This Week’s Lecture

• Introduction
  – Who are you/us? Major, year, background.
• What will we learn this semester?
  – What is AI? (with emphasis on probability, ML, & robotics)
  – How to learn a subject by myself?
  – Course Details
• Overview of Artificial Intelligence
  – Intelligence, Agents & Artificial Intelligence
  – Examples and Grand Challenges
• Friday’s lecture
  – Intelligent Agents and Robots
    • Agents/robots, sensors, actions, thinking
    • Environments
  – Project 0-1 description and assignment
Prof Wei-Min Shen (http://www.isi.edu/robots)

Welcome

Projects

We conduct research in adaptive, self-reconfigurable, autonomous robots and systems, including StarCell, modular, multifunctional and self-reconfigurable SuperBot, Hormone-Ledged Control (HLC), and Sonic-Propelled Vehicle (SPV), etc.
Who are we?

• Instructor: Prof Wei-Min Shen
• TA: Thomas Collins, Joseph (Chi-An) Chen
• Lectures: Wed, Fri. 4:30-6:20PM
• Office Hours: Room RTH512, Wed/Fri 1-3pm
• Class web: www.isi.edu/~shen/CS360
• Text Books: (read the chapters before class)
  – (1) Artificial Intelligence: Modern Approach (MIMA) by Stuart Russell and Peter Norvig (3rd ed), 2009
  – (2) Autonomous Learning from the Environment (ALFE) by Wei-Min Shen 1994
Who are you?

- Major
- Year
- Where you from?
- Why you take this class?
What Will We Learn?

Learn AI and ML (robotics)
Learn how to learn by yourself

General AI
Representation, Search, Logics
Probability Reasoning
Machine Learning
EM Algorithm

Learn AI and ML (robotics)
Learn how to learn by yourself
# Course Overview (Syllabus)

Please read the syllabus carefully

<table>
<thead>
<tr>
<th>Week</th>
<th>Date</th>
<th>Topic</th>
<th>Reading</th>
<th>Homework</th>
<th>Project</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Jan 10</td>
<td>Welcome, Class lectures, readings, homework, projects, exams, grades</td>
<td>AIMA1-2 (ALFE-1)</td>
<td></td>
<td>Project-0 out: Robot alive</td>
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<td></td>
<td>Jan 12</td>
<td><strong>Introduction to AI</strong>, intelligent agents, environments, systems, and robots</td>
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<td>2</td>
<td>Jan 17</td>
<td><strong>Problem Solving, Search and Optimization (1-2)</strong></td>
<td>AIMA3 (ALFE-2,6)</td>
<td>HW1</td>
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<td></td>
<td>Jan 19</td>
<td>Problem representation and search algorithms (DFS, BFS, BFS, A*, etc.)</td>
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<td>3</td>
<td>Jan 24</td>
<td><em><em>Search Algorithms (DFS, BFS, BFS, A</em>, etc.) (3)</em>*</td>
<td>AIMA4</td>
<td>HW2</td>
<td>Project-1 out: Robot search</td>
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<td></td>
<td>Jan 26</td>
<td><strong>Game Playing, Representations and Algorithms (min-max, alpha-beta)</strong></td>
<td>AIMA5</td>
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<td>4</td>
<td>Jan 31</td>
<td><strong>Propositional Logic</strong>: Syntax, Semantics, Representations, and Inferences</td>
<td>AIMA7</td>
<td>HW3</td>
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<td></td>
<td>Feb 2</td>
<td><strong>First-Order Logic</strong>: Syntax, Semantics, Representations, and Inferences</td>
<td>AIMA8-9</td>
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<td>5</td>
<td>Feb 7</td>
<td>Planning and <strong>Actions and Sensor Models</strong></td>
<td>AIMA10-11 (ALFE-3, 6.1)</td>
<td>HW4</td>
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<td></td>
<td>Feb 9</td>
<td><strong>Neural Networks and Back-Propagation</strong></td>
<td>AIMA 13,18 (ALFE-4)</td>
<td>HW5</td>
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<td>6</td>
<td>Feb 14</td>
<td><strong>Probability</strong>: Representations and Inferences (22)</td>
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<td>Feb 16</td>
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<td>7</td>
<td>Feb 21</td>
<td><strong>Bayesian Networks</strong></td>
<td>AIMA14 (ALFE-4)</td>
<td>HW6</td>
<td>Project-2 out: Robot search</td>
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<td></td>
<td>Feb 23</td>
<td>Representation and reasoning of uncertain models &amp; knowledge (23)</td>
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<td>8</td>
<td>Feb 28</td>
<td><strong>Supervised Learning</strong>: Decision Trees</td>
<td>AIMA18 (ALFE-4)</td>
<td>HW7</td>
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<td></td>
<td>Mar 2</td>
<td>Support Vector Machines</td>
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<td>9</td>
<td>Mar 7</td>
<td>Review for the midterm exam</td>
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<td></td>
<td>Mar 9</td>
<td><strong>Midterm Exam</strong>: Close-book Exam (all materials above) – in class</td>
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<td>10</td>
<td>Mar 14</td>
<td>Spring Break</td>
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Overall, this class will emphasize

