### Narrative-Centered Learning Environments

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### Narrative-Centered Learning Environments

- Intelligent Tutoring Systems in which learners
  - Actively participate in "story-centric" problemsolving activities
  - Immersed in captivating highly tailored narratives
- Revolve around
  - Believable characters
  - Compelling virtual worlds
  - Rich stories



### **Narrative-Centered Environments**





### Narrative-Centered Learning Environments

- Provide students with engaging worlds to participate in motivating story-based problemsolving activities
- Support appropriate levels of student motivation and engagement by orchestrating events in unfolding stories
- Strike delicate balance between advancing the plot and achieving tutorial goals
- Support the hypothesis-generation-testing cycles that form the basis of inquiry-based learning



### Interactive Narrative Generation

- Script-Based Interactive Narrative
  - Linear Interactive Narrative
  - Branching Interactive Narrative
- Emergence-Based Interactive Narrative
- Plan-Based Interactive Narrative



### Crystal Island Storyworld





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### Crystal Island Storyworld









Al Schmidt (Foreman)

Alex Reid (User)

Audrey Newsome (Field Scientist)

**Brvce Reid** (Lead Scientist)



Elise Johnson (Lab Technician)

Jin Lee (Nurse)















**Robert Campbell** (Lab Scientist)



### Crystal Island: Outbreak

- Science mystery where students play the role of a medical detective
- Members of the research team have fallen ill
- Student must discover the cause (e.g., botulism, cholera, salmonellosis, tick paralysis) and source (e.g., milk, eggs, fruit, water) of the outbreak



### Requirements of Interactive Narrative Planning

- Balance between advancing the plot and achieving tutorial goals
- Customized narratives for individual students
- Support hypothesis-generation-testing cycles
- Must interleave planning and execution to satisfy real-time constraints



# Challenges of Interactive Narrative

#### Uncertainty in inferring users' ...

- Goals in the storyworld
- Beliefs about the storyworld
- Experiential states
- Multiplicity of factors bearing on the narrative decision making (e.g., ensuring plot progress, maintaining narrative coherence)
  - Users' goals, beliefs, experiential state
  - Users' activities in the storyworld
- Absence of a complete theory of narrative

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### Requirements of Interactive Narrative Planning

Narrative planning should satisfy the following requirement:

*Narrative Rationality*: Reasoning in a principled manner about narrative objectives, storyworld state, and user state, each with its own associated uncertainty, in the absence of a complete theory of interactive narrative, to rationally select actions that maximize expected narrative utility.



### Narrative-Centered Tutorial Planning Architecture





### **Dual Planning Space**







### **HTN Planning**

- Hierarchical Task Network (HTN) Planning has found broad use
  - Very efficient with sufficient application knowledge
  - More expressive than classic STRIPS-style planning (Erol *et al.* 1994)
- HTN Planning
  - Methods: Decompose non-primitive tasks
  - Operators: Achieve primitive tasks
- Several AI planning approaches proposed for narrative generation (Cavazza, Charles, & Mead 2002; Lebowitz 1985; Rield & Young 2004; Young 1999)

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### **HTN-Based Plot Graph Planning**

Plot Graph (Kelso, Weyhrauch, & Bates 1992)

- Directed acyclic graph (DAG) of significant events in the narrative
- Indicates required conditions before narrative progress can occur





### **HTN-Based Plot Graph Planning**

#### Approach

- Specify HTN domains
  - Tutorial planning domain
  - Storyworld planning domain
- Use HTN planner to …
  - Plan the tutorial constraints which constrain the space of possible stories
  - Plan the major events in the story
- Transform the plan into a plot graph
  - Create a node for each plan step
  - Add arcs between nodes based on preconditions

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### **Dual Planning Space**

#### Tutorial Planning Space

- Concepts, goals, methods, and operators for reasoning about student's learning experience
- Encode domain knowledge and curriculum sequence constraints

#### Narrative Planning Space

- Concepts, goals, methods, and operators for reasoning about the storyworld
- Encode plot construction knowledge, character behaviors, storyworld events, and narrative constraints



### Planning and Execution Phases

- Plan Construction: Create inquiry-based problem-solving constraints; create plot and character behaviors
- Plan Execution: Narrative operators drive events in the storyworld
- Plan Monitoring: Track activities in the world
- Replanning: Use current tutorial and narrative state to update plan as necessary



### Dynamic Decision Network Based Director Agents

Each time slice encodes:

- Plot Progress: Models the state of the storyworld's plot graph (waiting, ready, complete)
- Narrative Flow: Models the narrative's "thought flow" and "location flow"
- Plot Focus: Models which plot graph nodes are most likely in the users' focus



### Dynamic Decision Network Based Director Agents

Each time slice also encodes:

- Physical State: Models the location of the user, characters, and objects in the storyworld
- User Goals and Beliefs: Models the user's knowledge about the salient facts of the story and her goals in the story
- User Experiential State: Models the user's independence, her engagement, and her excitement



### Dynamic Decision Network Based Director Agents



### Implemented Narrative-Centered Tutorial Planner





### Implemented Narrative-Centered Tutorial Planner

- 3D Environment: Valve's Source Engine (Half-Life 2 Game Engine)
- Level Editor. Valve's Hammer Editor
- 3D Models and Sound Libraries: Half-Life 2, Counter-Strike, Internet mod resources
- HTN Planner: BISHOP, Custom-built C++ planner based on SHOP2 (Nau 2001)
- Dynamic Decision Network: GeNIe & SMILE Inference Engine (Druzdzel 1999)



- Narrative goal recognizers can exploit three sources of information to predict users' goals:
  - Narrative State: State of the narrative plan, the current focus of the story arc, goals of characters
  - User Actions: Interaction of the user within the interactive environment
  - User Location: Location of actions performed in the interactive environment by the user
- User goal recognizer provides director agent with kbest predictions about user's most likely current goals
- Director agent uses this information during its decision making process



- Predict users' goals by learning probabilistic goal recognition models
  - N-gram (unigram & bigram)
  - Bayesian network
- Observational Data
  - Narrative States, User Actions, User Locations



- Goal recognition data collected from eighty training sessions
- Approximately 20,000 training records
- Learned unigram, bigram, and Bayes Net goal recognition models







### Research Agenda

Studying the effectiveness and efficiency of narrative-centered science learning

- Motivating inquiry-based science learning
- Three-year rollout
- Content knowledge, transfer, strategy use
- Engagement: Self-efficacy, persistence

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### Affect-Informed Learning

## Supporting motivated learning via affective modeling





### Collaborators

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