

Intelligent Tutoring Systems (ITSs): Advanced Learning Technology for Enhancing Warfighter Performance

I/ITSEC 2012 Tutorial

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Learning Objectives

Tutorial attendees will be able to:

1. Describe an ITS, including its benefits
2. Determine whether an ITS is applicable and beneficial to a particular training simulation and context
3. Describe the components of an ITS along with methods commonly used to develop them
4. Describe the steps in the ITS development process
5. Depending on their background, perform or manage the ITS development process and/or individual steps within it

ITS Tutorial Overview

Description

High Level Context

Benefits

Components

ITS Development Process

Development Example

ITS Description

ITS Actions: ITSs do...

Evaluate performance in simulators (or other problem-solving environments) & debrief

Monitor decisions & infer knowledge/skill

- & student's ability to APPLY them when appropriate

Mimic human tutor by adapting instruction

Include “Student Model” - Mastery Estimate based on Student's Performance in Scenarios

Formulate instructional plans

ITS Attributes: ITSs are...

Based on Artificial Intelligence (AI)

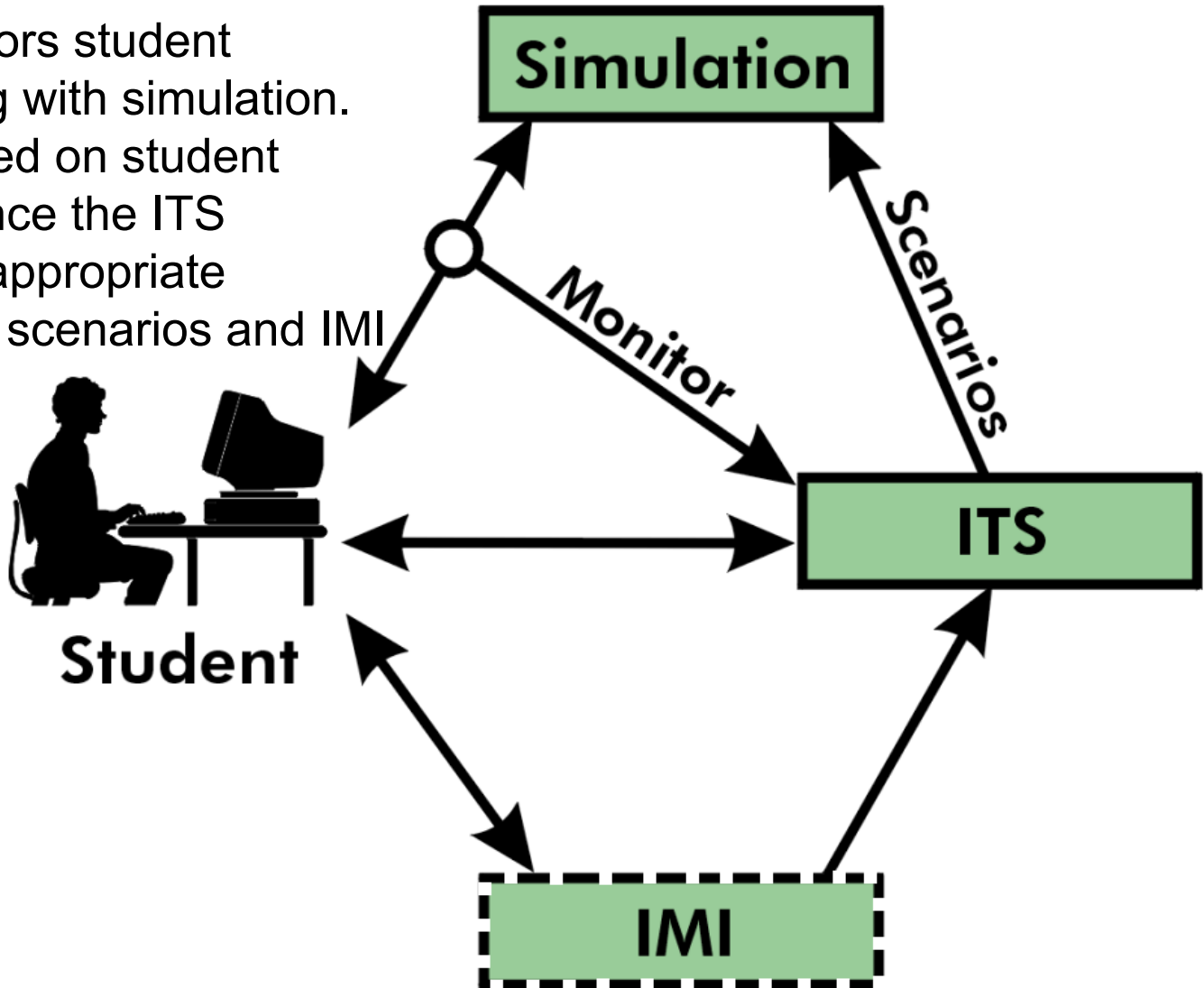
- Instruction adapted from Student Model, not directly on actions (branching)

Not Interactive Multimedia Instruction (IMI)

Interfaced to free-play simulators & often IMI

High Level Context

ITS monitors student interacting with simulation. Then based on student performance the ITS provides appropriate simulated scenarios and IMI



ITS Benefits

Training Benefits

Provides tactical decision making practice with feedback

Improves student problem-solving skills

Automatic After Action Review (AAR)

Improved training outcomes compared to classroom instruction

Improved training outcomes compared to traditional Computer Based Training (CBT)

Training/Evaluation more operationally realistic and relevant

Efficiency Benefits

Off-loads or replaces instructors not present (i.e. embedded)

More efficient student learning (tailored/customized)

Resource Benefits

Allows the use of lower fidelity simulations

Capture/distribute expertise of best instructors to all students

Leverages existing simulators and/or CBT

Quantitative Evaluation Results

Few in number, unfortunately normally not done

AF: Sherlock, diagnose electronics, 6 month post test results:

- Experts: 83%, ITS Group: 74%, Control Group: 58%

Carnegie Learning Algebra ITS: 87% passed vs. 40% without

LISP Programming Language ITS: 45% higher on final exam

Database programming tutor: improved 1 standard deviation

US Naval Academy: Andes Physics Tutor: improved 0.92 sd

CMU LISTEN Reading Tutor:

- Statistically significant improvement versus reading alone

US Navy SWOS: TAO ITS: Student Survey Results:

- Classroom aid: 75% Extremely Fav., 17% Fav., 8% Neutral
- Standalone Training Tool: 83% Ex. Favorable, 17% Favorable

