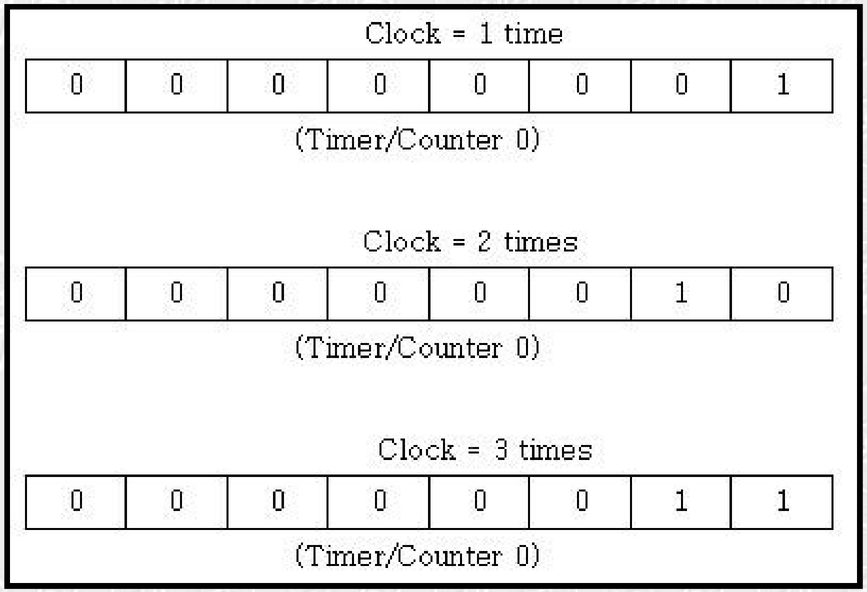
1. The period of our servo motor is 18 ms (0.018 s)
2. The turning angle depends on the length of a pulse



Reference:

YongSu Song, Sungjun Bae. AVR BIBLE (2002), bogdoo publishing company.

Signal Generation



< Figure 1 >

1. The internal clock
2. Overflow
3. Timer/Counter 0

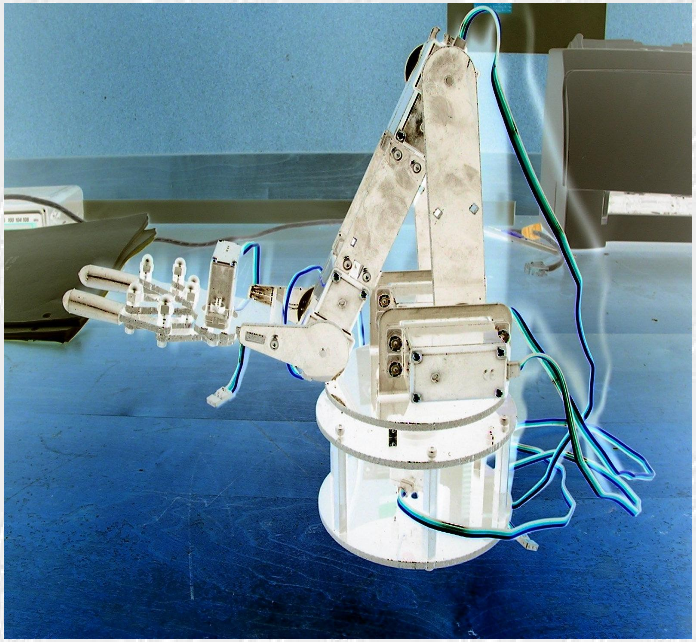
1.Program 1

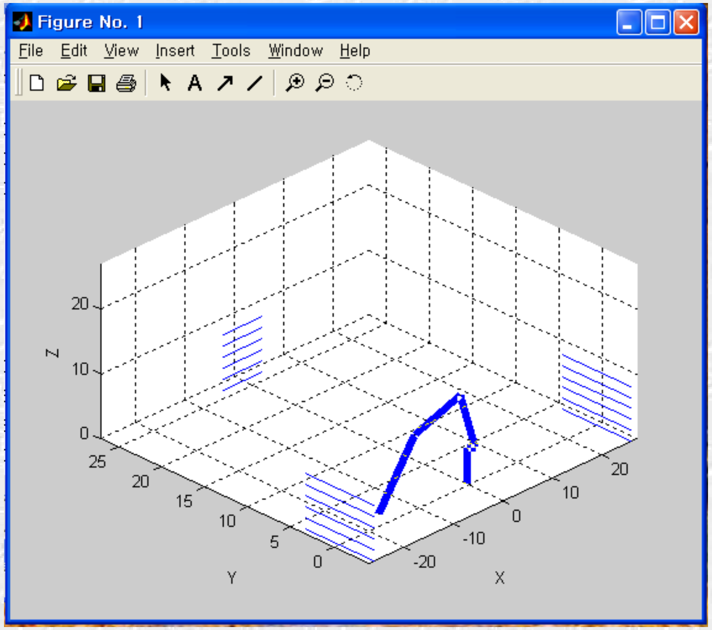
- Robot Arm move Hanoi towers by itself.

2.Program 2

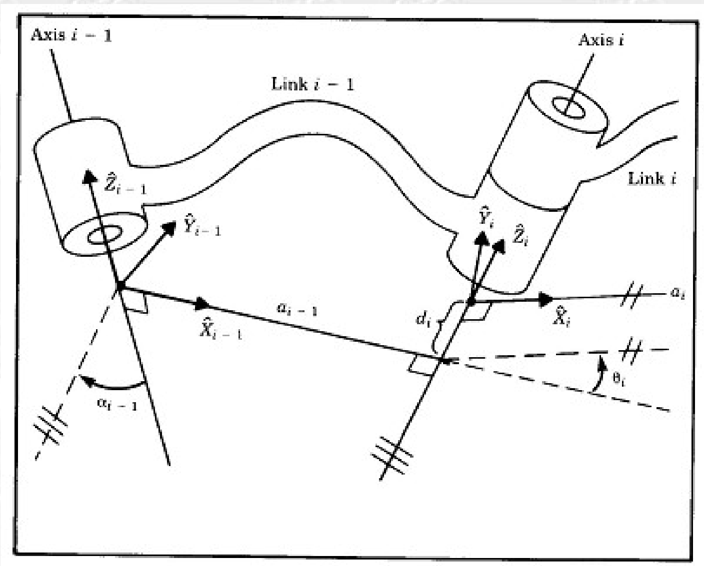
- User controlled Robot Arm
  - Move Hanoi tower.
  - Using a terminal

Simulation of Arm





Derivation of Link Transformation



The transformation of frame {i} relative to the frame {i-1}

- A function of four parameters
- Only one variable, the other three fixed

a_i = the distance from $\hat{Z}_i$ to $\hat{Z}_{i+1}$ measured along $\hat{X}_i$;
α_i = the angle between $\hat{Z}_i$ and $\hat{Z}_{i+1}$ measured about $\hat{X}_i$;
d_i = the distance from $\hat{X}_{i-1}$ to $\hat{X}_i$ measured along $\hat{Z}_i$; and
θ_i = the angle between $\hat{X}_{i-1}$ and $\hat{X}_i$ measured about $\hat{Z}_i$.

