Enhancing the Power of Game-based Training with Adaptive Tutors

Robert Sottilare, Ph.D.
Associate Director for Science & Technology
Human Research & Engineering Directorate
Army Research Laboratory

Director, Learning in Intelligent Tutoring Environment (LITE) Laboratory
@ SFC Paul Ray Smith Simulation & Training Technology Center

29 March 2012
Tutorial Outline

- Introduction & motivation
- Fundamentals of adaptive computer-based tutoring
- Adaptive tutoring concepts
- Generalized Intelligent Framework for Tutoring (GIFT)
- Game-based tutoring demonstration using GIFT
- Game-based tutoring design recommendations
- Game-based tutoring demonstration using GIFT – time permitting
ARL Research Goals

- **Adaptive Tutoring – personalized, easy to develop, access and use tutoring solutions**

- **Adaptive Tutoring Research:**
  - Enable computer-based tutors to adapt instruction in real-time to optimize trainee learning (e.g., knowledge acquisition, skill acquisition, retention) by assessing trainee state (e.g. cognition and affect) and influencing their engagement and motivation)
  
  - Research and prototype a computer-based tutoring testbed to evaluate adaptive tutoring concepts, models, authoring capabilities, and instructional strategies across various populations, training tasks and conditions, thus enabling summative and formative evaluations including between system evaluations
Games and Tutors

- Games are engaging
- Games are production units
- Games can support a variety of missions
- Games offer prescriptive feedback based on task performance
- Games are optimized for facilitated learning
- Focus has been on training small unit kinetic tasks

- Computer-based tutors need engaging content
- Tutors are handcrafted
- Tutors are generally domain specific
- Tutors can offer adaptive feedback based on real-time and historical trainee data
- Tutors are optimized for self-regulated learning
- Focus has been on training individual non-kinetic tasks
Motivation for an Adaptive Tutor

- **A Warfighter’s Tutor MUST:**
  - have comprehensive knowledge of the **operational context** during training
  - have the capability to **adapt** to the learner’s fatigue and cognitive load
  - **prepare** the Warfighter to become his/her individual best
  - **motivate** the Warfighter to become a beneficial contributor to the learning of fellow Warfighters (**social learning**) 
  - allow Warfighters to “**train as they fight**”

MG Nick Justice, Commanding General, US Army RDECOM
Senior Leader Panel on Adaptive Training, IITSEC, Orlando, December 2011
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

Fundamentals of adaptive computer-based tutoring
Elements of a computer-based tutor

- Training Media
- Trainee Model
- Expert Model
- Interface
- Trainee
- Pedagogy
- Domain Model


Elements of a computer-based tutor

- Training Media
- Trainee Model
- Expert Model
- Interface
- Pedagogy
- Domain Model
- Trainee
Elements of a computer-based tutor

also known as the learner, user, student or tutee

individually

Trainee

teams
Elements of a computer-based tutor

- Training Media
- Trainee
- Expert Model
- Interface
- Pedagogy
- Domain Model
Elements of a computer-based tutor

Trainee Model

domain-independent

basis for “adaptive tutoring”

what the tutor knows about the trainee...

• progress toward objectives
• actions taken through the interface (e.g., fire a weapon)
• sensor data (e.g., behavioral, physiological)
• survey data
• other historical data (e.g., previous performance)
Assessing cognition and affect during training is on the critical path of adapting to the trainee's individual learning needs.
Cognition and Affect

- **Cognitive learning**
  - behaviors indicating increasingly complex and abstract mental capabilities
    - Remembering (low)
    - Understanding
    - Applying
    - Analyzing
    - Evaluating
    - Creating (high)

- **Affective learning**
  - behaviors indicating emotional growth
    - Receiving (awareness)
    - Responding (interest)
    - Valuing (appreciation)
    - Organizing (responsibility)
    - Characterizing (commitment)

Source: Anderson and Krathwohl's Taxonomy (2000) aka Bloom’s Revised Taxonomy

Source: Krathwohl’s Taxonomy
Elements of a computer-based tutor

- Domain Model
- Training Media
- Trainee Model
- Pedagogy
- Trainee
- Expert Model
- Interface
Elements of a computer-based tutor

**Domain Model**

- **the stuff you want the trainee to learn...**
- **the tasks/problems presented to the trainee...**
- **the conditions in which the learning takes place**

