Artificial Intelligence Solutions for Healthcare Decision Making

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Summary

- hSITE's Original Agenda: our progress towards those aims
- overview of research conducted with my graduate students
- next steps

hSITE Agenda

- Theme 1: Information Flow
    - Bolstered by Theme 2 (Sensing) and Theme 3 (Networking)
- Three Contexts: Home Healthcare, Emergency and Critical; Decision Support
- hsite Mantra: Right Information, Right Person, Right Time
- Artificial Intelligence Algorithms

Context I -- Home Healthcare

- John Champaign PhD (May 2012)
- social networks of users: appropriate selection of content (web documents, videos, simulations, etc.)
- peer-based intelligent tutoring approach (similarity, benefit) using past interactions, simulated learning, user study (autism care)

Context II -- Emergency and Critical Care

- Hadi Hosseini and John Doucette
- multiagent resource allocation: doctors, equipment to patients
  - concern about bother costs, pre-emption; scheduling, multiple resources
- user modeling, transfer of control strategies; Markov Decision processes and auctions

Context III -- Decision Making Support

- Atif Khan and John Doucette
- question answering re treatment administration in real-time with multiple knowledge repositories
- combination of ontologies and machine learning (missing data)

Home healthcare: a peer-based tutoring approach - John Champaign (PhD)

- Allowing patients or caregivers to learn how to manage health
  - through learning objects (texts, videos) in repositories of knowledge
  - using experiences of and advice from peers
  - a style of peer-based intelligent tutoring
- Human study: personalized information for parents as primary caregivers for children on the austim spectrum (objects chosen by our algorithms led to greater learning gains)
- Find appropriate peers and learning objects
- Approach: similarity of peers, past benefits to peers, allow peer contributions to the repository
- Provides for patient-led care by streamlining vast stores of documents

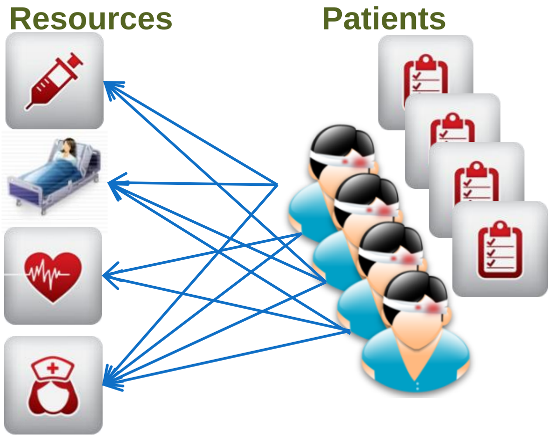
Models and Solutions

- Curriculum Sequencing
  - Ordering of learning objects based on experiences of similar peers
  - Validated by simulation and preliminary human study
- Annotations
  - Intelligently showing messages left by previous students
  - modeling reputation of annotation and annotator
  - validated by simulations: even when poor annotators are present and qualitative human study
- Corpus Divisions
  - peers can propose new, divided learning objects
  - validated: those preferring shorter objects, even if poor dividing skill and qualitative human study

Dynamic Multiagent Patient Scheduling – Hadi Hosseini (PhD)

- Issues in patient scheduling, medical resource allocation
  - Dynamic patient arrivals
  - Uncertainty in medical tasks (treatment, diagnosis, test, etc.)
  - Stochastic resource demands
  - Health model, different progression/diseases
  - Health state of patients as a measure of success
  - Temporal dependencies: Sequence in medical tasks (resources)

- Our approach
  - Market-inspired allocation mechanism for coordinating decentralized Markov decision processes (MDPs)
  - MDPs for planning efficiently under uncertainty considering future expected outcomes



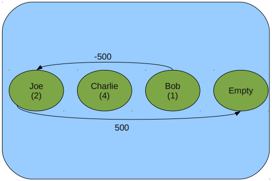
Dynamic Multiagent Patient Scheduling – Hadi Hosseini (PhD)

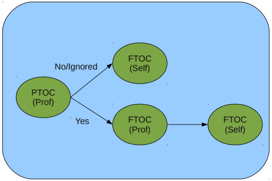
- Stochastic Resource Planning Through Auctioned MDPs
  - Efficiency is defined in terms of maximizing social welfare (utility of agents)
  - Utility is based on health state of patients
  - Patients are represented as independent MDPs
  - Market-inspired mechanism to reach approximate global optima: through auction-based coordination to minimize ***regret***
  - Scalable to large number of resources/agents: up to 100 agents and 30 resources