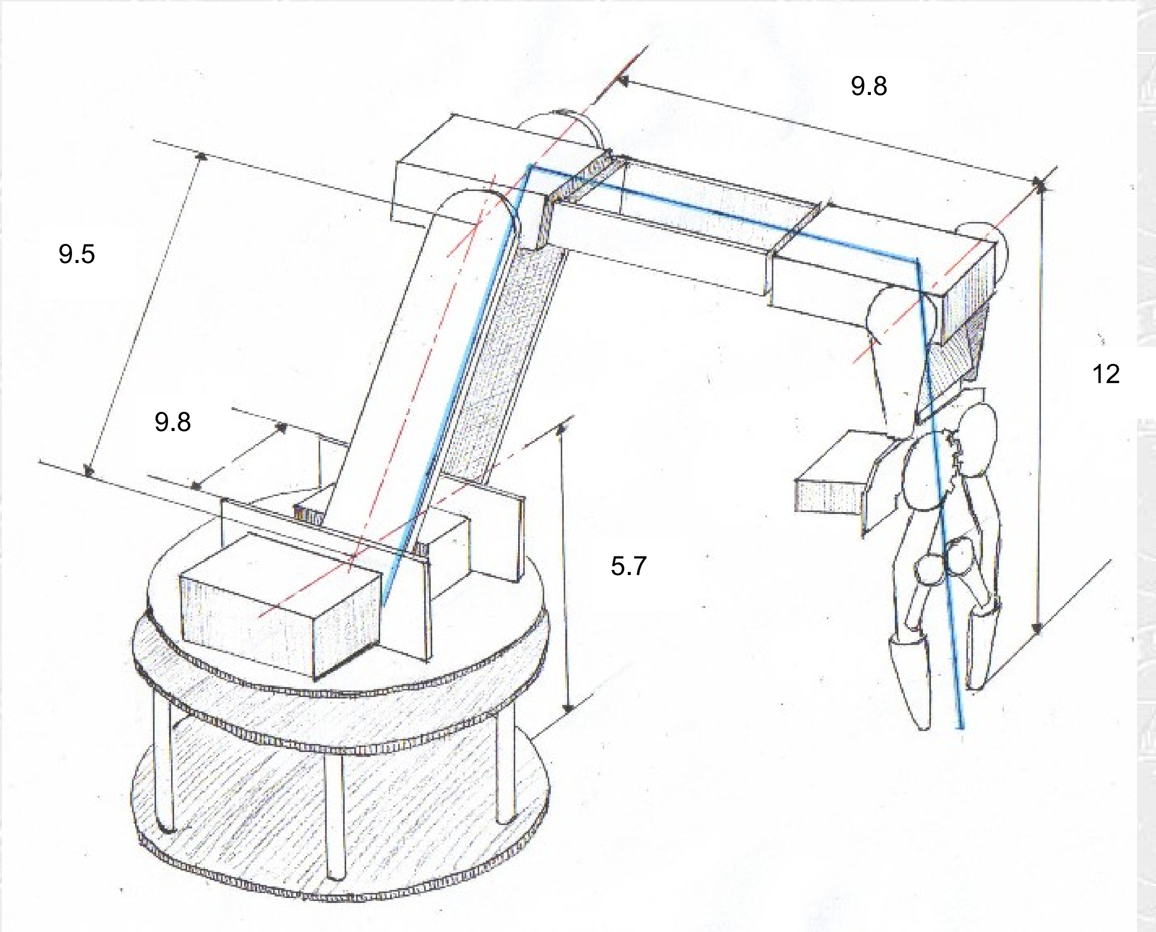
$$ {}^{i-1}_{\ \ i}T = \mathrm{Screw}_X(a_{i-1}, \alpha_{i-1})\ \mathrm{Screw}_Z(d_i, \theta_i), $$

$$ {}^{i-1}_{\ \ i}T = \begin{bmatrix} c\theta_i & -s\theta_i & 0 & a_{i-1} \\ s\theta_i c\alpha_{i-1} & c\theta_i c\alpha_{i-1} & -s\alpha_{i-1} & -s\alpha_{i-1} d_i \\ s\theta_i s\alpha_{i-1} & c\theta_i s\alpha_{i-1} & c\alpha_{i-1} & c\alpha_{i-1} d_i \\ 0 & 0 & 0 & 1 \end{bmatrix}. $$

Reference:

John J. Craig. *Introduction to Robotics Second Edition* **(1989), Addison-Wesley Publishing company.**