- Hands-on problem solving and programming
- Probabilistic Reasoning and Machine Learning
- Pre-Reading and Interactions in Classes
Grading Structures (Syllabus)

- **Grade Structure:**
  - **Exams**: Midterm: 30%, Final: 30%,
  - **Projects**: Project-0: 3%, Project-1: 7%, Project-2: 10%, Project-3: 10%
  - Self-study and Interactions in Class: 10%
    - Pre-reading report due right before each class
    - Sign-up sheets for your class participation/interaction at each class
  - **Homework**: no grades, but essential for your exam/projects

- **All exams are closed books**
  - Midterm date: Mar 9, Final exam date: May ?? (TBD)

- **All projects must be done by yourself without collaboration**
  - Projects are due midnight the day before the next project is released
  - Late project penalty: -30% of the grade for each day that is late

- **Prerequisites**: See class website. C/C++ are required for projects
Grading Structures (Syllabus)

**Midterm Exam:** Mar 9, in Class  
**Final Exam:** Time and Place to be announced

**Project 0:** Design and program a simple robot to move in an open environment  
**Project 1:** Program intelligence to your robot so that it can search and navigate a path from point A to point B in a crowded deterministic environment  
**Project 2:** Program intelligence to your robot so that it can search and solve problems in an non-deterministic environment  
**Project 3:** Program your robot to learn from its own experience so that it can solve complex problems quickly in stochastic environments

**Pre-Class Reading Reports:** These are short summaries (with 6 questions) of your readings of the class material due before each class  
**In-Class Participations:** You are encouraged to participate and ask questions in class, and such activities are recorded at each class by sign-up sheets  
**Homework:** Your answers to the homework questions are due on the day when the next homework is out (we will let you know the correct answers)

**Grades:** Midterm: 30%, Final: 30%, Project-0: 3%, Project-1: 7%, Project-2: 10%, Project-3: 10%, Homework/Reading Reports: 8%, In-Class: 2%  
**Late Project Penalty:** -30% of the project grade for each day that is late.

Grading is absolute and according to the following scale: 90 or more: A+; 80 or more: A; 75 or more: A-; 70 or more: B+; 60 or more: B; 55 or more: B-; 50 or more: C+; 40 or more: C; 35 or more: C-; less than 35: F.
Blackboard and Piazza

• Most assignments/announcements will be on blackboard and please check that often
• Please also enroll yourself on Piazza:
  – You can post your questions and join discussion about the course work during the semester
  – Announcements will also be posted here
Projects (hands-on)