- Connections to other themes
  - context aware, smart sensing systems (**Theme II**): sensors essentially are shaping perception by updating state/observation models in MDP/POMDP models
  - Auto configuration of the network system (**Theme III**):
    - Auto adaptation to adjust resources in the network by changes in the demand
    - Ensures privacy as only patient agents know about their local conditions

Transfer of Control Strategies for Multiagent Resource Allocation in Mass Casualty Scenarios **John A. Doucette (Masters)**

- Finding optimal assignments is NP-Hard.
  - maximize overall utility
- Existing Multi-Agent Resource Allocation methods overestimate the costs of preemption.
  - myopic view of utility: does not reassign resources
- Using Transfer-of-Control strategies to make contingency plans can provide a better approximation. (Cohen, et al. 2010)
  - reason about bother and likelihood of response
  - more optimistic about recouping utility





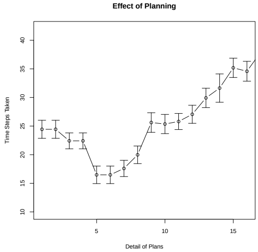
Optimal Doctor/Patient Assignments

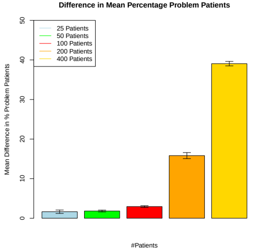
Completed Work:

- Detailed Implementations ✓
- Adaptive (learning) agents ✓
  - Learning: demand for resources, how dynamic enviroment is
- Improvements over existing systems confirmed in simulations ✓

Future Work:

- Simulations with more real-world data.
- Stronger learning models.

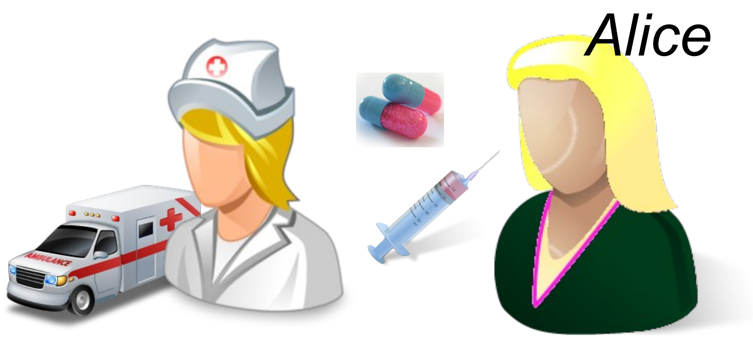




Holmes – hybrid ontological-machine learning decision support system

Atif Khan (PhD), John Doucette (Masters)

Scenario



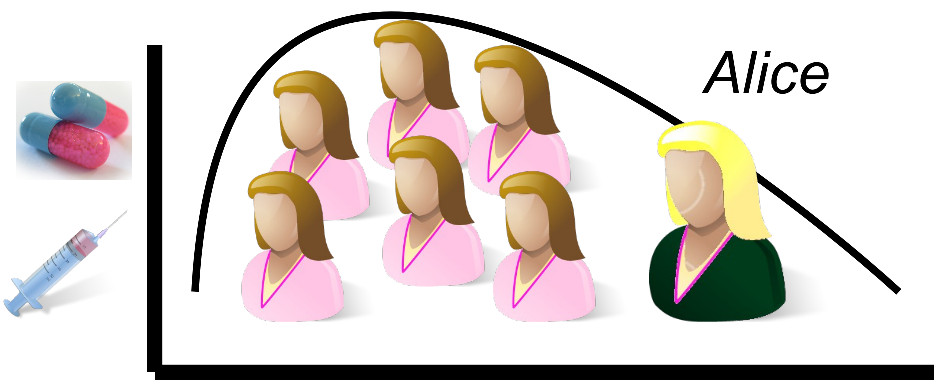
Objectives

1. patient centric evidence based
2. automated/machine processable
3. operate in constrained environments
4. decisions are easy to explain & verify
5. tolerant to noise in patient data