Kinematics in our Arm

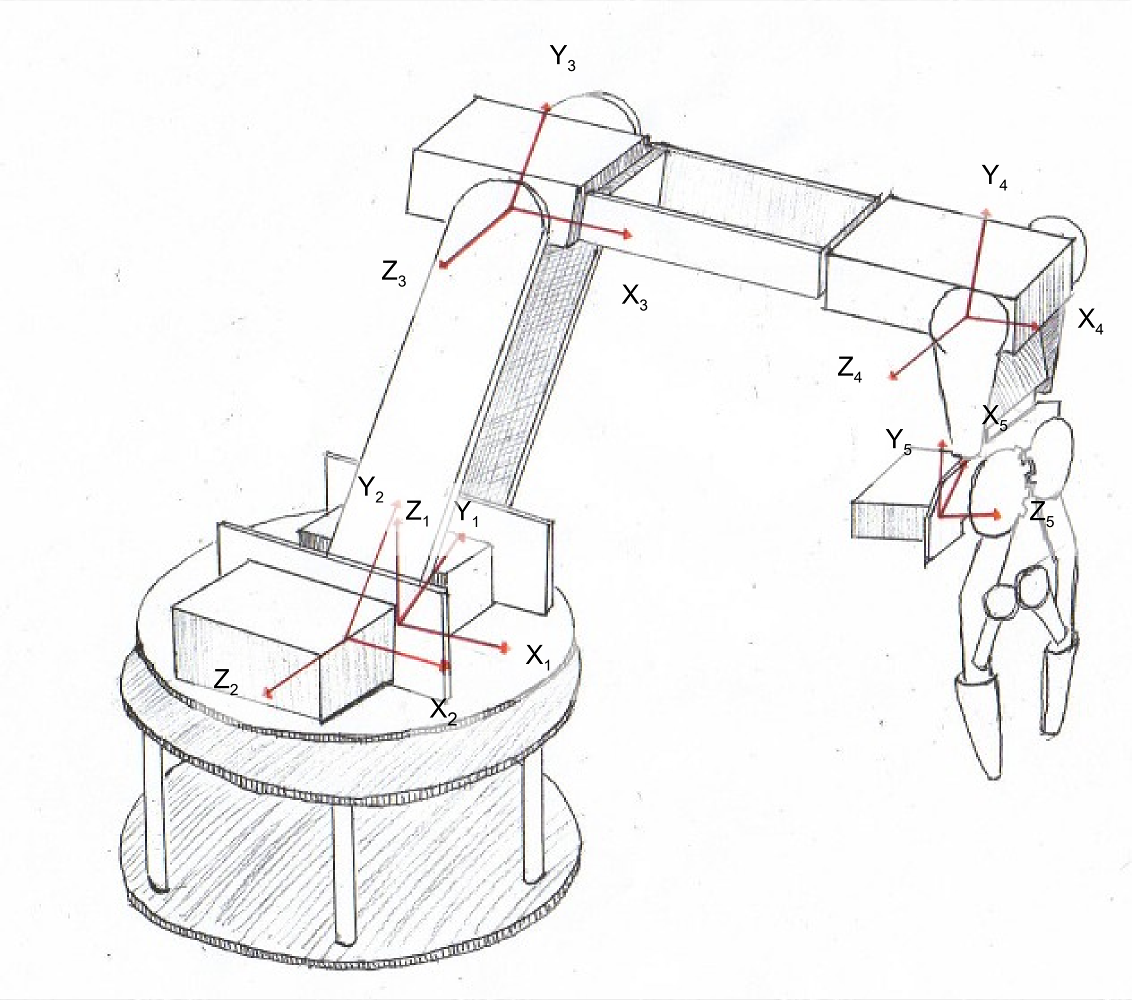


Link parameter

- length unit, cm

Six motors

Kinematics in our arm



Axes attached to the each link in arm

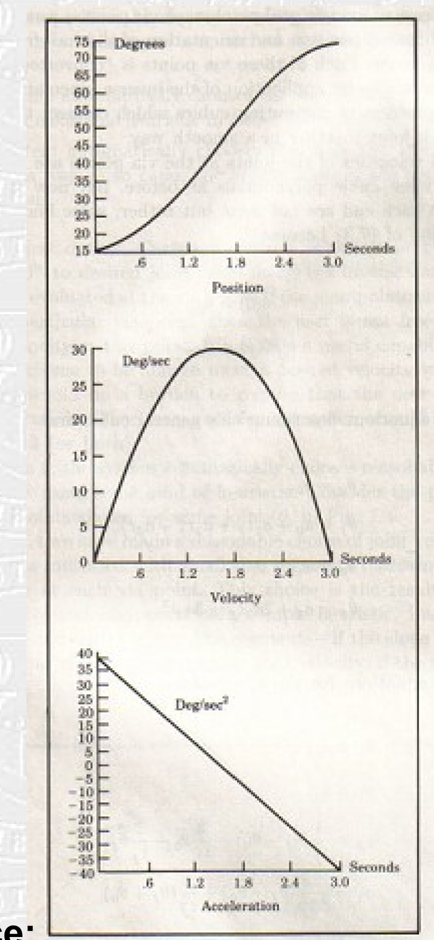
Kinematics in our Arm

	α_{i-1}	a_{i-1}	d_i	θ_i
1	0	0	5.7	θ_1
2	90	2	-2	θ_2
3	0	9.5	0	θ_3
4	0	9.8	0	θ_4
5	0	12	0	0

Table for the parameter for our arm kit

```
T1 =

[  cos(1/180*theta1*pi), -sin(1/180*theta1*pi),        0,       0]
[  sin(1/180*theta1*pi),  cos(1/180*theta1*pi),        0,       0]
[                     0,                     0,        1,     5.7]
[                     0,                     0,        0,       1]

T2 =

[  cos(1/180*theta2*pi), -sin(1/180*theta2*pi),        0,       2]
[                     0,                     0,       -1,       2]
[  sin(1/180*theta2*pi),  cos(1/180*theta2*pi),        0,       0]
[                     0,                     0,        0,       1]

T3 =

[  cos(1/180*theta3*pi), -sin(1/180*theta3*pi),        0,     9.5]
[  sin(1/180*theta3*pi),  cos(1/180*theta3*pi),        0,       0]
[                     0,                     0,        1,       0]
[                     0,                     0,        0,       1]

T4 =

[  cos(1/180*theta4*pi), -sin(1/180*theta4*pi),        0,     9.8]
[  sin(1/180*theta4*pi),  cos(1/180*theta4*pi),        0,       0]
[                     0,                     0,        1,       0]
[                     0,                     0,        0,       1]

T5 =

[                     1,                     0,        0,      12]
[                     0,                     1,        0,       0]
[                     0,                     0,        1,       0]
[                     0,                     0,        0,       1]
```