Almost all studies show measurable improvements

Components

Evaluation Module

Simulation Interface

Student Model

Auto AAR/Debriefing Module

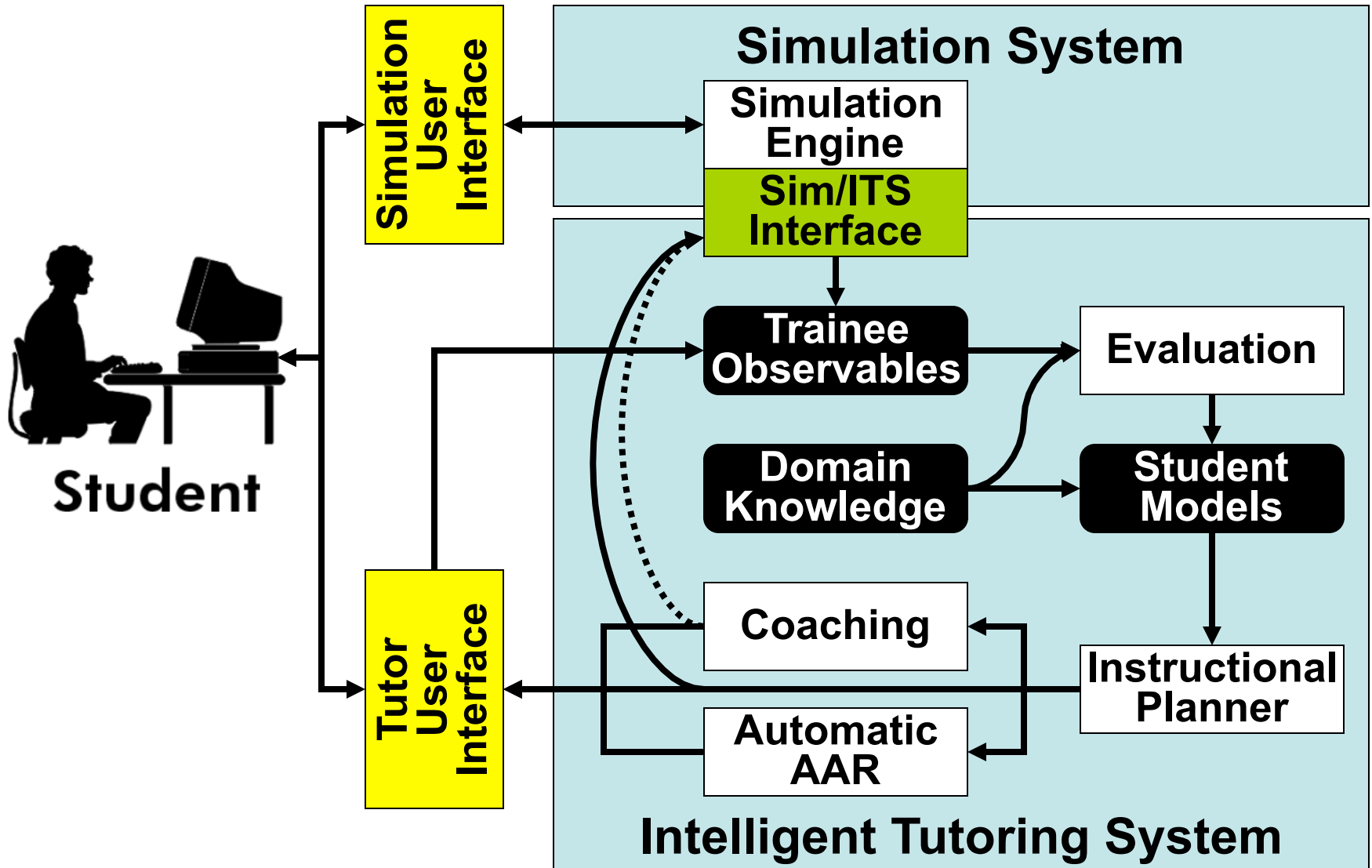
Instructional Planner

Coaching Module

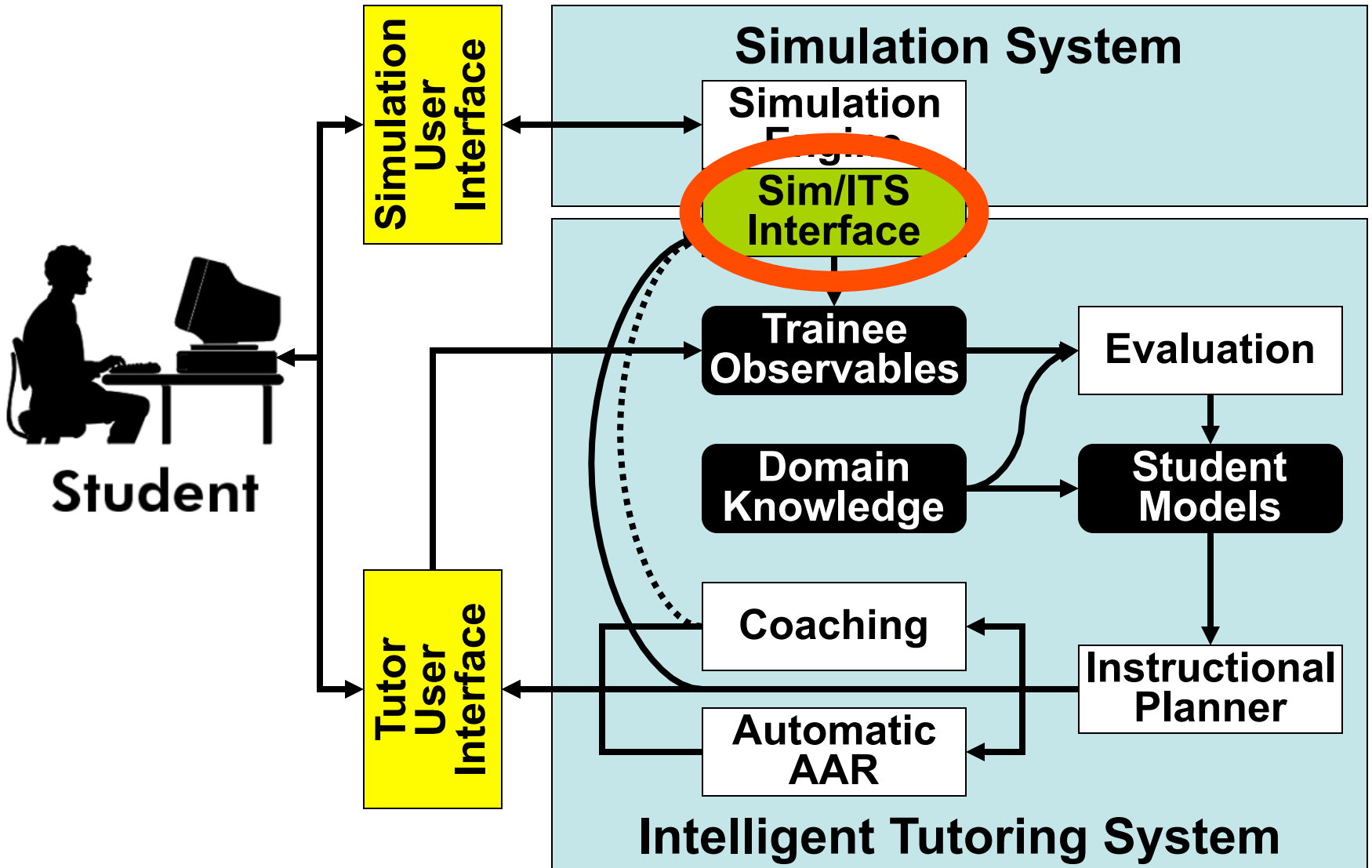
Domain Knowledge

User Interface (UI)

Overall Architecture



Simulation User Interface



Simulation Interface

Simulation data input to the ITS

- Distributed Interactive Simulation (DIS)
- DIS with embedded data
- High Level Architecture (HLA)
- HLA with extensions
- Log files
- Custom interface

Optional: ITS outputs to the simulation

Simulation Interoperability Standards Organization (SISO)

Draft ITS/Simulation Interoperability Standard (I/SIS)

- [SISO-REF-011-2005: Intelligent Tutoring System Interoperability \(ITSI\) Study Group Final Report](#)
- <http://www.sisostds.org/ProductsPublications/ReferenceDocuments.aspx>

SISO Draft I/SIS Overview

HLA/DIS Based

Move information via HLA/DIS

Information Represented in XML or a specific XML standard

Service Request/Response

Platform and Aggregate details and interactions available in
DIS and standard Federation Object Models (FOMs) (Real-time Platform-Level Reference (RPR), Naval Training Meta-FOM (NTMF), etc.)

Standardized definitions for planning objects (tactical graphics or other planning documents)

XML formatted orders, text, audio, displayed units/values

XML formatted control actions and instrument values

HLA/DIS Simulation Management capabilities

Level 1

Service Requests (SR) via Action Request messages

Feedback SR

Developer Created Documentation of Interface

Tactical Decision Making (TDM) ITSs

- DIS or HLA RPR FOM
- ITS access to additional scenario-related ITS information

Equipment Operations/Maintenance (EOM)

- XML Data in Experimental PDUs or HLA Simulation Data Interaction in I/SIS FOM
- XML formatted lists of control actions and instrument values

Level 2

Interactive Feedback SR

Controlling component sends and other accepts Start/Resume & Stop/Freeze Simulation Management (SIMAN) messages

Universal Unique Identifier (UUID) Student IDs

Logon SR from controlling component

Log Annotation SR

Tactical Decision Making (TDM) ITSs

- XML Data in Experimental Protocol Data Units (PDUs) or HLA Simulation Data Interaction in I/SIS FOM
- Orders in XML, Audio in files/XML, other communications/actions/context in XML
- Military Scenario Definition Language (MSDL) & XML Scenario Files

Equipment Operations/Maintenance (EOM)

- XML Scenario Files
- ITS access to additional scenario-related ITS information

ITS Centered (IC)

Level 1

- Command Line Simulation Start (scenario file)

Level 2

- ITS sends and Sim accepts Reset, Load Scenario, & Start AAR SRs
- Entity control via HLA Ownership Switch or DIS Set Data

Simulation Centered (SC)

Level 1

- Command Line ITS Start (scenario file)

Level 2

- Simulation sends and ITS accepts Evaluation, Coaching, and Debriefing SRs,
- Simulation Sends and ITS accepts Assign Team Member SR

