Transfer Learning

Program Briefing
Motivation: Military Needs

- Adapt rapidly to new situations
  - Sensor systems:
    - Target recognition systems need to adapt quickly to new target types, new background/atmospheric conditions, new sensor hardware
    - IED detection systems need to adapt quickly to new IED and camouflage types
  - Control systems:
    - UAV controllers need to adapt quickly to new payloads, damaged control and lift surfaces
    - AGV controllers need to adapt quickly to new terrain types, road surfaces, obstacle/vegetation types, etc.
  - Decision (support) systems:
    - Tactical and strategic planning systems must adapt quickly to novel enemy behavior, new weapon systems, new terrain factors, etc., without having to relearn all levels of behavior from scratch
- Take advantage of totality of training data from diverse populations while avoiding overfitting to unique characteristics

“... What you have here is not a static situation, you have a dynamic situation with an enemy that thinks, uses their brain, constantly adjusts, and therefore our commanders have to constantly make tactical adjustments”

- from an interview with Secretary Rumsfeld, 7 April 2006
Program Goals and Structure

- **Program Goals:**
  - Transform focus of machine learning research and capability of ML software from “performance improvement on same/similar tasks” to “take advantage of previous experience in novel situations”
    - Motivated by how people learn and use learned knowledge, skills, abilities
  - Develop general capabilities useful in many domains, to enable wide-range of military applications that need this capability
  - 10 “transfer levels” capture similarity/difference between source and target domains

- **Program Structure:**
  - Two large technology development teams
    - Each proposed their own domains, metrics, Go/NoGo criteria, etc.; ≥3 per team
    - Distinct approaches
    - Evaluate technologies in at least 3 domains
  - One evaluation team
    - Internal and external domains
    - Support Go/No-Go decisions
    - Leverage beyond funded research
Herb Simon defined learning as:

“Any change in a system that allows it to perform better the second time on repetition of the same task or on another task drawn from the same distribution.” (1983)

THIS HAS BEEN THE PREDOMINANT TASK OF MACHINE LEARNING RESEARCH

IN CONTRAST, PEOPLE USE WHAT THEY HAVE LEARNED FROM PREVIOUS EXPERIENCES TO PERFORM WELL IN NOVEL SITUATIONS

WE WILL SHIFT THE FOCUS OF MACHINE LEARNING RESEARCHERS TO WHAT PEOPLE DO:

**Transfer Learning:**
The ability of a system to recognize and apply knowledge and skills learned in previous tasks to novel tasks (in new domains)

THIS IS IMPORTANT NOT ONLY AS PART OF OUR COGNITIVE SYSTEMS AGENDA, BUT ALSO BECAUSE FUTURE MILITARY MISSIONS WILL INVOLVE NOVEL SITUATIONS, AND WE MUST GET THEM RIGHT THE FIRST TIME
### Levels of Transfer

<table>
<thead>
<tr>
<th><strong>Strategy Games</strong></th>
<th><strong>Physics (Mechanics)</strong></th>
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</thead>
<tbody>
<tr>
<td><strong>0. Memorizing</strong></td>
<td><strong>Not transfer</strong></td>
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<tr>
<td><strong>1. Parameterizing</strong></td>
<td><strong>Not transfer</strong></td>
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<tr>
<td><strong>2. Extrapolating</strong></td>
<td><strong>Different parameter values cause qualitatively different problems</strong></td>
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<td><strong>3. Restructuring</strong></td>
<td><strong>Test on problems with different parameter values</strong></td>
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<td><strong>4. Extending</strong></td>
<td><strong>Same formulas, different variables, or same components, different configs</strong></td>
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<td><strong>5. Restyling</strong></td>
<td><strong>Train on one textbook’s formulation, test on another’s formulation, but more of them</strong></td>
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<tr>
<td><strong>6. Composing</strong></td>
<td><strong>Combine knowledge about rotational motion &amp; momentum, test on angular momentum, train on momentum problems, test on conservation of momentum, apply conserv. to other quantities</strong></td>
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<tr>
<td><strong>7. Abstracting</strong></td>
<td><strong>Train on one real-time game, test on another</strong></td>
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<tr>
<td><strong>8. Generalizing</strong></td>
<td><strong>Train on momentum problems, test on angular momentum, combine knowledge about rotational motion &amp; momentum, train on one textbook’s formulation, test on another’s formulation, but more of them</strong></td>
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<tr>
<td><strong>9. Reformulating</strong></td>
<td><strong>Learn use of Newtonian eqns, apply Hamiltonian eqns</strong></td>
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<tr>
<td><strong>10. Differing</strong></td>
<td><strong>Apply learning from other courses; learn use of Newtonian eqns, apply Hamiltonian eqns</strong></td>
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### TL Schedule & Metrics

<table>
<thead>
<tr>
<th>Performer</th>
<th>Management Milestones</th>
<th>UCB</th>
<th>ISLE</th>
<th>NRL (Evaluation)</th>
<th>Transition</th>
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<tbody>
<tr>
<td><strong>Phase I (Oct 2005 - Oct 2006)</strong></td>
<td>BAA Released Source Selection Contracts</td>
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<tr>
<td><strong>Phase II (Nov 2006 - Oct 2007)</strong></td>
<td>Year 2 Option Decisions/Awards (Go/NoGo)</td>
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<tr>
<td><strong>Phase III (Nov 2007 - Oct 2008)</strong></td>
<td>Year 3 Option Decisions/Awards (Go/NoGo)</td>
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#### UCB
- **Go/No-Go**
  - Object Recognition - TL 3
  - Object Manipulation - TL 3
  - Stratagus - TL 3

#### ISLE
- **Go/No-Go**
  - Physics - Mechanics TL 6
  - GGP - Complete Info Games TL 8
  - MadRTS - TL 3
  - RoboCup Soccer - Passing/Shooting TL 8
  - Urban Combat - Adversary Evasion TL 8

#### NRL (Evaluation)
- Common Metrics
- Common Domains/Tasks
- Surprise Domains/Tasks
- Leverage Testbeds to non-funded Research

#### Transition
- Spin-off component technologies as available
- Construct novel applications

**Program Year**

<table>
<thead>
<tr>
<th>Year 2 Option Decisions/Awards (Go/NoGo)</th>
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<tr>
<td>Object Recognition - TL 6</td>
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<td>Object Manipulation - TL 6</td>
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<td>Stratagus - TL 6</td>
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<tr>
<th>Year 3 Option Decisions/Awards (Go/NoGo)</th>
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<tbody>
<tr>
<td>Object Recognition/Manipulation - Integrated Object Recognition &amp; Manipulation TL 10</td>
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<tr>
<td>Stratagus (Merged with MadRTS) - TL 10</td>
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**Program Year**

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<tr>
<td>Exploration</td>
<td>Integration</td>
<td>Productization</td>
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**Surprise Domains/Tasks**

- Urban Combat/RoboCup - Multiagent Adversaries: High Level Reasoning TL 10/8

**Integrated "TL" Products**

- AFRL (Agent)

**Spin-off component technologies as available**

**Construct novel applications**

**Surprise Domains/Tasks**

- Urban Combat/RoboCup - Multiagent Adversaries: High Level Reasoning TL 10/8

**Integrated "TL" Products**

- AFRL (Agent)

**Spin-off component technologies as available**

**Construct novel applications**