Kinematics in our Arm

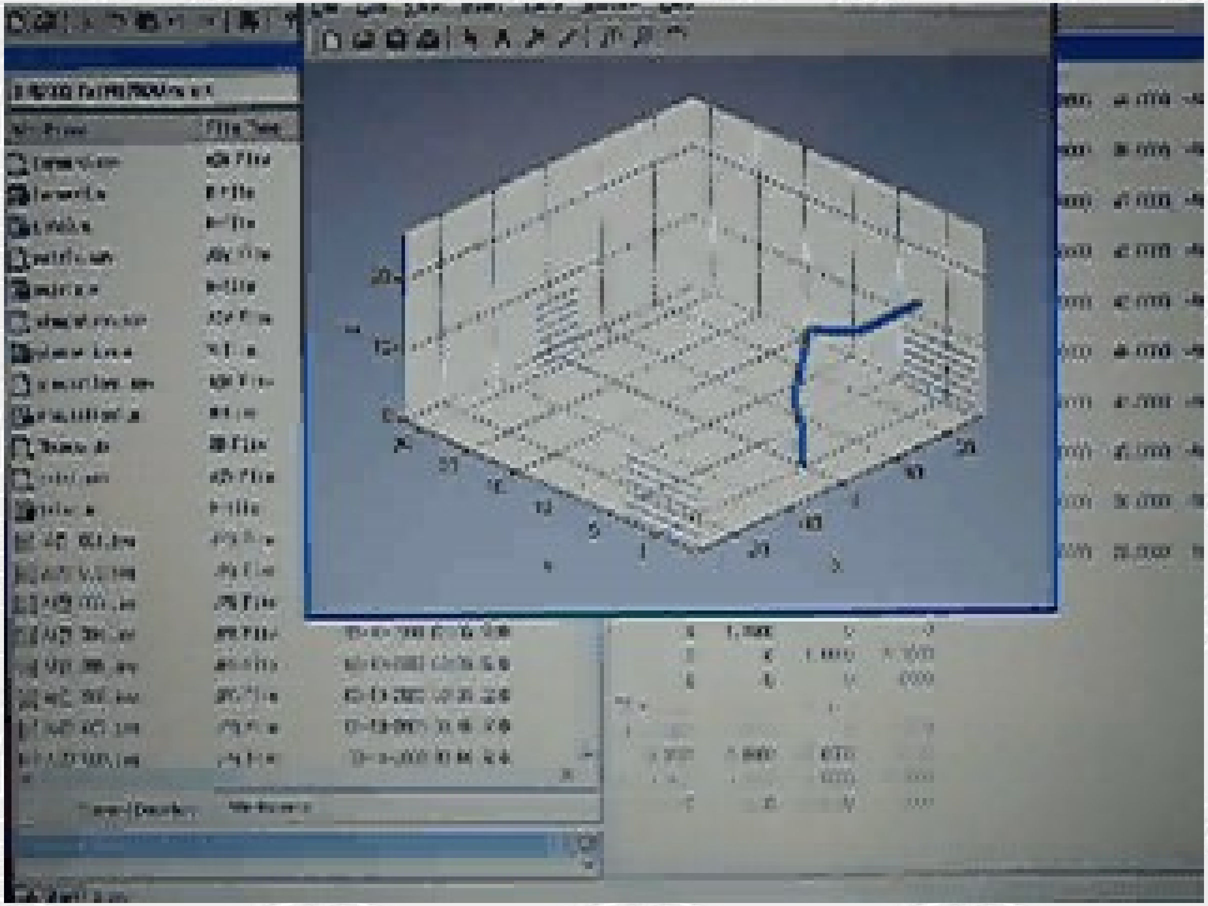


- Issues Considered
  - Minimize the inertia,
    - the acceleration, velocity should be controlled.
- Demonstration of simulation program

Reference:

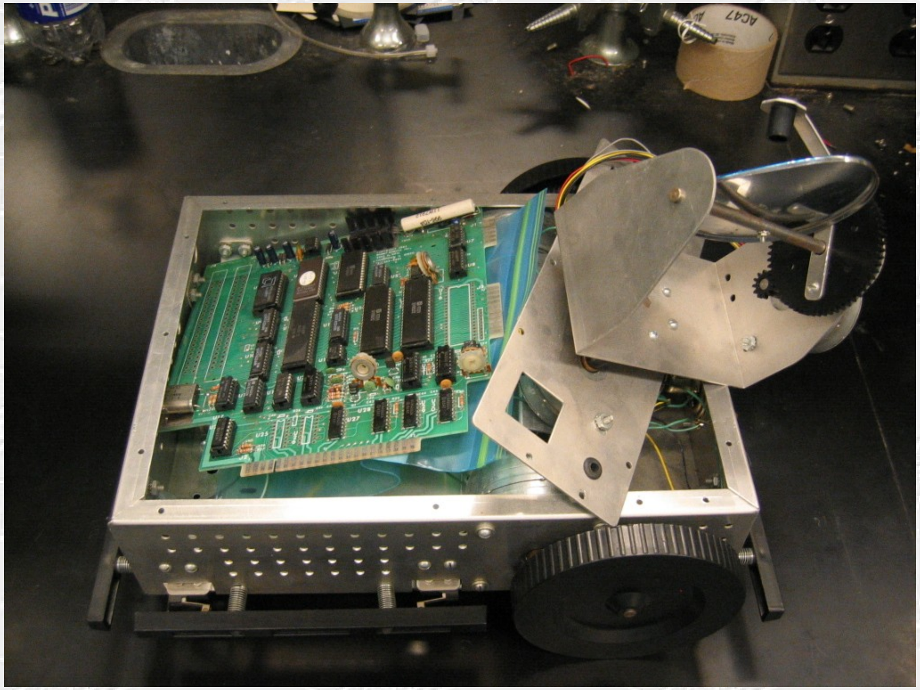
John J. Craig. *Introduction to Robotics Second Edition* **(1989), Addison-Wesley Publishing company.**

Video Clip (Simulation)



Scorpion Background

- Created by Prof. H.S. Sandhu in 1983 at UIUC
- Intended for educational use
- Donated in non-working condition by graduate students working on Leonard



Objectives

- Rehabilitation of Scorpion unit
  - Original microcontroller in irreparable condition and not well suited to interface with modern devices (e.g. GPS)
  - Including integration of new microcontroller, the Handy Board, to replace the obsolete controller board
- Development of line following behavior
  - step toward goal of incorporating GPS functionality

Original Specifications

- Dimensions
  - Main chassis:
    12” x 9” x 3” high
- Motors
  - Drive wheels: 2 stepper motors
- Original Controller
  - Took commands from PC
  - Sent sensor data to PC
- No internal power source
- Optical Sensors
  - One in center of scanner unit
  - Two on bottom of scorpion for pattern detection
- Touch Sensors
  - 8 touch sensors, 1 on each end of 4 bumpers