Optional Levels

LIDR – ITS Driven Replay

- Set Time SR
- Set Perspective SR
- Play SR
- Freeze SR

LCSE – Coordinated Scenario Entry

- Command Line Start of Sim & ITS Scenario Editors
- Sim notifies ITS of scenario changes
- Level 2 implemented
- LSUI implemented
- LCSE Feedback SR
- LCSE Interactive Feedback SR

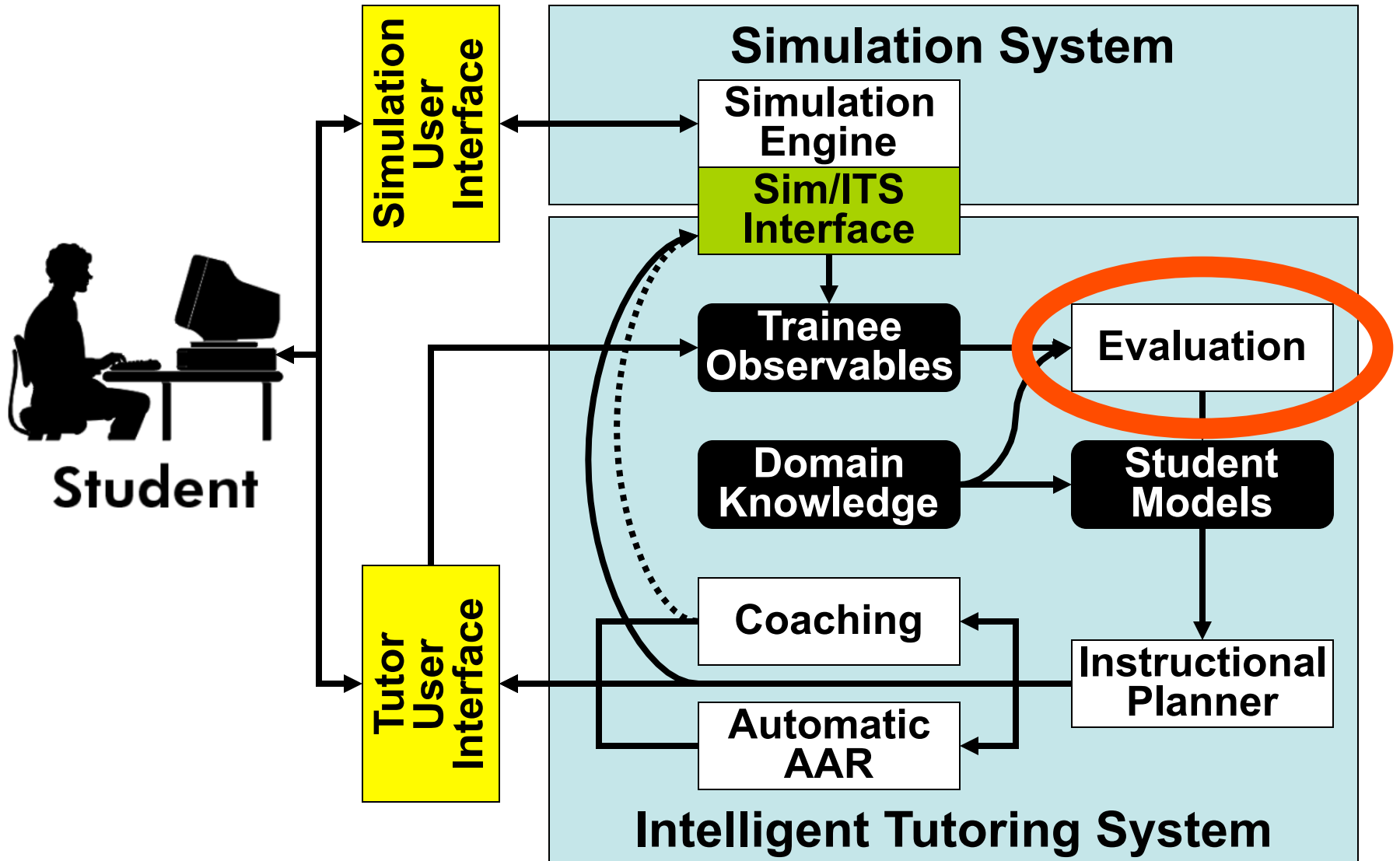
LSUI – Simulation User Interface partial control from ITS

- LSUI Feedback SR
- LSUI Interactive Feedback SR

Additional Items

- XML Data and SRs as required

Evaluation Engines



Evaluation – FSMs

Often useful for real-time tactical decisions

Network of states

Transitions between states

Finite State Machine (FSM) is in **one state** at a time.

Each state may have software that executes

Each transition has a **condition**

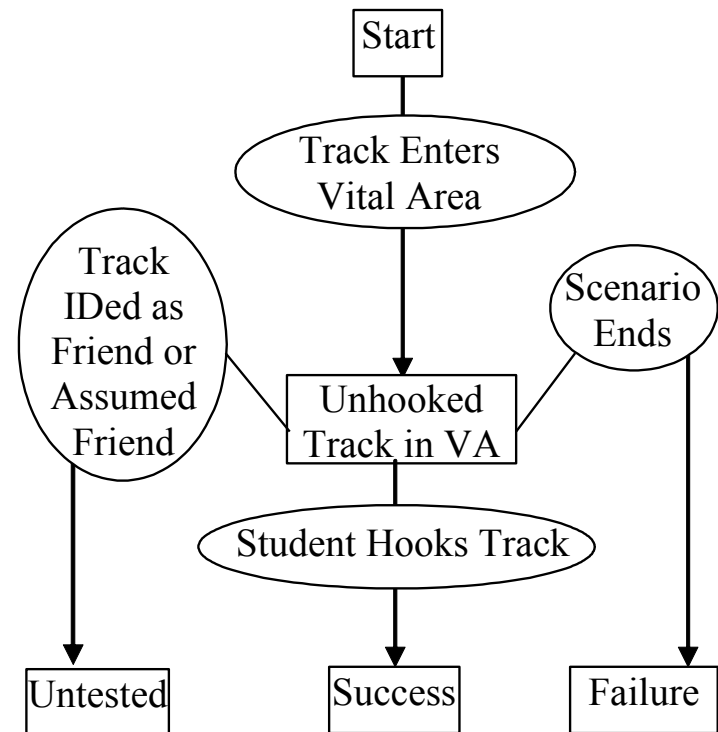
When true, transition from one state to another

FSMs have **1 initial state**

Part looks for **a situation** type

Remainder **evaluates** student response to that situation

Many operate in parallel



Evaluation - Comparison

Often useful for plan/analysis evaluation

Student creates solution

- e.g. a plan, encoded as a set of symbols

Expert has previously created solutions

- Expert plans can be good or bad solutions
- Using augmented student multimedia interface
- Expert plans annotated with reasons good or bad
 - Bad symbols include reasons why choice is bad
 - Good symbols include rationale (why needed, unit type, size, general location, specific location)

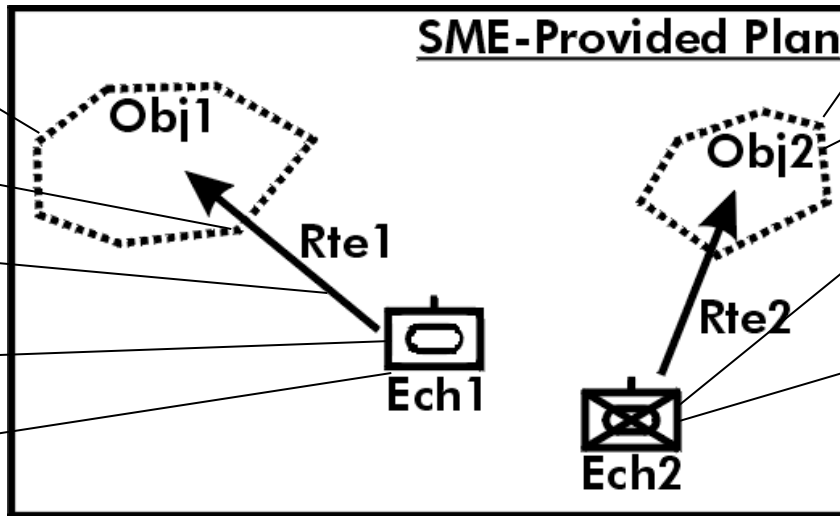
Compare student's plan to expert plans

- Debrief based on differences from good plans
- Debrief based on reasons matching plan is bad