• All projects must be done by yourself (no collaboration)
• Late project penalty
  – -30% of the project grade for each day that is late
• **Project 0: (3%)**
  – Design and build your robot to move purposefully in an open and possibly stochastic environment
• **Project 1: (7%)**
  – Give your robot intelligence so that it can search and navigate a path from a place to a target in a crowded but deterministic environment
• **Project 2: (10%)**
  – Give your robot intelligence and local sensing capabilities to solve problems in (real-world) stochastic environments
• **Project 3: (10%)**
  – Make your robot learn from its own experience so that it will learn how to find a target in its environment
Homework

- Homework: preparing you for the projects and tests
  - HW1, Encode State Space
  - HW2: Search
  - HW3: Logic Reasoning
  - HW4: Planning
  - HW5: Neural Networks
  - HW6: Probability and Bayes Net,
  - HW7: Learning - Decision Trees, Neural Network, State Vectors
  - HW8: Markov Models, State Automata, Utilities
  - HW9: Temporal reasoning, Markov Decision Process, Partially observable
  - HW10: Learning - Relational Learning (e.g., FOIL, CDL)
  - HW11: Unsupervised Learning - Naïve Bayesian Model, EM
  - HW12: Learning POMDPs - Surprise-Based Learning
Ground Rules for HW, Tests, Projects

• **You may work together on homework**
  – They are there for you to learn and apply your knowledge
  – They do not contribute to your grade, but sample answers will be provided at the due date as feedback for your efforts

• **Exams are in class and are closed book & notes**
  – Bring only pens and your student ID, nothing else

• **Project assignments must be all your own work**
  – No collaboration or outside help
  – You can ask questions to your TAs
  – No use of any code from elsewhere (including the Internet)

• **Standard penalty for violation is F in the course**
Pre-Class Reading Reports

• Submit to blackboard
• Due before each class
  – The first one due this Friday, 4:30PM
• Report template (you answer 6 questions)
  1. What is the main problem/topic?
  2. Why is it interesting?
  3. Why is it hard and difficult?
  4. What are the key approaches/methods?
  5. What are the examples used in the chapter?
  6. Which parts you have trouble to understand?
What is the main problem/topic?

Chapter 1 establishes ideas and definitions of AI, comparing different ideas against one another (human vs rational), ultimately establishing rational agents as the focus. We’re then walked through what I’d describe as an academic history of AI, or what fields and individuals have contributed to conceptualization and birth of AI, followed by a history of AI itself as a field. It concludes with a bit of “where are we now” that really feels more like a few highlights from the field rather than a robust description of what we’re doing in academia and industry. In short, this chapter explores the nature, history and trajectory of AI.

Why is it interesting?

Chapter 1 is interesting because it provides history and context for the subject of this class. I am most impressed with how thoroughly the field is really a reflection on ourselves, that in striving to understand the mind and replicate it we see both successes and failures, and these successes and failures in turn inspire new insights into our own condition (for instance, papers presented by Miller, Chomsky, and Newell and Simon all presented the idea that “a cognitive theory should be like a computer program,” a notion that is apparently still accepted today). Really though, it’s a bit ridiculous to ask why this is interesting – AI challenges deep philosophical questions about who and what we are, as well as what we’re (intellectually) capable of. It provides more powerful tools for inquiry into all aspects of our lives, academic and mundane.

Why is it hard and difficult?

For chapter 1, I take this to mean why is building effective AI challenging. The book isn’t incredibly descriptive on this front, but the impression I get from the text is that we’re moving away from coding specific knowledge and more towards developing algorithms and systems designed to digest larger volumes of information in order to compile knowledge (that is, finding ways of effectively delivering/communicating mass amounts of information to these learning systems). Presumably finding ways of constructing these algorithms and systems is our great challenge.
What are the key approaches/methods?

For chapter 1, again, if we’re talking about the most effective ways of creating AI, the present paradigm (according to our text at least) seems to be finding ways of compiling mass amounts of data. One example given indicating that this is a recipe for success was for a program designed for word disambiguation. When a mediocre algorithm was provided 100 million words of training data, it generally outperforms even the best algorithm with 1 million words.

What are the examples used in the book?

