Adaptive Computer-based Tutoring in an ADL Context

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Agenda

• Intro to Intelligent Tutoring Systems (ITS) - Bob
• Tutoring Research Highlights – Bob
• Vision for ITS in ADL 2025 - Bob
• Technical Foundations of ITS - Scott
• ITS in Service Oriented Architectures - Scott
• Vision for ITS in ADL 2025 - Scott
Distributed Learning meets Computer-based Tutoring

• U.S. Military is deployed worldwide on a consistent basis so training technology should be:
  – **accessible** wherever the Soldier is located and whenever they need training
  – **interactive** regardless of infrastructure available
  – **intelligent** so it can be used in the absence of human instructors

• The time allotted for training is limited so training should be:
  – **efficient** as well as effective
  – **engaging, challenging and relevant** to the Soldier’s mission
  – **adaptive** to the trainee’s needs and capabilities
Grand Challenges for Educational Technology

- Personalize Education
- Assess Student Learning
- Support Social Learning
- Diminish Boundaries
- Develop Alternative Teaching Methods
- Enhance the Role of Stakeholders
- Address Policy Changes

Do computer-based tutors support these goals?
Does ADL support these goals?

The Tutoring Process

• **Problem Selection**
  - selection based on student’s knowledge, understanding of the material and motivational state

• **Problem Presentation**
  - tutor informs student about problem; encourages and motivates

• **Problem Solution**
  - student attempts to solve problem; tutor provides feedback appropriate to their competence

• **Reflection**
  - once problem is solved, tutor encourages student to consider process, methods and relationship to other contexts

• **Instruction**
  - additional information about concepts and remediation as needed


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INSPIRE Model of Tutoring Success

• Intelligent – credible

• Nurturing – supportive

• Socratic – questions, not directions; hints not answers

• Progressive – planned, structured and systematic

• Indirect – avoid overt criticism; less explicit or profuse positive feedback

• Reflective – ask students to discuss process, explain answers and generalize problem to other domains

• Encouraging – bolster confidence; challenge students; pique curiosity

Human Tutoring Topologies

One-to-One  
(Private Tutoring)

One-to-Many  
(Traditional Classroom)

Students who work one-to-one with expert human tutors often score 2.0 standard deviations higher than students in a conventional classroom (Bloom, 1984)

Computer-Based Individual Tutoring Topologies

One-to-One (Private Tutoring)

One-to-Many (Concurrent Users Working Separately, Asynchronously)

Distributed Learning

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Computer-Based
Team Tutoring Topologies

One-to-Many
(Concurrent Users Working Together)

Mobile Learning
Computer-Based Tutoring Taxonomy

Assess → Model → Predict → Adapt → Influence Learning

-understand individual trainee learning needs

make tutors & models easy to create and use

-use trainee state & learning context to select appropriate strategies

- trainee state
- cognitive modeling
- affective modeling
- individual differences

- behavioral sensing
- physiological sensing
- performance assessment

- automated cognitive task analyses
- tutor framework

- simulation interoperability
- multi-domain
- discovery engines

- diagnosis
- prescription
- feedback
- orienting
- questioning

- remediation
- demonstration
- motivational support
- attention

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

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Goals for Adaptive Tutoring

Assess → Model → Predict → Adapt → Influence Learning

- low-cost, passive sensing of trainee physiology and behaviors
- near real-time classification of trainee cognition and affect
- near real-time classification of optimal instructional strategies based on:
  - cognition (attention, engagement...)
  - affect (personality, mood, emotions)
  - historical trainee data (competence, preferences...)
- automated authoring
  - student modeling
  - expert modeling
Cognition and Affect

Assessing cognition and affect during training is on the critical path of adapting training to Soldiers’ individual differences.
Tutoring Research Questions

Assess → Model → Predict → Adapt → Influence Learning

• **General**: How can computer-based tutoring technologies accelerate learning and facilitate retention in distributed environments?

• **Learner Modeling**:
  • How should a learner’s individual differences be used by tutors to influence learning and retention?
  • Which individual differences have the most significant impact on learning?
  • Which classification methods are most accurate for determining the learner’s cognitive and affective states?

• **Authoring and Expert Modeling**:
  • Which frameworks, tools and methods are making tutors easier to develop, assess, deploy and use?