Evaluation - Comparison

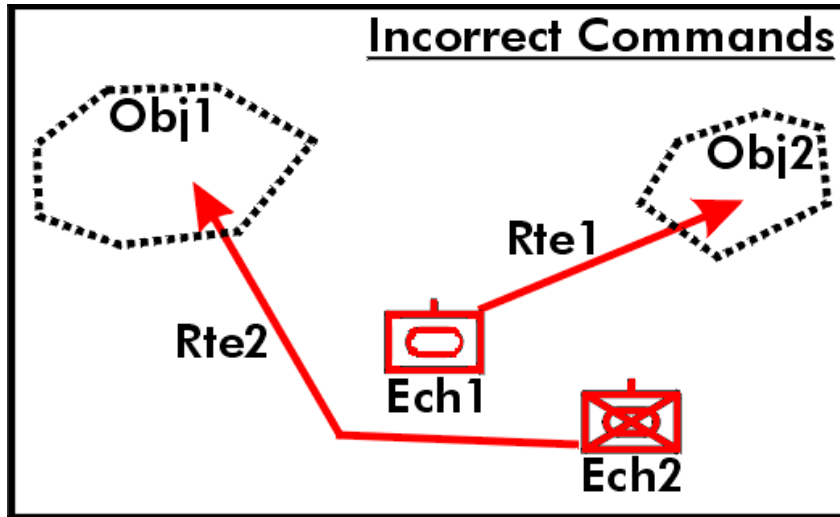
Plan Evaluation Example

Cmnd Cntr
 Weakest
 Covered
 Ar to Attack
 Main Effort



Protect R Flank
 Defensible
 MI to hold terrain
 Company to hold
 Battalion

Failed:
 Covered;
 Ar to Attack;
 Main Effrt;
 MI



Student Debrief:
 Use armor to attack
 Maximize M effort
 Use Covered Rte
 MI to hold terrain

Evaluation – Comp. (Expected Actions) Task Tutor Toolkit

Purpose Enable rapid development of tutoring scenarios for technical training that provide step-by-step coaching and performance assessment.

Approach Solution template encodes the correct sequences of actions for each scenario, with some variation allowed.

Authoring tool enables rapid development by demonstrating, generalizing, and annotating solution templates.

Evaluation – Cognitive Modeling

Traditional ITS approach

- Model the decision-making to be taught
- Construct computable model (Expert Model)
- Compare student's actions to those of the model
- Use comparison and inference trace to diagnose

Concerns

- Assumes computable model can be constructed
- Really need human if have an expert model?

Evaluation: Chat AAR Chat Log Review Tool

There is a need for a tool that will facilitate

- Debrief preparation at end of a large team training exercise
- Visualizing the large volume of chat log data
- Analysis of chat data to support AAR

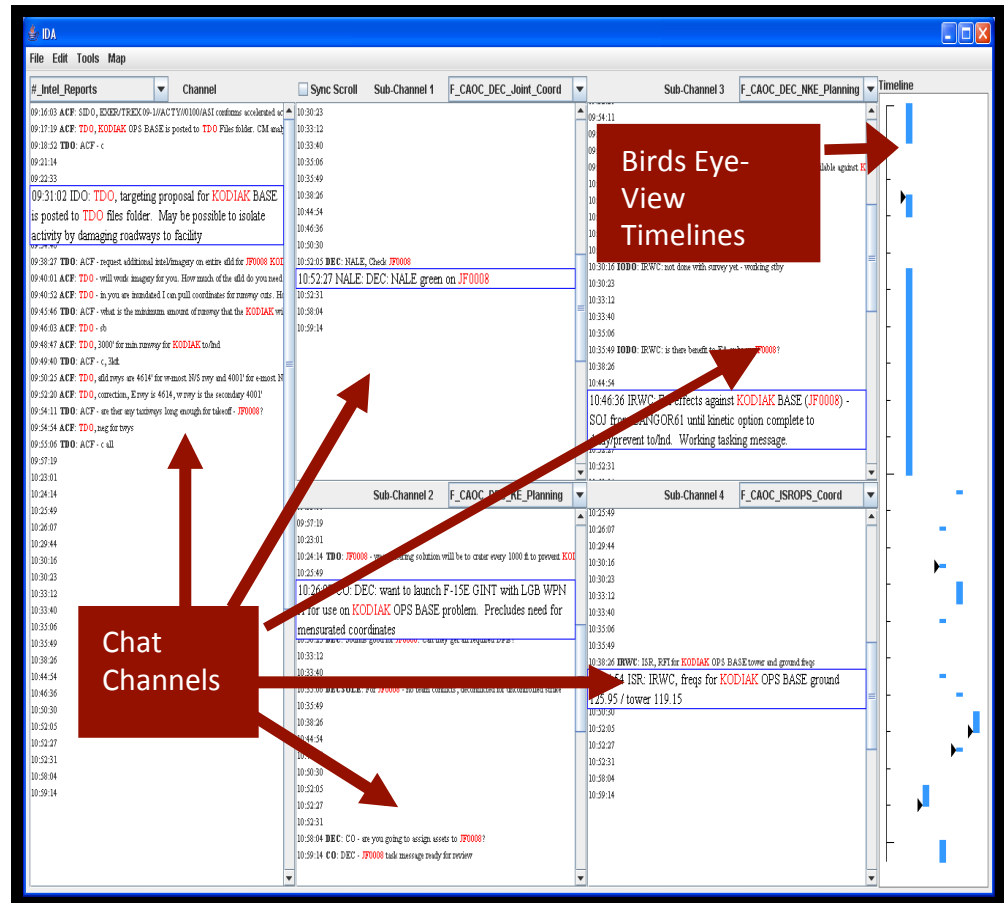
Develop a partially-automated solution

- Computers manage, organize, filter the data, & perform preliminary analysis & associations (e.g. identify dialog threads)
- Humans responsible for high-level interpretation & analysis of data (e.g. tracing through a dialog thread to identify communication breakdown)

Intelligent Diagnostic Assistant (IDA) Chat AAR Tool

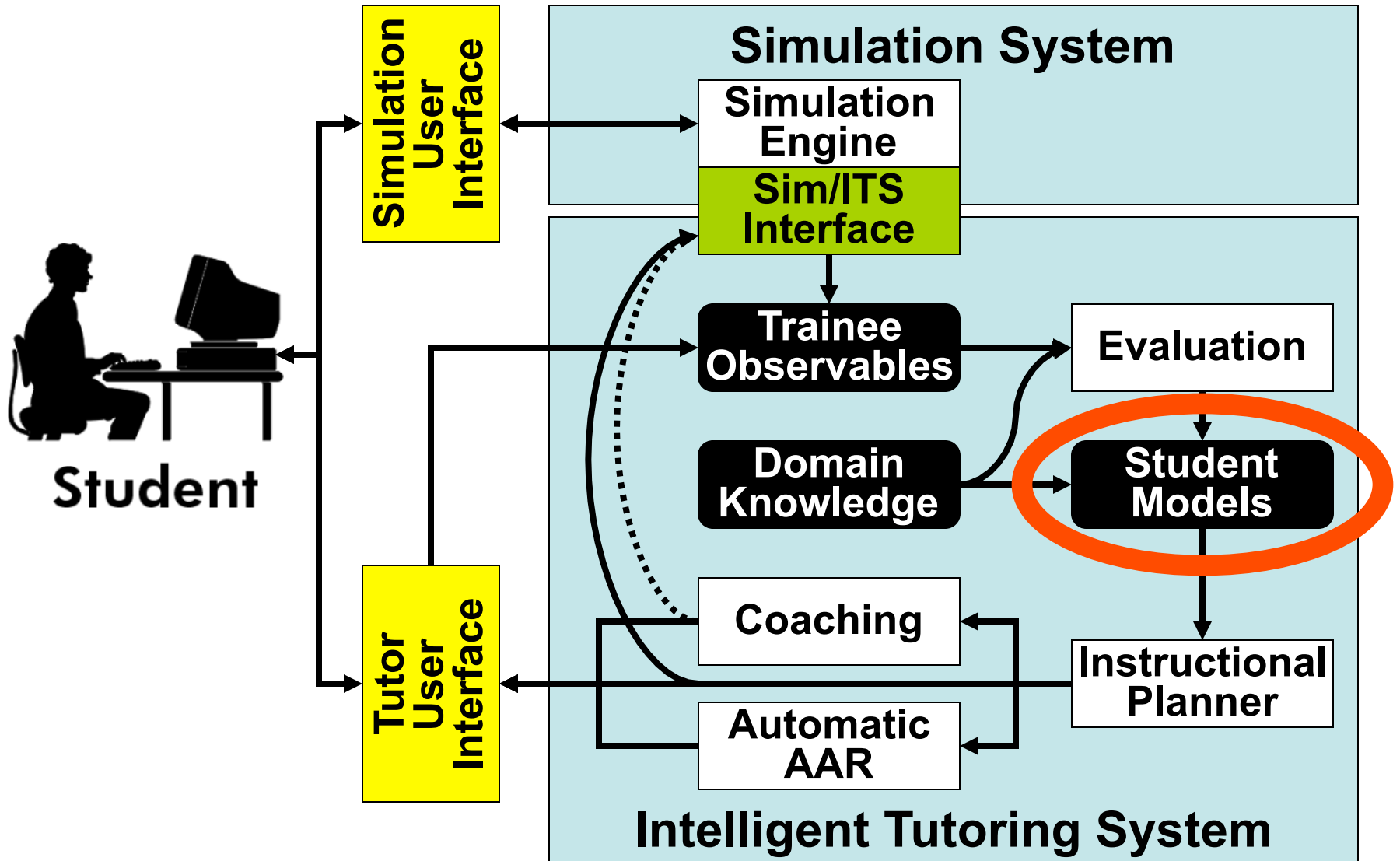
IDA supports

- Visualization and browsing of chat logs
- Automated topic identification of chat conversations