Aside from those already mentioned, chapter 1 is pretty rich with examples to bolster its claims. It walks us through the Turing test as a means of discerning both thinking humanly and acting rationally. Through the history sections, we learn about Aristotle’s syllogisms contributing to early logic, decision and game theory in economics, and many, many other topics and how the influenced the conception of AI. For modern feats of AI, we’re offered examples the autonomous vehicles competing the DARPA Grand Challenge, Deep Blue’s defeat of Kasparov and even the Roomba robotic vacuum cleaners.

Which parts you have trouble to understand?

Chapter 1 really covers a lot of ground, but it also glosses over a lot of material as well. There’s a lot here that I only vaguely understand. I think the two topics that frustrate me most are hidden Markov model and neural nets. I really have no idea what HMMs actually are or how they effectively with speech recognition or incorporate mathematics, only that they indeed do (as per the text). Similarly, I really don’t know what a neural net is or how it works at all. Moreover I don’t really understand the nuances between the connectionist models of intelligent systems vs the symbolic models.
Interactions in Class

• We will teach you **how to teach yourself**
  – Read the chapters and lecture nodes before class
  – Ask questions in classes
  – There will be sign-up sheets in each class
    • For Participation and Interaction in classes

• This will count for 10% of your grades
Any questions so far?
Overview of Artificial Intelligence

• Over 50 years of history --- Founding Fathers
• What is Intelligence?
• What is “Artificial” Intelligence?
• What are the related fields of AI?
• How was AI started? (history)
• What is the state of the art of AI?
• In this course, you will learn
  – Basic AI concepts, methodologies, and techniques
  – How do I learn a new subject in the future? (improve your own “intelligence”)
Why study AI?

- Search engines
- Science
- Medicine / Diagnosis
- Labor
- Appliances / Internet of Things (IoT)
- What else?
DARPA Robotics Challenge
DeepMind AlphaGO vs Human
Google Cloud Vision APL:

- "running", "score": 0.99803412, "marathon", "score": 0.99482006
- "joyLikelihood": "VERY LIKELY"
- "description": "ABIERTO\n", "local": "es"
What is Intelligence?

Any Ideas?

• What is measured by a test/standard, e.g.:
  – “Intelligence is what is measured by intelligence tests.” *E. Boring*
  – Thought processes, or behavior, that is indistinguishable from what a human would produce (at some level of abstraction)
    • *The Turing test*
  – What about non-human intelligence?
    • Animals? (detecting natural disasters)
What is AI?

- The exciting new effort to make computers think ... machines with minds, in the full and literal sense” (Haugeland 1985)

- “The study of mental faculties through the use of computational models” (Charniak et al. 1985)

- “The art of creating machines that perform functions that require intelligence when performed by people” (Kurzweil, 1990)

- A field of study that seeks to explain and emulate intelligent behavior in terms of computational processes” (Schalkol, 1990)

- Systems that think like humans
- Systems that act like humans
- Systems that think rationally
- Systems that act rationally
Acting Rationally: The Rational Agent

- Rational behavior: Doing the right thing!
- The right thing: That which is expected to maximize the expected return
- Provides the most general view of AI because it includes:
  - Correct inference (“Laws of thought”)
  - Uncertainty handling
  - Resource limitation considerations (e.g., reflex vs. deliberation)
  - Cognitive skills (NLP, AR, knowledge representation, ML, etc.)

- **Advantages:**
  1) More general
  2) Its goal of rationality is well defined
Acting Humanly: The Turing Test

• Alan Turing's 1950 article Computing Machinery and Intelligence discussed conditions for considering a machine to be intelligent

  – “Can machines think?” ↔ “Can machines behave intelligently?”
  – The Turing test (The Imitation Game): Operational definition of intelligence.
Acting Humanly: The Turing Test

Computer needs to possess: Natural language processing, Knowledge representation, Automated reasoning, and Machine learning

Are there any problems/limitations to the Turing Test?
Acting Humanly: The Full Turing Test

- Alan Turing's 1950 article Computing Machinery and Intelligence discussed conditions for considering a machine to be intelligent
  - “Can machines think?” ←→ “Can machines behave intelligently?”
  - The Turing test (The Imitation Game): Operational definition of intelligence.