Restoration

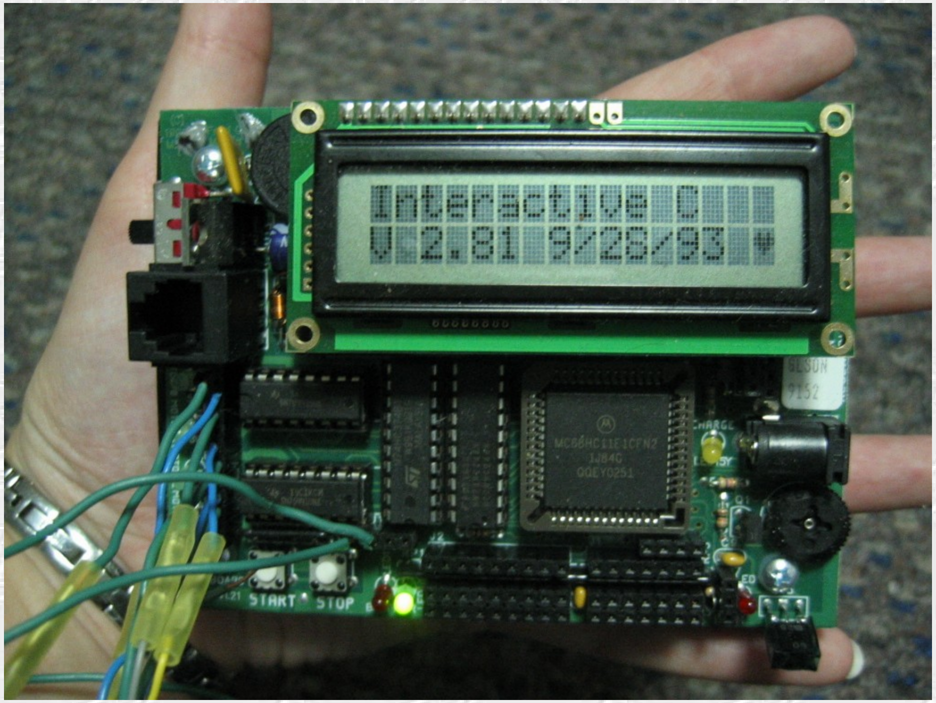
- Obsolete parts removed
  - Controller board
- Replace faulty touch sensors in key positions
  - Exchanged with the sensors least likely to be used, behind the wheels

Development

- Interface Handy Board with existing unit
- Test functionality of sensors
  - optical
  - mechanical
- Write program governing robot behavior

Handy Board

- Designed by Fred Martin of MIT
- Available for purchase fully assembled or as a kit



Handy Board (cont.)

- 9 digital inputs
- 7 analog inputs
- IR Input/Output port
- 4 DC motor outputs
- 16x2 LCD screen
- Internal 9.6v nicad battery & recharging circuits
- Motorola 68HC11 microprocessor
- 32k static RAM
- Runs Interactive C

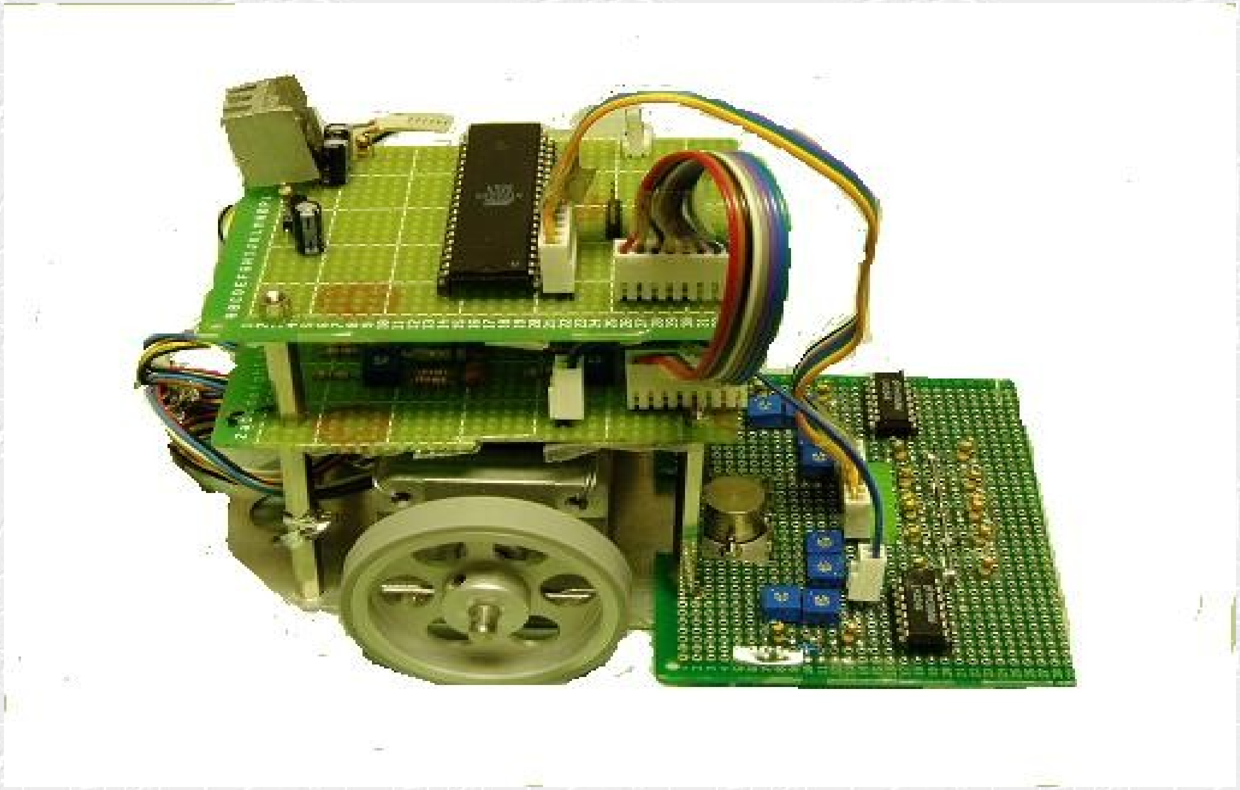
Programming

- Interactive C
  - Immediate compilation
  - Easy to use
  - Open source
  - Cross-platform, Multi-tasking version of C
- Movement Functions
  - Forwards/Backwards
  - Turns
  - Pivot using both wheels
  - Controlled speed & distance
- Driver program
  - Calls other functions e.g. move forwards, check sensors
  - Passes parameters to other functions based on desired behavior

Future Plans

- Activation of Optical & Touch sensors
- Further development of algorithm to regain path after encounter with obstacle
- Explore alternative power sources for motors
- Addition of GPS