• **Instructional Strategy Selection**:
  • Which instructional strategies are optimal for learning and retention given the learner’s state (cognitive, affective) and the learning context?
  • Which instructional strategy selection methods are most consistent in selecting strategies that are optimal for the learner’s state and learning context?
Conceptual → Practical → Ubiquitous

Taxonomy

- **Trainee Modeling**: Improve methods to determine learner’s cognitive and affective states in real-time
- **Instructional Strategy Selection**: Improved methods to optimize instruction based on trainee’s state
- **Authoring**: Automated processes to enhance interoperability of tutors with training simulations
- **Authoring**: Automated processes to: build models and content; test tutoring concepts; and reduce development/support costs

**Research & Development**

1. Adaptive Tutoring Research
2. Generalized Intelligent Framework for Tutoring (GIFT)

**Technology Areas of Interest**

A. Trainee Modeling – Improve methods to determine learner’s cognitive and affective states in real-time
B. Instructional Strategy Selection – Improved methods to optimize instruction based on trainee’s state
C. Authoring – automated processes to enhance interoperability of tutors with training simulations
D. Authoring – automated processes to: build models and content; test tutoring concepts; and reduce development/support costs

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Trainee Modeling

**Trainee Modeling**

- Low-cost behavioral and physiological sensors
- Predictive cognitive and affective modeling
- Trainee modeling to inform instructional strategy decisions
- Assessment of the influence of individual differences


- Improved understanding of trainee’s “readiness to learn”
  - cognition – thinking skills
  - affect – motivation and commitment to learning
  - Tailored, optimal instructional decisions by tutors
- Integrated, historical perspective of trainee performance
  - More effective computer-based tutors/coaches
  - improved trainee performance
  - improved trainee knowledge

**Innovative machine modeling techniques**

**Cognitive & affective state models for teams**

**Unobtrusive, real-time individual and team modeling technologies**

unobtrusive sensing
Authoring and Expert Modeling

Generalized Intelligent Framework for Tutoring (GIFT)
- Innovative expert modeling techniques
- Fully automated intelligent authoring tools for tutors

Game-Tutor Standardized Interface
- Discovery engines to model expert teams

Discovery engines to model individual expert behaviors

Human-Tutor Interaction Design

**PAYOFFS – REDUCED TUTOR DEVELOPMENT COSTS AND USABILITY**

- Standard architecture (GIFT) for tutor R&D
  - test new concepts and models
  - develop tutoring content and models
  - develop standards for integration with training sims
  - domain-independent approach

- Reduced cost for tutor integration with game-based training
- Reduced cost to develop expert models for individuals & teams
- Improve usability of tools for domain experts (e.g., trainers)
  - enhanced automation

Methodology derived from:


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Instructional Strategy Selection

Strategy selection models based on trainee state
Learning strategies tailored to training objectives
Strategy selection to optimize learning and retention
   Macro and micro-adaptation
   Scaffolding

Innovative machine decision techniques
Adaptive, career-long learning companion to inform instruction
Strategy selection models based on team state
Adaptive instruction in ill-defined domains

PAYOFFS – EFFICIENT AND EFFECTIVE COMPUTER-BASED TUTORING

- Efficient tutoring processes
  - content and feedback tailored to trainee needs
  - adaptive challenge-level and flow of instruction

- Effective tutoring processes
  - content selection appropriate to trainee competency
  - validated strategies for use across:
    - well-define and ill-defined domains
    - simple and complex tasks
    - various populations

σ Optimized trainee performance/retention
   2-3 σ
   4-5 σ

50% Improved strategy selection accuracy [%]
   90%
   → 100%

Technologies Driven. Warfighter Focused.

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A Computer-Based Tutoring Model

Tutor

- Sensor Module
  - raw sensor data
  - processed sensor data

- Trainee Module
  - trainee states and traits from LMS
  - new performance \( \Delta \) performance

- Pedagogical Module
  - current and predicted trainee affective and cognitive states
  - requests for performance assessment feedback
  - scenario changes

- Domain Module
  - domain knowledge from LMS and training simulation data
  - competency to LMS
  - filtering schema to communication module instructional strategies
  - instructional media and strategies

- Communication Module

- Server-based Learning Management System (LMS)
  - input new trainee states
  - output initial trainee states
  - domain knowledge
  - trainee competency
  - trainee demographics

Service Oriented Architecture (Communications Framework)

- HLA: entity states, entity interactions

Sensors

Trainee, raw user input

Local Client

Server-based Training Simulation

GiFT

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A Team Tutoring Model

Adapted from:

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Bob’s Vision for Mobile Tutoring 2025

Conceptual → Practical → Ubiquitous

- personalized learning for individuals and teams
  - as common as smart phones are today
  - low-cost, distributed, portable, passive sensing
  - natural interaction available via small interface package
    - glasses – 3-D visual and aural stimulation; communications; eye tracking; mixed reality; natural language interaction
    - gloves – behavioral and physiological measures; haptic feedback

- accelerated learning and facilitated retention through:
  - tailored learner modeling
  - efficient, adaptive and challenging pedagogy

- learning framework to support:
  - rapid content and model development
  - concept evaluation
  - practice, training, education
  - decision-making in operational contexts
  - standard measures of tutor capabilities and effectiveness
Platinum Tutors

• adapt to the learner **better** than a human tutor

• enable learning **better** than a human tutor

• **fully perceive** learner behaviors and physiology through **remote** sensing

• support fully **mobile** training

• are **consistently accurate** (near 100%) in classifying the learner’s cognitive/affective state in near real-time

• have an **optimized** repertoire of instructional strategies

• are **automatically integrated** with a variety of training platforms (e.g., serious games, commercial/military training simulations).