Computer needs to possess: Natural language processing, Knowledge representation, Automated reasoning, and Machine learning

**Problem:**
1) Turing test is not reproducible, constructive, and amenable to mathematic analysis.
2) What about physical interaction with interrogator and environment?

**Total Turing Test:** Requires physical interaction and needs perception and actuation.
Acting Humanly: The Full Turing Test

Problem:

1) Turing test is not reproducible, constructive, and amenable to mathematic analysis.
2) What about physical interaction with interrogator and environment?

Trap door
What would a computer need to pass the Turing test?

• **Natural language processing:** to communicate with examiner.

• **Knowledge representation:** to store and retrieve information provided before or during interrogation.

• **Automated reasoning:** to use the stored information to answer questions and to draw new conclusions.

• **Machine learning:** to adapt to new circumstances and to detect and extrapolate patterns.
What would a computer need to pass the Turing test?

• **Natural language processing**: to communicate with examiner.

• **Knowledge representation**: to store and retrieve information provided before or during interrogation.

• **Automated reasoning**: to use the stored information to answer questions and to draw new conclusions.

• **Machine learning**: to adapt to new circumstances and to detect and extrapolate patterns.

*Core focus in this course*
What would a computer need to pass the Full Turing test?

- **Vision** (for Total Turing test): to recognize the examiner’s actions and various objects presented by the examiner.
- **Motor control** (total test): to act upon objects as requested.
- **Other senses** (total test): such as audition, smell, touch, etc.
CAPTCHAs or “reverse Turing tests”

• **Vision** is a particularly difficult one for machines...

• Gave rise to “Completely Automated Public Turing test to tell Computers and Humans Apart” (CAPTCHA)
## AI Prehistory

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<tr>
<th>Philosophy</th>
<th>Logic, methods of reasoning, mind as physical system, foundations of learning</th>
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<tr>
<td>Mathematics</td>
<td>Formal representation and algorithms, computation, (un)decidability, probability</td>
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<tr>
<td>Psychology</td>
<td>Adaptation, phenomena of perception, experimental techniques</td>
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<tr>
<td>Linguistics</td>
<td>Knowledge representation, grammar</td>
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<tr>
<td>Neuroscience</td>
<td>Physical substrate for natural and homeostatic systems, simple optimal agents</td>
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<tr>
<td>Control theory</td>
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<tr>
<td>Year</td>
<td>Event</td>
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<td>--------</td>
<td>----------------------------------------------------------------------</td>
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<tr>
<td>1943</td>
<td>McCulloch &amp; Pitts: Boolean circuit model of brain</td>
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<tr>
<td>1950</td>
<td>Turing’s “Computing Machinery and Intelligence”</td>
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<td>1952–69</td>
<td>Look, Ma, no hands!</td>
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<td>1950s</td>
<td>Early AI programs, including Samuel’s checkers program,</td>
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<td>Newell &amp; Simon’s Logic Theorist, Gelernter’s Geometry Engine</td>
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<td>1956</td>
<td>Dartmouth meeting: “Artificial Intelligence” adopted</td>
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<td>1965</td>
<td>Robinson’s complete algorithm for logical reasoning</td>
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<td>1966–74</td>
<td>AI discovers computational complexity</td>
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<td>Neural network research almost disappears</td>
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<td>1969–79</td>
<td>Early development of knowledge-based systems</td>
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<td>1980–88</td>
<td>Expert systems industry booms</td>
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<td>1985–95</td>
<td>Neural networks return to popularity</td>
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<td>1988—</td>
<td>Resurgence of probabilistic and decision-theoretic methods</td>
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<td>Rapid increase in technical depth of mainstream AI</td>
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<td>“Nouvelle AI”: ALife, GAs, soft computing</td>
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Professor Herbert A. Simon
Nobel Price Winner
A Founding Father of Artificial Intelligence
The State of the Art (of AI)

• Have the following been achieved by AI?