Ramachandran, S., R. Jensen, O. Bascara, T. Carpenter, T. Denning, S. Sucillon (2009) After Action Review Tools For Team Training with Chat Communications. *Proceedings of the Industry/Interservice, Training, Simulation & Education Conference (IITSEC 2009)*.

Student Modeling



Student Model

Mastery Estimate of skills and knowledge

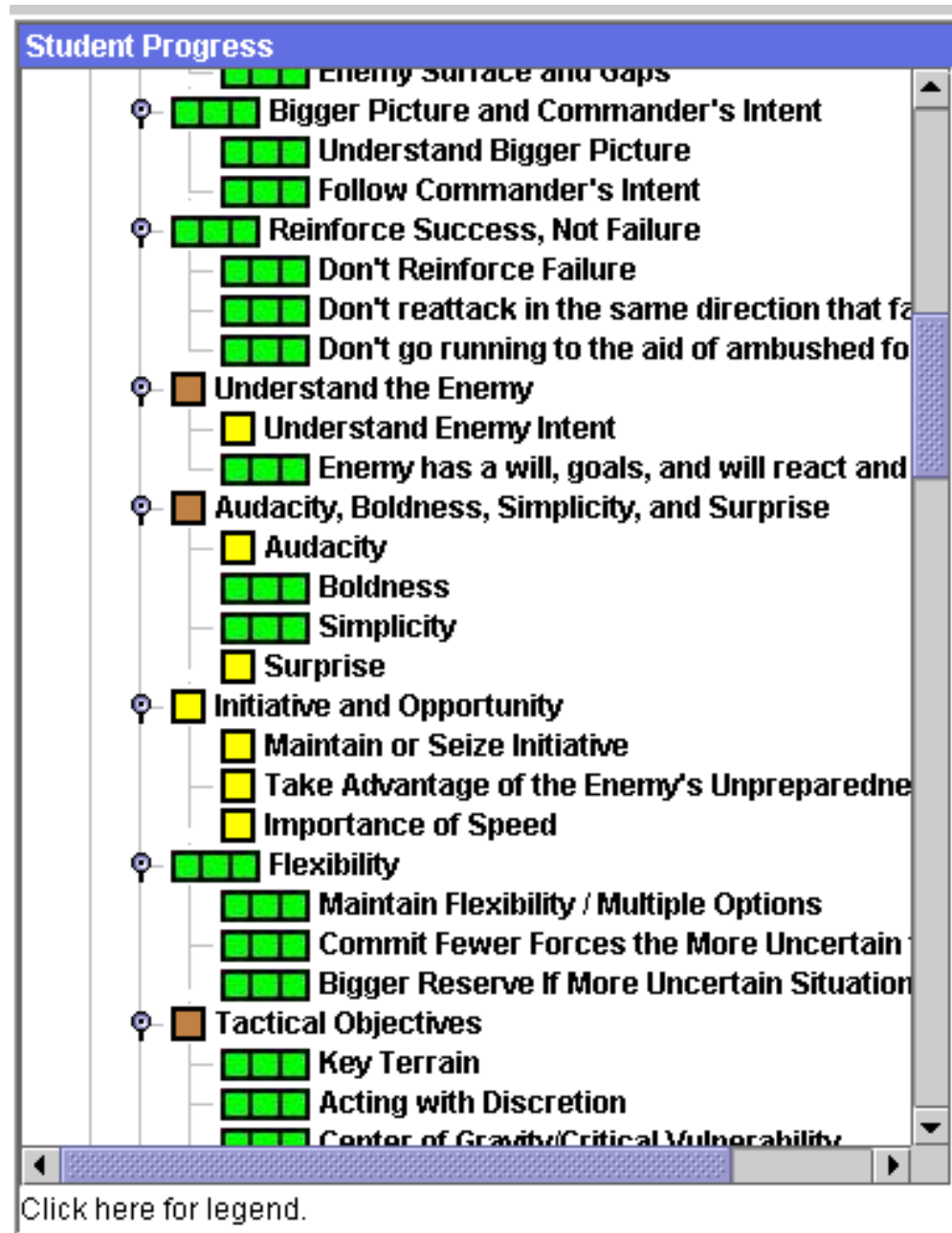
- Student's ability to APPLY them as appropriate
- Inferred from actions in **all** simulated scenarios
- “Principle” hierarchy (many dimensional)
- Parallels domain knowledge model

Each principle mastery estimate based on number of relevant, recent successes/failures

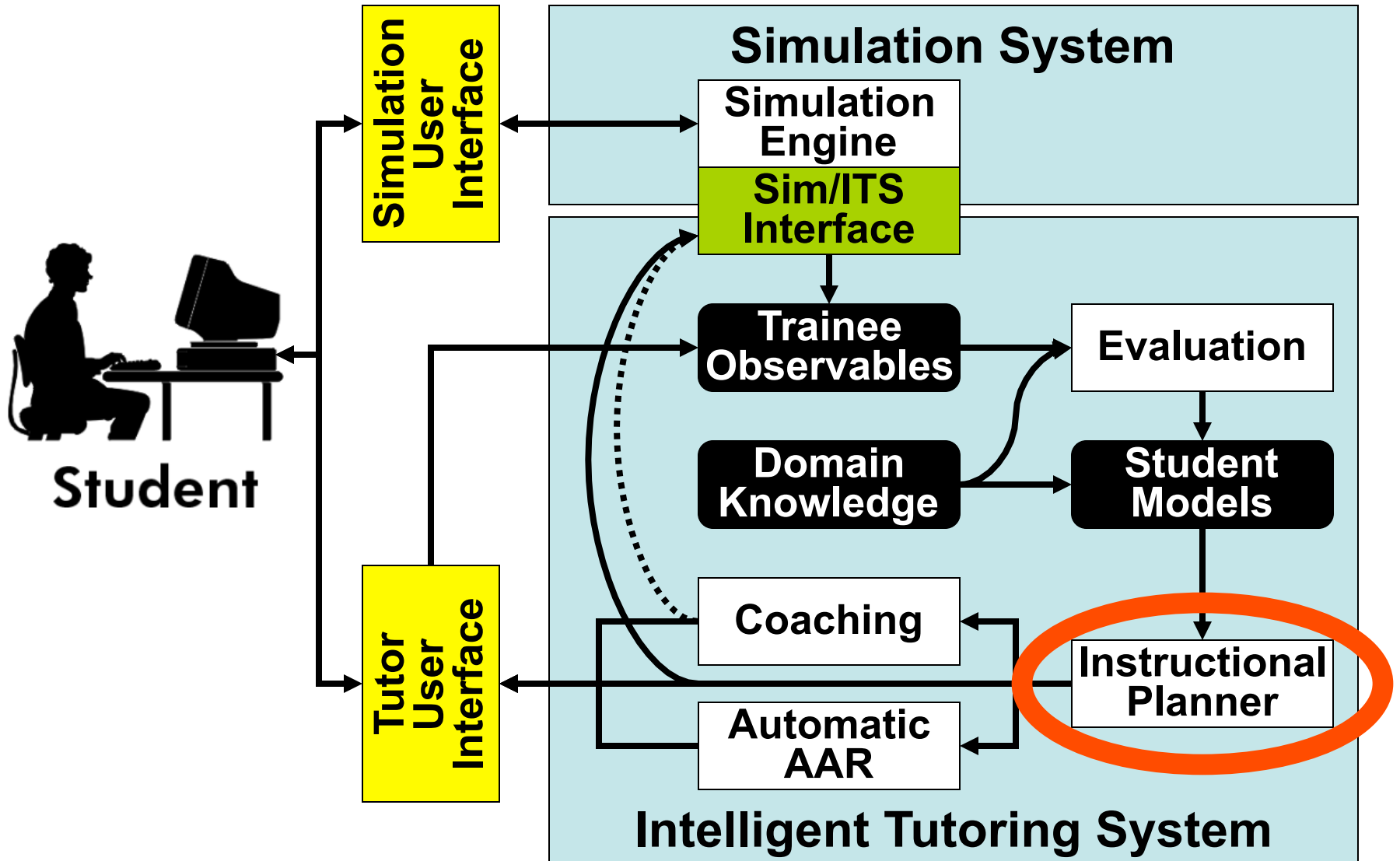
Uses:

- Feeds into all instructional decisions by ITS
- Can present as feedback to student
- Can report to instructor/supervisor/commander

Student Model Example:



Instructional Planner



Instructional Planner

Formulates instructional plan from student model

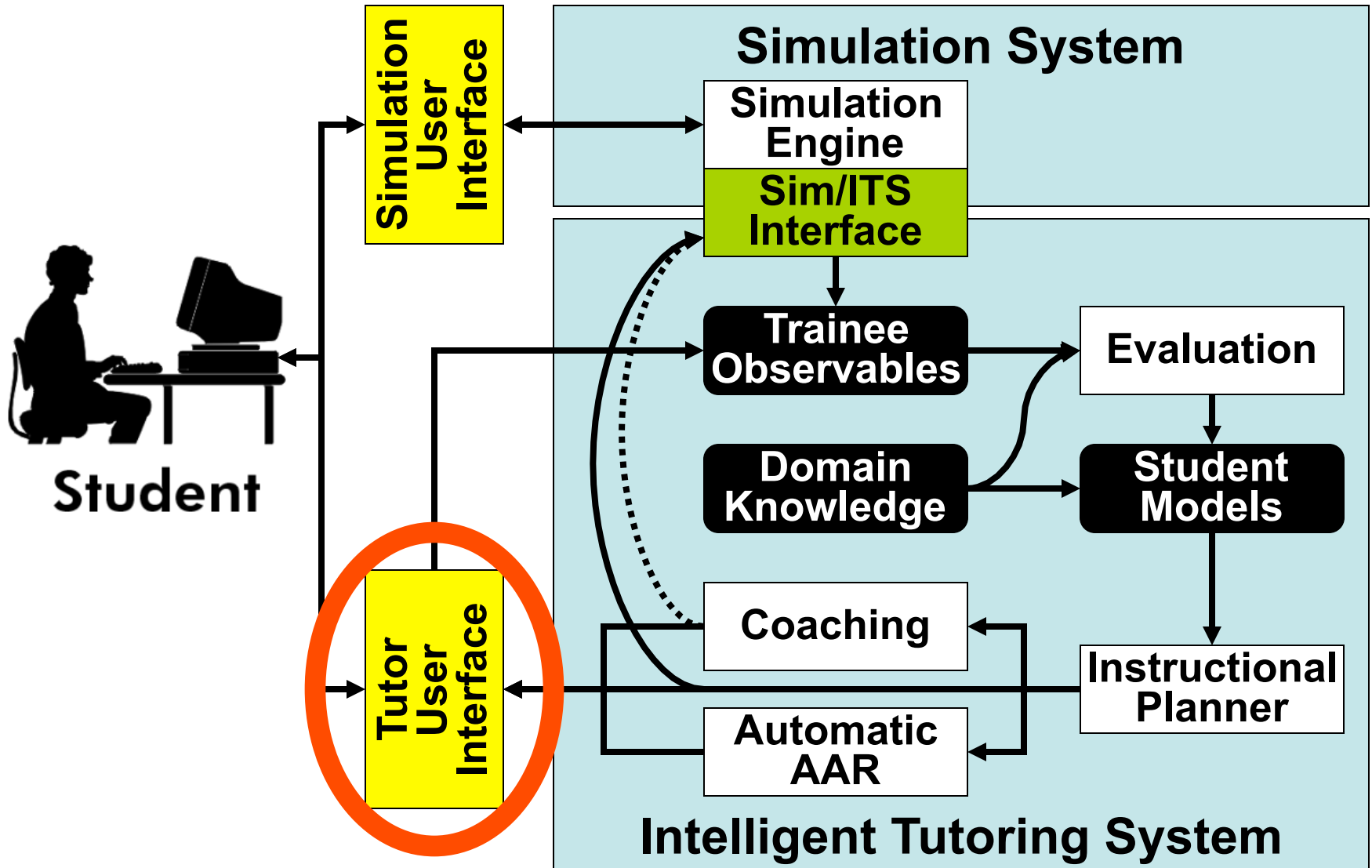
Decides next instructional event

- Next scenario
- Hint
- Positive/negative feedback, when
- Remedial exercises
- Direct instruction
- IMI
- Demonstrations

Student population diversity affects complexity

Developed with tool/Java/C++/AI Planner/etc.

Tutor User Interface



User Interface

Session management & information conduit...

- Logon, briefing, hints, feedback, questions, etc.

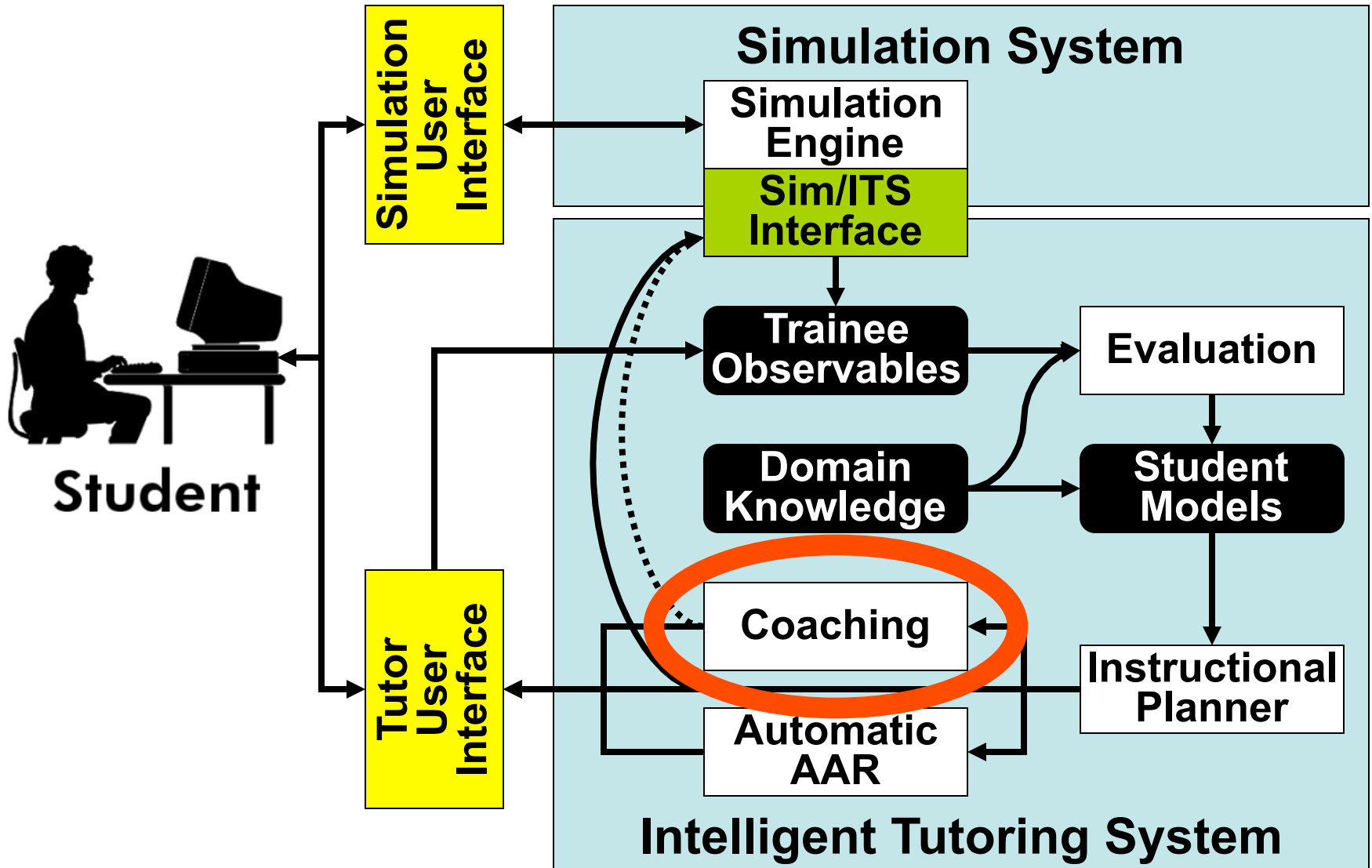
Variety of control schemes

- Student control
- Off-line instructor control
- Live instructor control (coordination required)
- ITS control
- Dynamic mix (requires careful usability design)