Line Tracer Robot

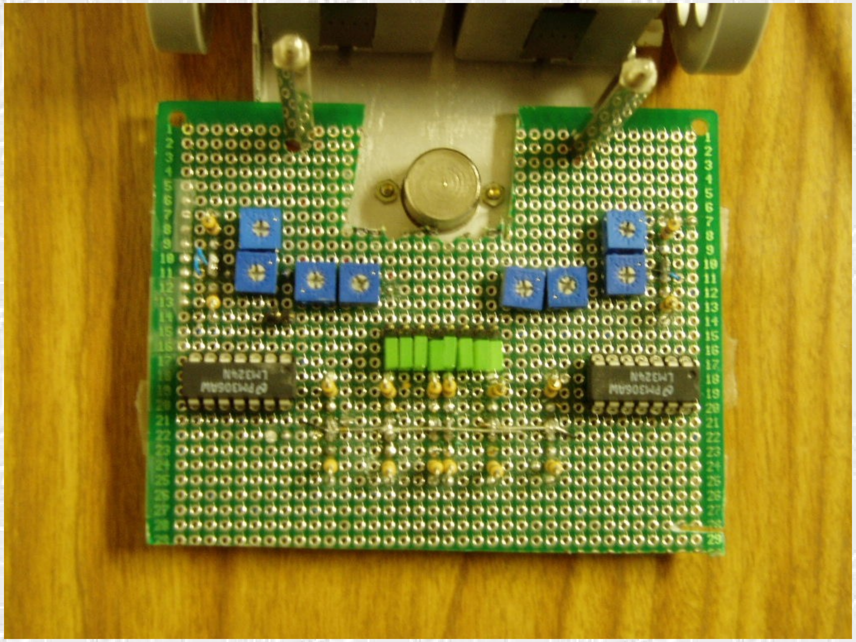


Line Tracer Robot

- Follows a white line
- Three parts
  - center processing part
  - sensor part
  - motor controller part
- LM324 chip, SLA7024 chip and L297. L297, AT89C52 chip, 8051 chip

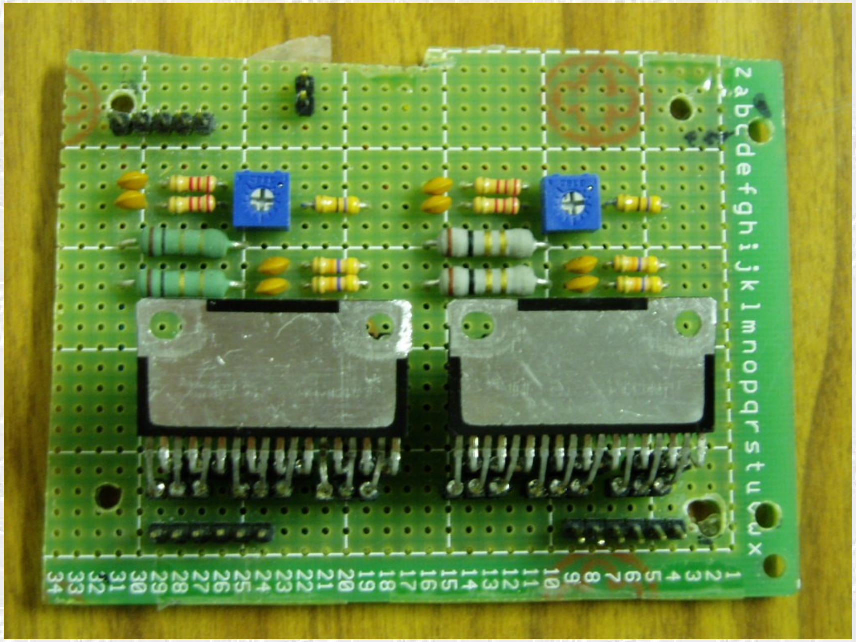
How to control the Robot

- Sensor part
  - 8 Light sensors
  - Each light sensor
    - light-emitting sensor
    - light-receiving sensor



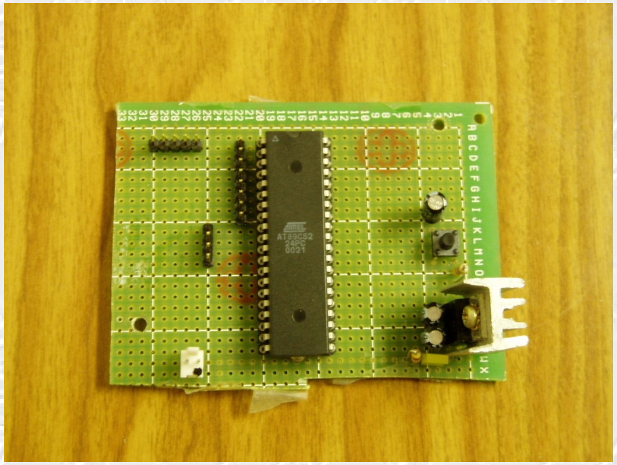
Motor controller part.

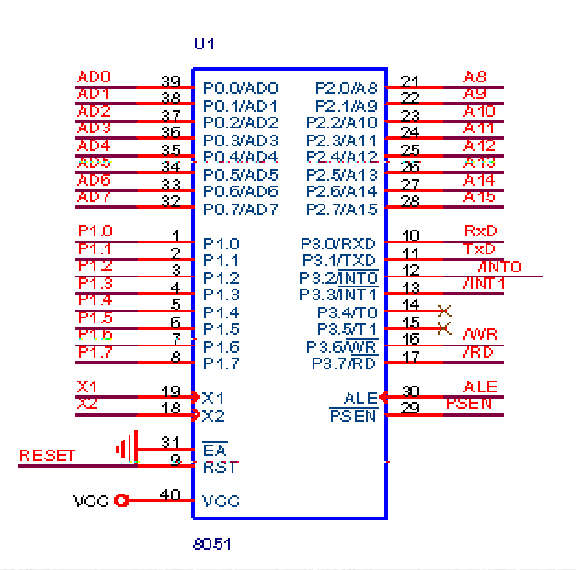
- Motor Controller Part
  - made up of two circuits
  - Both circuits have identical functionality and behavior
- Step motor



Center processing part

- AT89C52 chip
  - Belongs to a family of 8051 chip series.
- Circuit diagram of 8051 chip





Multitasking Robot

- This robot has four modes: Following, Escaping, Line tracer, Micro mouse.
- Microprocessor 89C51 used
  - made by ATMEL
- Performs same function as Line Tracer

The Existing Gap

- FIRST Robotics – motivate young people to pursue careers in science, technology, and engineering:
  - Age 9 through 14 – FIRST LEGO League
    - 26,000 children across the US and over 5,000 from other countries
    - LEGO bricks, sensors, motors, and gears
  - High school students – FIRST Robotics Competition
    - 20,000 students, 900 teams, and 27 regional competitions
    - Actual size robot with motors, wheels, metal parts, batteries, sensors, controller, etc
- Graduate courses and advanced researches

Top Universities

- Princeton (18) *
- Carnegie Mellon (11) *
- University of Illinois – Urbana Champaign (4)
- Stanford (2)
- University of Michigan (6)
- Rensselar

Princeton

- One year program designed for students who are interested in pursuing careers or graduate education in robotics.