  – Pass the Turing test
  – World-class chess playing
  – Playing table tennis
  – Cross-country driving
  – Solving mathematical problems
  – Discovering and proving mathematical theories
  – Engaging in a meaningful conversation
  – Understanding spoken language
  – Observing and understanding human emotions
  – Expressing emotions
  – ...

First RoboCup (1997, USC Dreamteam)
DARPA Urban Challenge (2007)

• “Autonomous vehicles that safely execute missions in a complex urban environment with moving traffic.”
  – “The objective of this program is safe and correct autonomous driving capability in traffic at 20 mph.”
In 1997 Deep Blue became the first machine to win a match against a reigning world chess champion (by 3.5-2.5)
Deep Blue Combined

- Parallel and special purpose hardware
  - A 30-node IBM RS/6000, enhanced with
    - 480 special purpose VLSI chess chips
- A heuristic game-tree search algorithm
  - Capable of searching 200M positions/sec
  - Searched 6-12 moves deep on average, sometimes to 40
- Chess knowledge
  - An opening book of 4K positions and 700K GM games
  - An endgame database for when only 5-6 pieces left
  - A positional evaluation function with 8K parts and many parameters that were tuned by learning over thousands of Master games
WATSON Won Jeopardy! (2013)
Virtual Humans for Tactical Language Learning

- Teach *language* and *culture* in context
- Trainee plays one character
- Teammates & locals are “socially intelligent” agents
  - Understand task and other characters
  - Have goals and emotions
  - Use speech and gesture
  - One teammate acts as guide
- Versions exist for Iraqi, Pashto, French, Dari, ...
Example Virtual Humans (USC/ICT)
Grand Challenges for AI

• **Human-level AI**
  – *Intelligent virtual humans*
  – Humanoid robots

• **Superhuman performance in limited domains**
  – *Beat the world champion at chess* (or Go)
  – Effective control of very complex systems
  – Self-reconfigurable transformer robots!

• **Specific advanced capabilities of interest**
  – Mathematical or scientific discovery
  – *Automatically drive a vehicle in real world*
  – *Answer a wide range of questions*
  – Autonomously behave and learn continuously over years
  – *Automated real-time language* and speech translation
  – Learn to perform a new task from scratch
  – Self-Reconfigurable and self-organizing swarms
Self-Reconfigurable Robots
Self-Reconfigurable “SuperBot”
SuperBot Vision for Space
Modular, Multifunction, Self-Reconfiguration
Single Module = Complete Robot

Flexibility

Diversity

Durability

Autonomous Feedback Control

Synchronization
20 Modules in Configurations
Multifunction, Reconfiguration, Distributed Control and Learning

Dr. Wei-Min Shen, www.isi.edu/robots/, shen@isi.edu, 310-448-8710
Caterpillars on Beach
Other Forms for Locomotion

Sidewinder

Butterfly

Scorpin
Walking with Legs
Digging and Burying
Going through Pipes
Crawl up Steep Slopes
Climbing Sand Dunes
Rolling, Recovering, & Turning

USC/ISI Polymorphic Robotics Laboratory
http://www.isi.edu/robots
Climbing – Horizontally & Vertically
Tele Operations
Roller, Skate and Payload
Resilient to Shape Changes
Self Reconfiguration
Actions in Space (animation)
Infrastructure Inspections
Scalable Self-Healing

Cut in half

Self-healing

Self-healing
Research in Prof. Shen’s Lab?

Prof Wei-Min Shen [http://www.isi.edu/robots](http://www.isi.edu/robots)

Self-Reconfigurable Modular Robots (System of Systems)

Surprise-Based Learning

Self-Reconfigurable Robots, Digital Hormones, and Surprise-Based Learning

Self-Reconfigurable Robots