Possibly integrated into simulation

- ITS window
- Simulation window
- Simulation “character”

Automated Coaching



Coaching

Real-time simulation interface for evaluation

Immediately notify student of mistakes

Proactively hint when student likely to fail

- Based on student model & principles about to fail
- Least specific hint which allows correct decision

Reactively respond to student questions

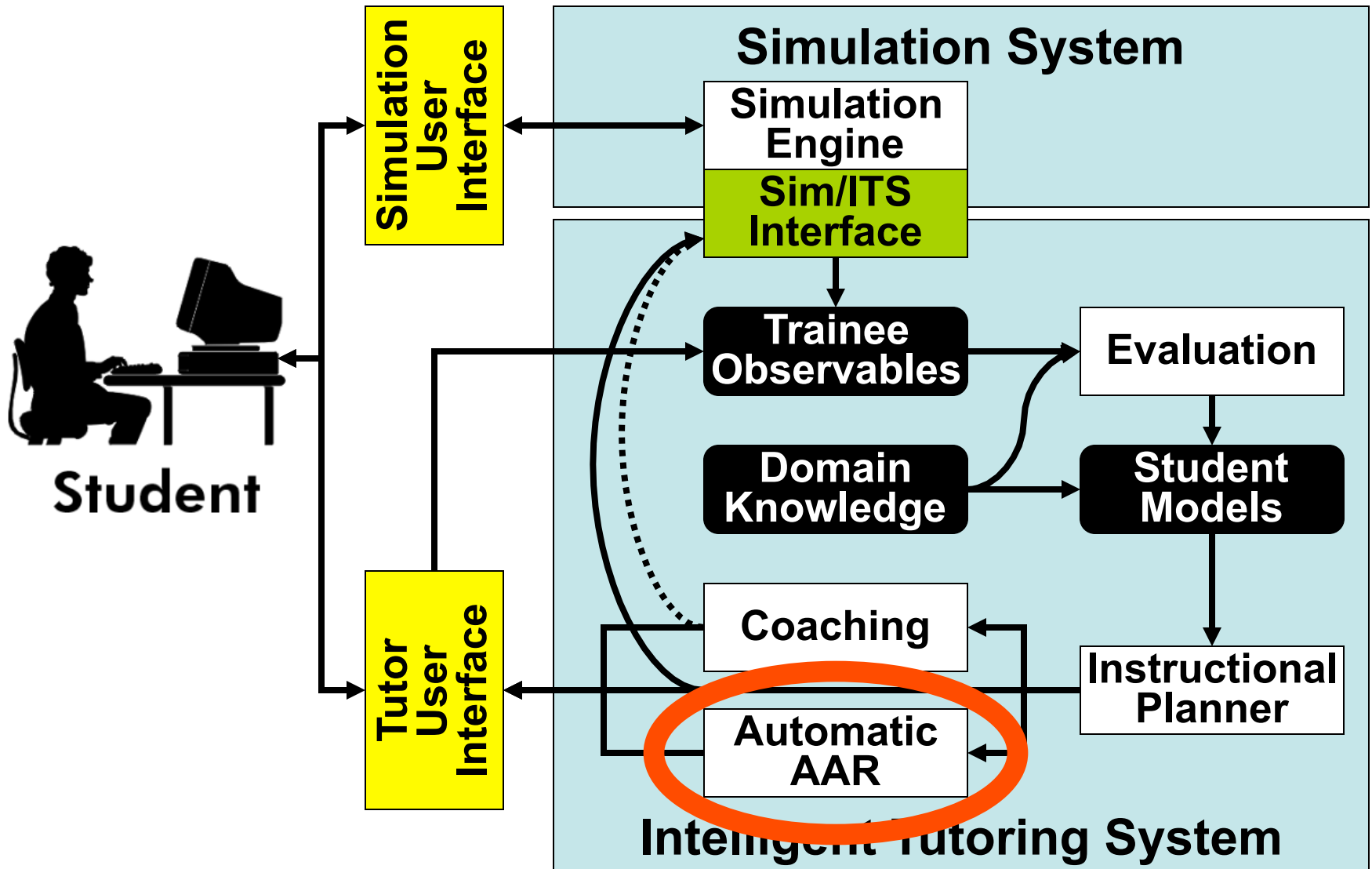
Less commonly notify student of correct actions

- Most appropriate for beginners

Aim to avoid disruption

- Small text/audio comments, highlight element, etc.

Automatic After Action Review



Automatic AAR/Debriefing

Report card format

- Sorted by Correct/Incorrect
- Sorted by priority
- Sorted by principle and principle category
- Sorted by chronology (log)
- Generally allow access to multimedia descriptions

Interactive format

Narrative format

Socratic AAR

Interactive format for AAR

Extended dialog, built around tutor questions

Tutor gets chance to build insight into student

- Not just their actions, but their *reasons* for action

Student gets chance to originate/own/explore critiques of own actions

- Not just told, but led to *conclude for self*

Can go beyond overt simulation outcomes

- Questions can address hypotheticals

ITS Authoring Process

Overall Process

Tools

Specific Example

Overall Process

Similar to Systems Approach to Training (SAT)/Instructional Systems Design (ISD)' s Analyze/Design/Develop/Implement/Evaluate (ADDIE)

Knowledge Elicitation/Cognitive Task Analysis of Problem solving and Instruction

- **Scenario based** - step through decisions

|| **Design** (in parallel with develop scenarios)

- Instructional Strategy - Scenario Practice/Debrief
- Training simulation integration requirements/available data
- Budget / Tools

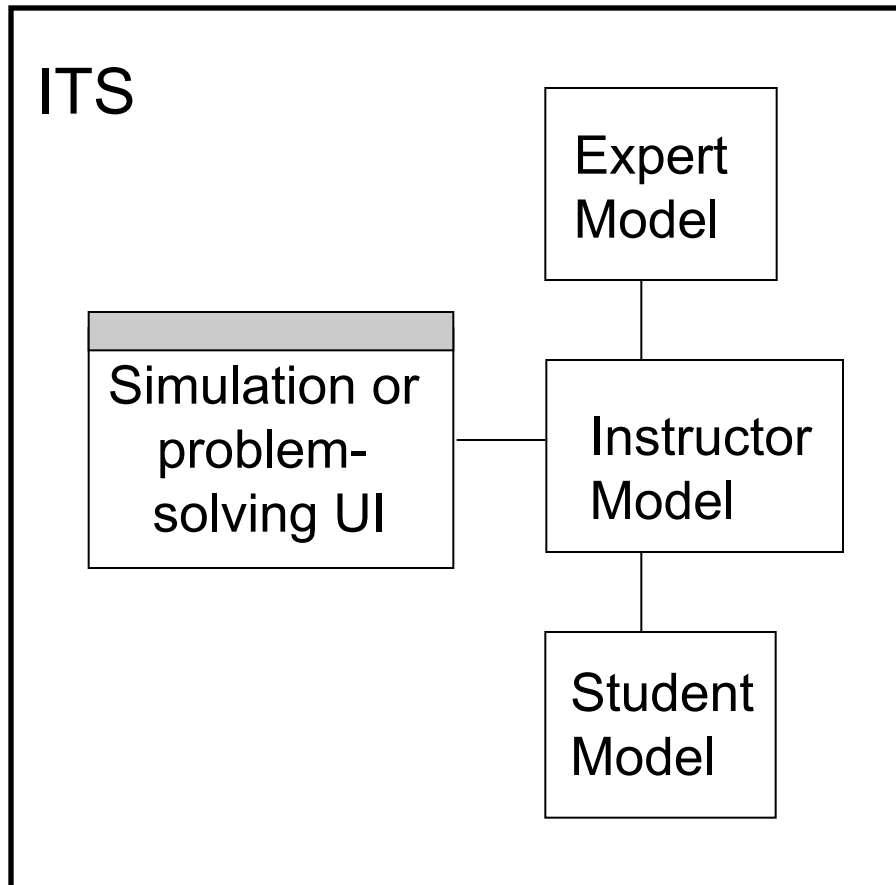
|| Develop **Scenarios** (in parallel with design)