  Courses to be completed:

  Electronics – 1, Control Systems – 1, Cognitive Studies – 1, and 3 electives – junior and senior level courses in electrical engineering, mechanical engineering, computer science, chemical engineering, and psychology.

Courses

- Prerequisites:
  - ✓ Mathematics through MATH 202 or 204

    -- *MATH 151, 152, 251, 333*
  - ✓ B.S.E Science Requirements

    -- *BIOL 115, CHEM 124, PHYS 123, 221, 224*
  - ✓ Computer Science: 111, 126

    -- *CS 105, 106 or CS 220, CS 331*

- Electronics(1):
  - ✓ ELE 201: Introduction to Electrical Systems and Signals

    -- *ECE 308 (signals and system)*
  - ✓ ELE 203: Electronic Circuits

    -- *ECE 211, 213 (Circuit Analysis)*
  - ✓ ELE 206: Introduction to Logic Design

    -- *ECE 218 (Digital Systems)*
  - ✓ MAE 224: Integrated Engineering Sciences Laboratory

    -- *MMAE 305 (Dynamics), 310 (Fluid Mechanics)*

Courses Continues…

- Control Systems(1):
  - ✓ CHE 445 Process Control
    -- CHE 435 (Process Control)
  - ✓ ELE 483 Feedback Systems
    -- ECE 438 (Control Systems)
  - ✓ MAE 345 Robotics and Intelligent Systems
    -- CS 480 (AI)
  - ✓ MAE 433 Automatic Control Systems
    -- MMAE 440 (Introduction to Robotics)
  - ✓ MAE 434 Modern Control
    -- MMAE 443 (System Analysis and Control)
- Cognitive Studies (1):
  - ✓ PSY 255 Cognitive Psychology
    -- PSYC 221(Human Behavior, Growth and Learning)
  - ✓ PSY 258 Introduction to Neuroscience
    -- PSYC 222 (Brain, Mind, and Behavior)
  - ✓ PSY 259 Introduction to Cognitive Neuroscience
  - ✓ PSY 322 Human Machine Interaction
    -- PSYC 456 (Engineering Psychology)

Carnegie Mellon

- Courses to be Completed for Undergraduate Minor in Robotics:
  - General Robotics
  - 1 from Controls
  - 1 from Manipulations, Dynamics, and Mechanism
  - 2 electives from Computer Science, Electrical Engineering, Mechanical Engineering, and Psychology

Courses

- Controls (1)
  - ✓ 06-205 Chemical Engineering Process Control
  - ✓ 18-370 Fundamentals of Control
  - ✓ 24-451 Feedback Control Systems
  - ✓ 16-299 Introduction to Feedback Control Systems

  -- MMAE 443 System Analysis and Control

  -- ECE 438 Control Systems

  -- CHE 435 Process Control

- Manipulation, Dynamics, Mechanism (1)
  - ✓ 15-384 Manipulation
  - ✓ 24-353 Intermediate Dynamics
  - ✓ 24-355 Kinematics and Dynamics of Mechanisms

  -- MMAE 305 Dynamics

  -- MMAE 440 Introduction to Robotics

Proposal for Robotics Minor at IIT

ILLINOIS INSTITUTE OF TECHNOLOGY

Transforming Lives. Inventing the Future.

- ECE majors:

- Social sciences: PSYC 221, PSYC 222
- Technical elective: CS 331
- Professional elective: ECE 438
- Additional classes to be completed:
  - ✓ MMAE(3): 305* (Dynamics), 440* (Introduction to Robotics), 431 (Design of Machine Elements), 443 (System Analysis and Control), 445 (CAD/CAM w/ Numerical Control)
  - ✓ CS(1): 445 (Object-Oriented Design and Programming), 480 (Artificial Intelligence), 411 (Computer Graphics)
  - ✓ PSYC(1): 409 (Psychological Testing), 426 (Cognitive Processes), 456 (Engineering Psychology)

* Required courses.

Minor Proposal Continues…

ILLINOIS INSTITUTE OF TECHNOLOGY
Transforming Lives. Inventing the Future.

- MMAE Major:

➢ Social sciences: PSYC 221, PSYC 222

➢ Technical elective: CS 331

➢ Professional electives: MMAE 443

➢ Additional classes to be completed:

  ✓ ECE(3): 211* (Circuit Analysis I), 213* (Circuit Analysis II), 308* (Signals and Systems)

  ✓ CS(1): 445 (Object-Oriented Design and Programming), 480 (Artificial Intelligence), 411 (Computer Graphics)

  ✓ PSYC(1): 409 (Psychological Testing), 426 (Cognitive Processes), 456 (Engineering Psychology)

* Required courses.