→ “**information challenge**”

Considerations

1. black swan theory
2. Alice's medical history
3. nature of the prescription
4. who is administering the drug?
5. time constraints



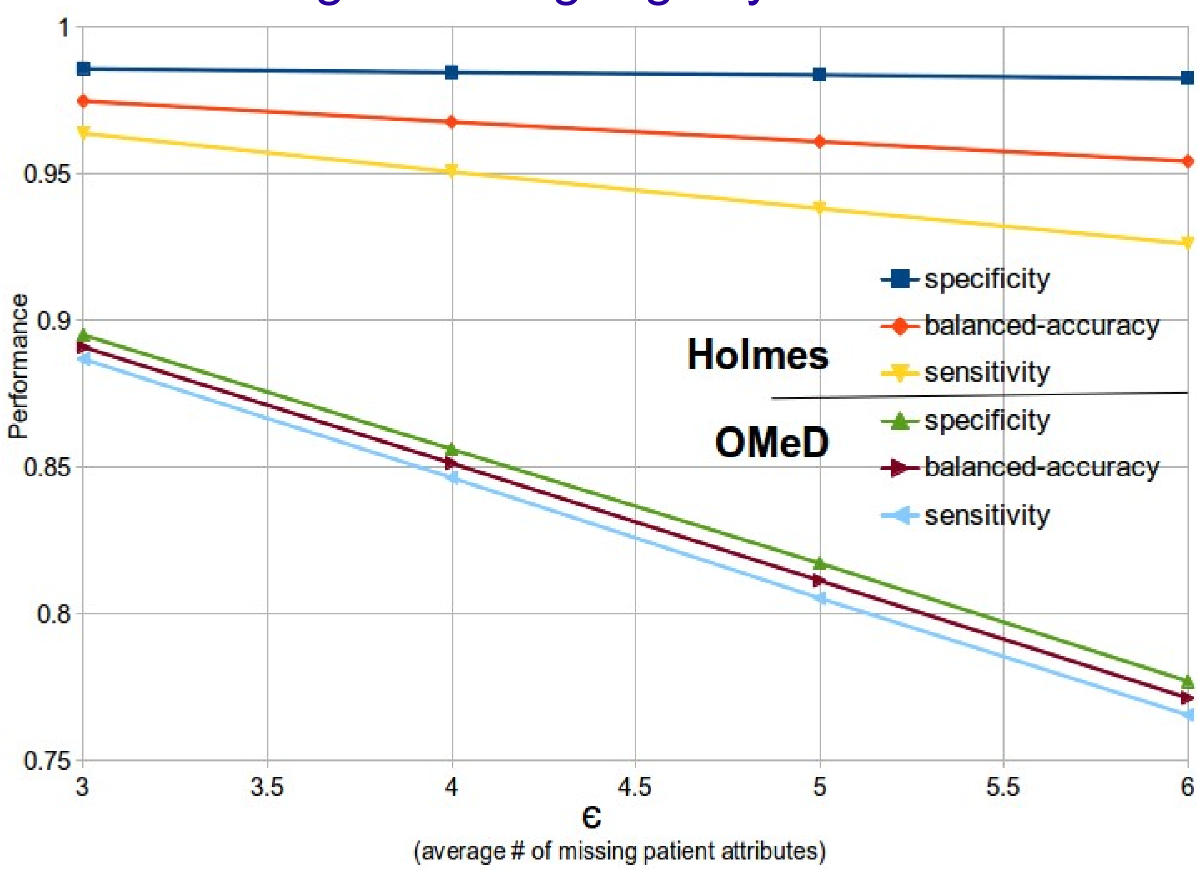
Details of Holmes

Construction

- knowledge-based decision support engine
  - ontological data representation
  - semantic reasoner for decision making
- augmented with machine learning techniques
  - to cope with the "information challenge"
  - predict values for missing attributes

Evaluation

- "sleeping pill prescription" with real world datasets
  1. BRFSS-2010 patient data
  2. Mayo clinic sleep prescription protocol,
  3. Drug.com drug registry



Conclusion

- Information used most effectively when intelligently reasoning about its use
- All 3 contexts
- All parts of the hSITE mantra