Implement/Integrate

Evaluate

Evolve/Iteratively Improve, **Spiral** Methodology

ITS Relevant Authoring Tools



What they are teaching

How to teach

Who they are teaching

Relevant Authoring Tools

Entire system (simulation & ITS, combined) RIDES/
VIVIDS, SIMQUEST, SimCore

Academic Domain Authoring Tools (Tom Murray Book)

Sim. development tools (many); IMI Dev. Tools (several)

Constraint-Based Tutors

ITS authoring

Evaluation authoring

Specifics:

- SimBionic / SimVentive
- Task Tutor Toolkit
- FlexiTrainer
- Cognitive Tutor Authoring Tools (CTAT)
- REDEEM

Specific Example

ITS for Navy Tactical Action Officer (TAO)

CTA of TAO instructors

In Parallel: Create **scenario** / **Design** ITS

Existing CORBA/DLL **interface** to CTTAS/PORTS
TAO Watchstation simulation

Create **FSM evaluation** of reaction to inbound aircraft

Edit **principle** hierarchy

Implement **student modeling**

Coaching Setup (Sim. & Automated Role Player
(ARP) event driven)

AAR Setup

Run it

CORBA/DLL Interface to PORTS

CTTAS Messaging

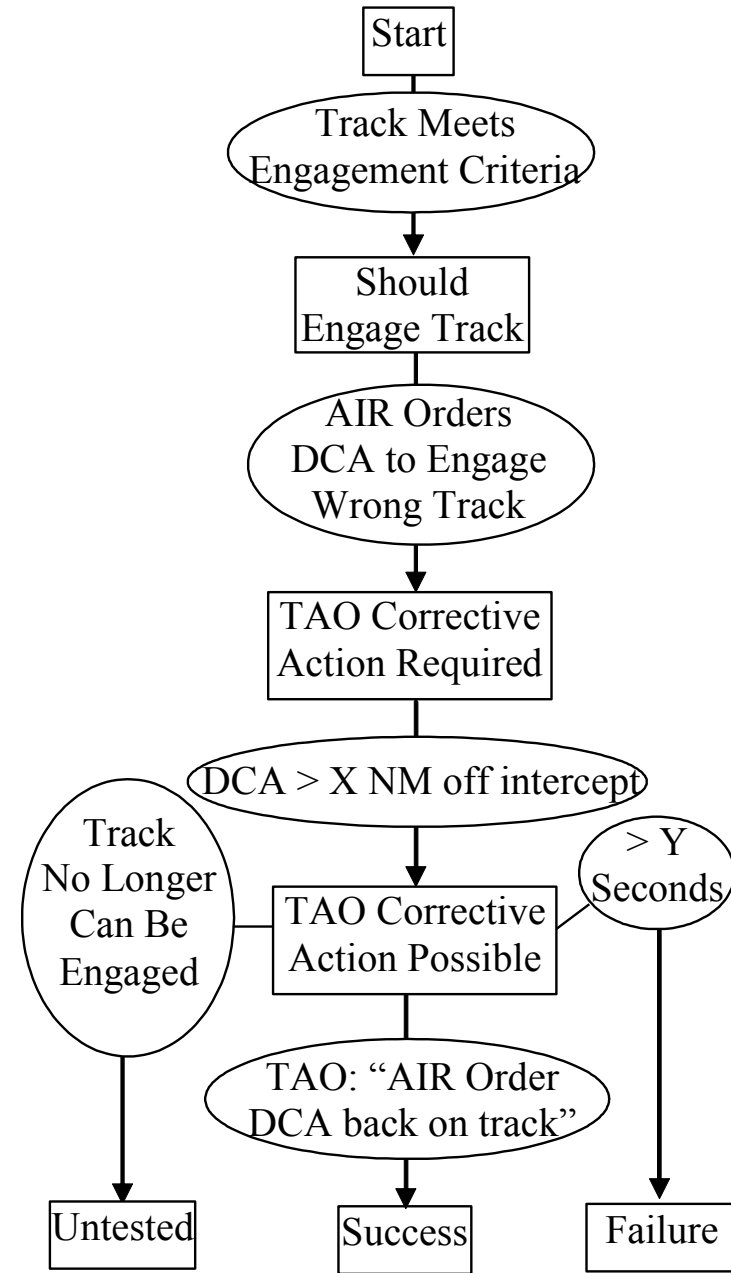
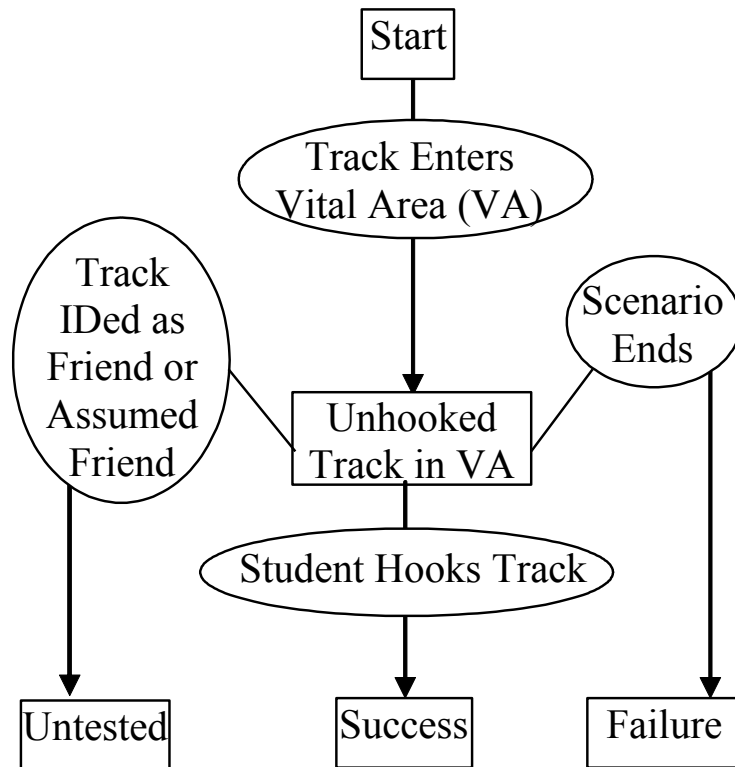
- Contains the World View: Environment, Tracks, Start/Stop Simulation
- API Connects via Windows C DLL

TAO Console Messaging

- Contains TAO Console View: Visible Tracks, Ownership Status, User Input
- API Connects via CORBA ORB

Create one Java API to hide the CTTAS and CORBA communication layers

Inbound Track Reaction & Defense Counter Air (DCA) Correction Evaluation



Student Modeling

Scoring each principle application attempt:

- Score = 1.0, correct, no hints;
0.8, blue bar;
0.6, general hint;
0.4, specific hint;
0.2, prompt

Mastery estimation for each principle:

- $\text{NewEstimate} = (\text{OldEstimate} + \text{score})/2$

Mastery Categories:

- Begun: 0 – 0.4
- Partly Mastered: 0.4 – 0.7
- Almost Mastered: 0.7 – 0.85
- Mastered: 0.85 – 1.0

Coaching

Each principle in the “Begun” Category is hinted

Mastery estimate updated after each attempt

Therefore hinting turns off and/or back on during a scenario

Hinting for different principles is independent of each other (i.e. hinting will occur for some principles and not others at the same time)

Instructional Planning

Instruction is based on a scenario practice –
debrief loop, with and without hinting

Practice scenarios are chosen based on
student's weakest principles

- Pick principles with lowest mastery
- Pick scenarios that exercise those principles
- This will only pick scenarios with principles previously attempted

Instructors assign scenarios with new
principles

ITS Assessment

Large body of work at universities, primarily in academic subjects

Fair amount of work at DOD research labs

- Evaluations have generally shown good results

DOD ITSs primarily developed through research oriented programs (SBIRs, ATDs, etc.) and suffered from long-term lack of support

ITS development starting to enter DOD acquisition process

DOD ITS results generally favorable, initially

Team member tutoring generally avoided

- Avoid natural language, other interactions between humans
- Treat team as black box
- Automated role players (software plays role of team mates)

ITS Future Directions

Mainstream DOD acquisition upswing

More emphasis on supported, commercial authoring tools

- Second generation
- Easy to author

Natural Dialogue (verbal and/or chat)

Emotional modeling, emotional agents

Game-based

Traditional vendors co-opting ITS terminology

Summary

ITS - automatic AAR and offload instructors

ITSs interface with simulations, utilize IMI

FSMs useful for mission execution evaluation

Comparison useful for plan evaluation

Student Model represents principles mastery

Instructional planner decides next event

Development process similar to SAT/ISD

Check relevant authoring tools

Get ITS developers involved early

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