---

Elements of a computer-based tutor

- Training Media
- Trainee Model
- Trainee
- Expert Model
- Interface
- Pedagogy
- Domain Model
Elements of a computer-based tutor

the trainee’s access to the training environment...
and the computer’s capability to collect data about the trainee

data & language I/O & sensory stimuli

Interface

Natural Language Interface

domain-independent
Elements of a computer-based tutor

- Training Media
- Domain Model
- Trainee Model
- Pedagogy
- Trainee
- Expert Model
- Interface
Elements of a computer-based tutor

Training Media

generally domain-dependent, but games offer some domain-independence... many missions can be trained in games

the training environment... computer media used to deliver training...

• simulation, game, powerpoint...
• ideally, adapted to support individual/team learning needs
Elements of a computer-based tutor

- Training Media
- Trainee Model
- Trainee
- Expert Model
- Interface
- Pedagogy
- Domain Model
Elements of a computer-based tutor

perceptions, decisions and actions of an expert ...

• sets standards modeled on an “ideal trainee”
• defines mastery standards
• compares trainee actions to determine progress

domain-dependent

Expert Model
Elements of a computer-based tutor

- Training Media
- Trainee Model
- Trainee
- Expert Model
- Interface
- Pedagogy
- Domain Model
Elements of a computer-based tutor

how you want the trainee to learn...

• pace
• challenge level
• support
• selection of instructional content, instructional strategies and feedback

we want pedagogy to:

• adapt to trainee’s learning needs
• be domain-independent


Elements of a computer-based tutor

- Training Media
- Trainee Model
- Expert Model
- Interface
- Trainee
- Pedagogy
- Domain Model
Elements of a computer-based tutor

- Domain Model
- Trainee Model
- Pedagogy
- Trainee
- Interface
Adaptive game-based tutoring schema
Interaction in game-based tutoring

Tutoring Agent(s)

1. agent observes world
2. agent acts to change world
3. agent observes effect on game objectives

Game World

Trainee

1. agent observes trainee
2. agent acts to provide feedback or instruction
3. agent observes effect on learning

Trainee acts on world

Game World

trainee observes world
Adaptation Schema

- **Macro-adaptation for learning**
  - *pre-training* tailoring based on historical data
  - initializes trainee model
  - affects domain content and objectives
  - evaluates *recency*...
    - e.g., prerequisites taken 20 years ago vs. last 6 months

- **Micro-adaptation for learning**
  - *in-situ* tailoring of training based on:
    - performance, cognitive & affective states derived from sensor data
  - near real-time assessment of sensor data
  - maintains trainee model
  - evaluates *recency*...
    - e.g., localized vs. global effects in feedback decisions
Making Adaptive Tutoring Practical

- Low-cost, passive sensing of trainee physiology and behaviors
- Near real-time classification of trainee cognition and affect
- Near real-time selection of optimal instructional strategies (questions, reflection, hints, prompts, pumps...) based on:
  - Cognition (attention, engagement, understanding...)
  - Affect (personality, mood, emotions, motivation)
  - Historical trainee data (performance, preferences...)
  - Training context

- Automated authoring
  - Automate trainee and expert modeling
  - Standardized, mostly domain-independent tutor components and processes
  - Leverage games for tutoring

- Enhanced human-agent interaction
  - Content and strategy presentation
  - Virtual humans (optimized to support learning)
Generalized Intelligent Framework for Tutoring

GiFT
1 GIFT
1.1 Modeling
1.1.1 Trainee Modeling
   1.1.1.1 Sensing Technologies
      1.1.1.1.1 Behavioral Sensing
      1.1.1.1.2 Physiological Sensing
   1.1.1.2 State Classification
      1.1.1.2.1 Affective State Classification
         1.1.1.2.1.1 Emotion Classification
         1.1.1.2.1.2 Motivation Classification
      1.1.1.2.2 Cognitive State Classification
         1.1.1.2.2.1 Workload Classification
         1.1.1.2.2.2 Engagement Classification
   1.1.2 Expert Modeling
1.1.3 Domain Modeling
1.2 Instruction
1.2.1 Content
   1.2.1.1 Content Authoring
   1.2.1.2 Content Delivery
   1.2.1.3 Content Validation
1.2.2 Instructional Strategies
   1.2.2.1 Instructional Strategy Authoring
   1.2.2.2 Instructional Strategy Delivery
   1.2.2.3 Instructional Strategy Assessment

open source tools, standards and best practices to:

- **author tutoring systems**
  - domain content
  - instructional strategies
  - human-system interaction
  - expert models

- **provide instruction**
  - present content
  - implement strategies

- **assess effectiveness**
  - learning effect size
  - performance effect size
Individual tutoring schema

Tutor A (local)

- Sensor Module
  - Raw sensor data
  - Processed sensor data
  - Trainee states from LMS and training simulation

- Trainee Module
  - Current and predicted trainee affective and cognitive states

- Pedagogical Module
  - Performance
  - Requests for performance assessment feedback scenario changes

- Communication Module
  - Domain knowledge from LMS
  - Competency to LMS

- Domain Module
  - Instructional media and strategies

- Trainee A
  - Trainee actions
  - Trainee actions raw user input

Server-based Learning Management System (LMS)

- Input: New trainee states
  - Competency
  - Domain knowledge
  - Trainee competency
  - Trainee demographics
- Output: Initial trainee states

Service Oriented Architecture (Communications Framework)

- Input: Trainee interaction data
  - Trainee actions
  - Raw user input
- Output: Simulation states
  - Entity states
  - Entity interactions

Server-based Training Simulation
Team tutoring schema
Assessment schema

**Generalized Intelligent Framework for Tutoring (GIFT)**

- Open source
- Modular, reusable components
- Agent-based capabilities
- Server-based architecture
- Sensor interface library
- Scenario library
- Survey library tool
- Game-based tutoring interface
- Tutoring assessment standards

**Tools to support:**
- Automated Authoring
- Concept Assessment
- Individual training
- Small unit training
- Desktop training
- Kinetic training
- Distributed (mobile) learning
- Social learning

**Coming soon…**
- AutoTutor interface
- Automated Expert Modeling Methods
- Virtual Human interface

**Assess → Model → Predict → Adapt → Influence Learning**

*TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.*
Game-based tutoring demonstration using GIFT
Game-based tutoring design recommendations
Next Steps for Educational Technology

- User Modeling
- Mobile Learning
- Networking Tools
- Serious Games
- Intelligent Environments
- Educational Data Mining... Big Data
  - Tailored content development
  - Methods to generate expert models
- Rich Interfaces

Research question: what is the minimum set of sensors needed to assess engagement, workload, motivational level and emotional state?

Bob playing in traffic : )
Standards for Game-based Tutor Interaction

Standards to Assess/Compare Tutor Performance

- 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
- Fully support **mobile** training
- Are **consistently accurate** (near 100%) in classifying the learner’s cognitive 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)

Challenges Ahead for Game-based Tutoring

- Limitations/challenges imposed by desire to generalize across:
  - different game platforms and training domains

- Limited push/pull of data through game interface:
  - DIS/HLA interfaces... not all games have these interfaces
  - Scripting interfaces... need standard interfaces
  - Remotely controlling game entities using intelligent agents

- Applying context to trainee state assessment

- Need for terrain reasoning in the tutor
  - understanding the significance of location to learning objectives
Challenges Ahead for Game-based Tutoring

- Translation of subject matter expert knowledge into tutor expert model
  - automating knowledge acquisition to reduce development costs
  - validating expert models

- Optimizing instructional strategies for individuals and teams

- Recognition of learning need events by the tutor*
  - when presented with new learning opportunities
  - when motivated to learn more
  - when trying to recall information
  - when things change
  - when something goes wrong

* Adapted from: Five Moments of Learning Need, Conrad Gottfredson, co-author of “Innovative Performance Support”
Adaptive and predictive computer-based tutoring track


Key Dates:

Submissions of Extended Abstracts (2 pages): April 12, 2012
Notification of acceptance: May 12, 2012
Final Camera-Ready Submission: June 12, 2012
Early Registration: July 01, 2012
Selected Readings:

Woolf, B. P. (2010). *A Roadmap for Education Technology*. National Science Foundation # 0637190


Coming soon:

- Generalized Intelligent Framework for Tutors (GIFT) Build 1.0
- GIFT Interface Control Documentation
- GIFT Research and Design Documentation
Thank you for your attention!

Questions?

robert.sottileare@us.army.mil
Game-based tutoring demonstration using GIFT