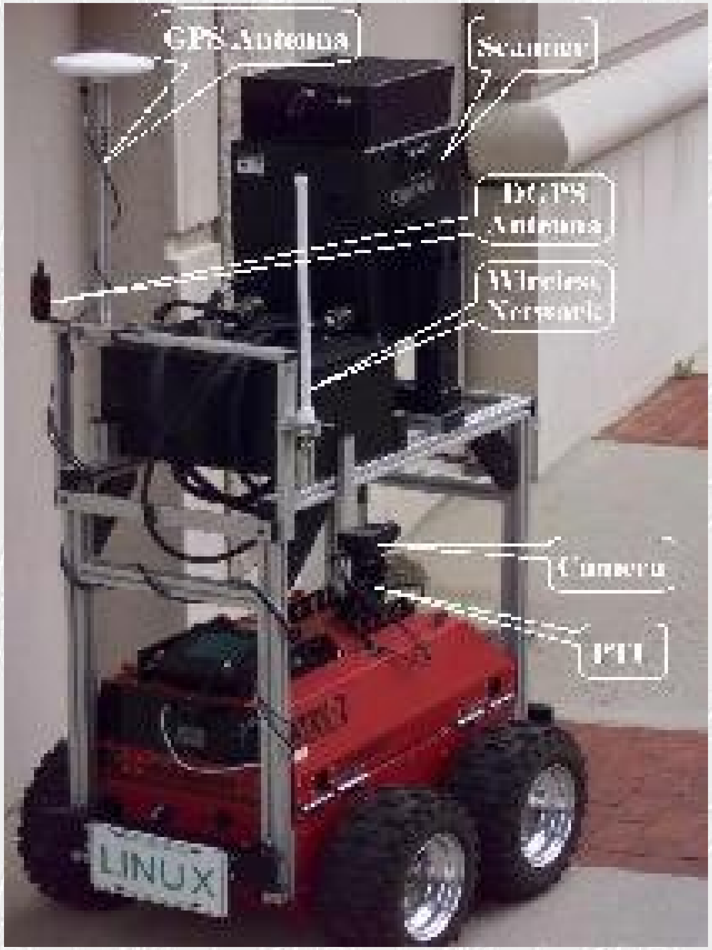
Conclusion

- ARM
    - lot of potential for growth
    - possibility of adding new features such as
        - Sensors
        - Make it mobile
        - Pattern recognition
        - GPS system

- Make it a dynamic unit
    - track objects, reach it and pick it up with the help of pattern recognition and sensor.
        - helpful feature in accessing materials harmful to humans.

- Building a unit of this potential in an affordable price bracket
    - Valuable learning experience for high school and college students.
    - Provides good hands on experience for students considering a career in robotics.

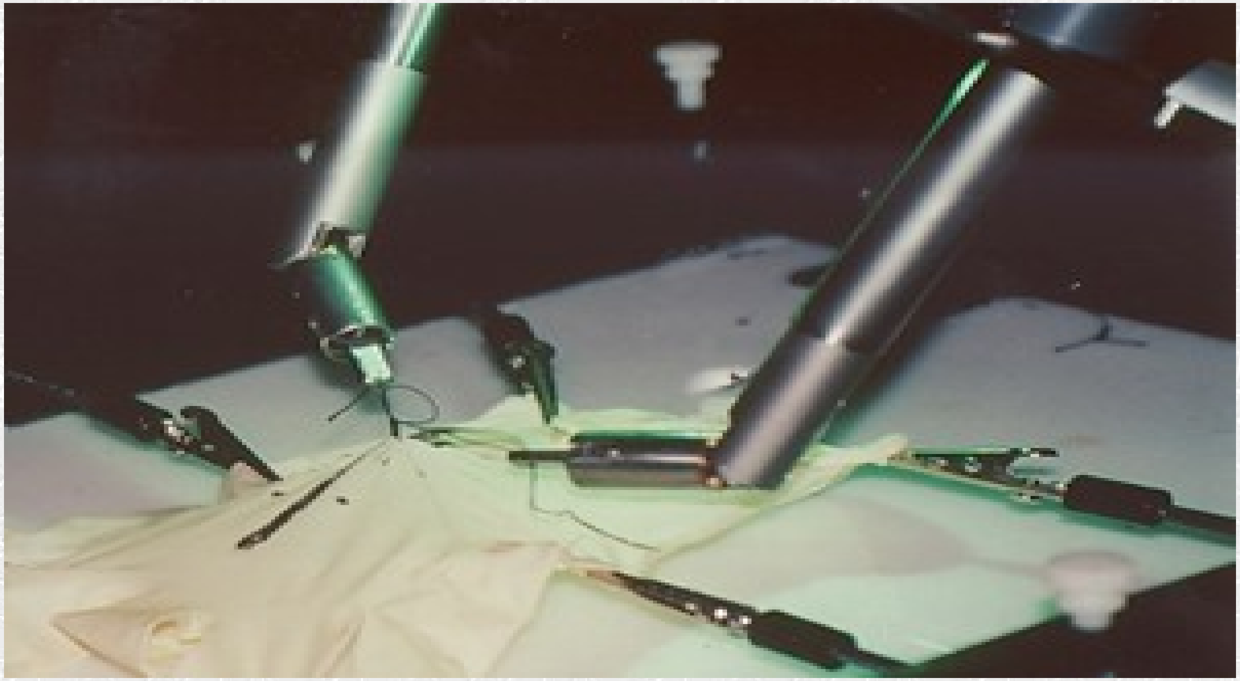
The HRL Manipulator at Harvard University, which has sensors, attached.



Though the purpose of both the robots are very different it further emphasizes the utility of a robot with the basic features mentioned above.

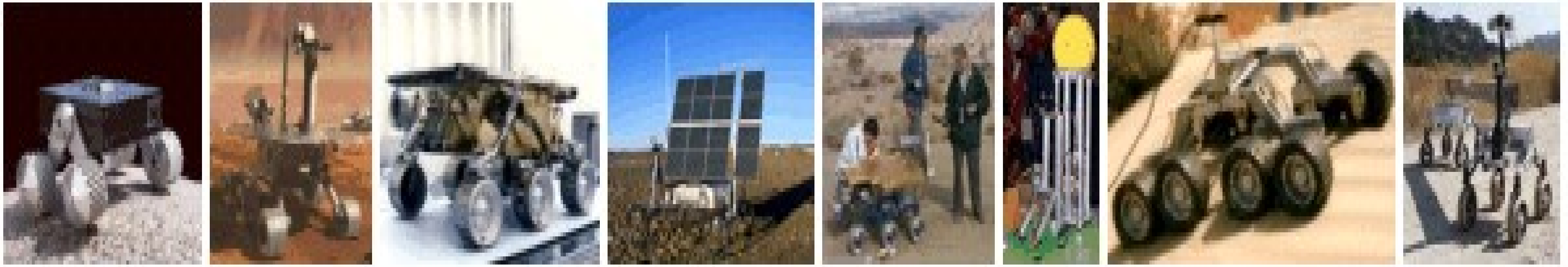
- AVENUE (*Autonomous Vehicle for Exploration and Navigation in Urban Environments*)
    - Developed at Columbia university
    - Goal - create an autonomous system capable of building photo-realistic 3D geometrically accurate models of outdoor sites
    - Features very similar to the proposed additional features of the ARM.

- To further promote the interest in robotics
  - Courses designed to help students from various fields integrate their major with robotic technology
  - Achievable via introduction of a robotics minor at IIT.



Final Words

- Various engineering and computer science courses from all across the country very easily integrated robotics with engineering.
- Encourage the substantial number of interested students at IIT
- Open students with no prior exposure to robotics to a possibly new field of interest.



Thank you

Any Questions?