Smart Scheduling Using Transfer of Control Strategies for Multiagent Resource Allocation in Mass Casualty Scenarios

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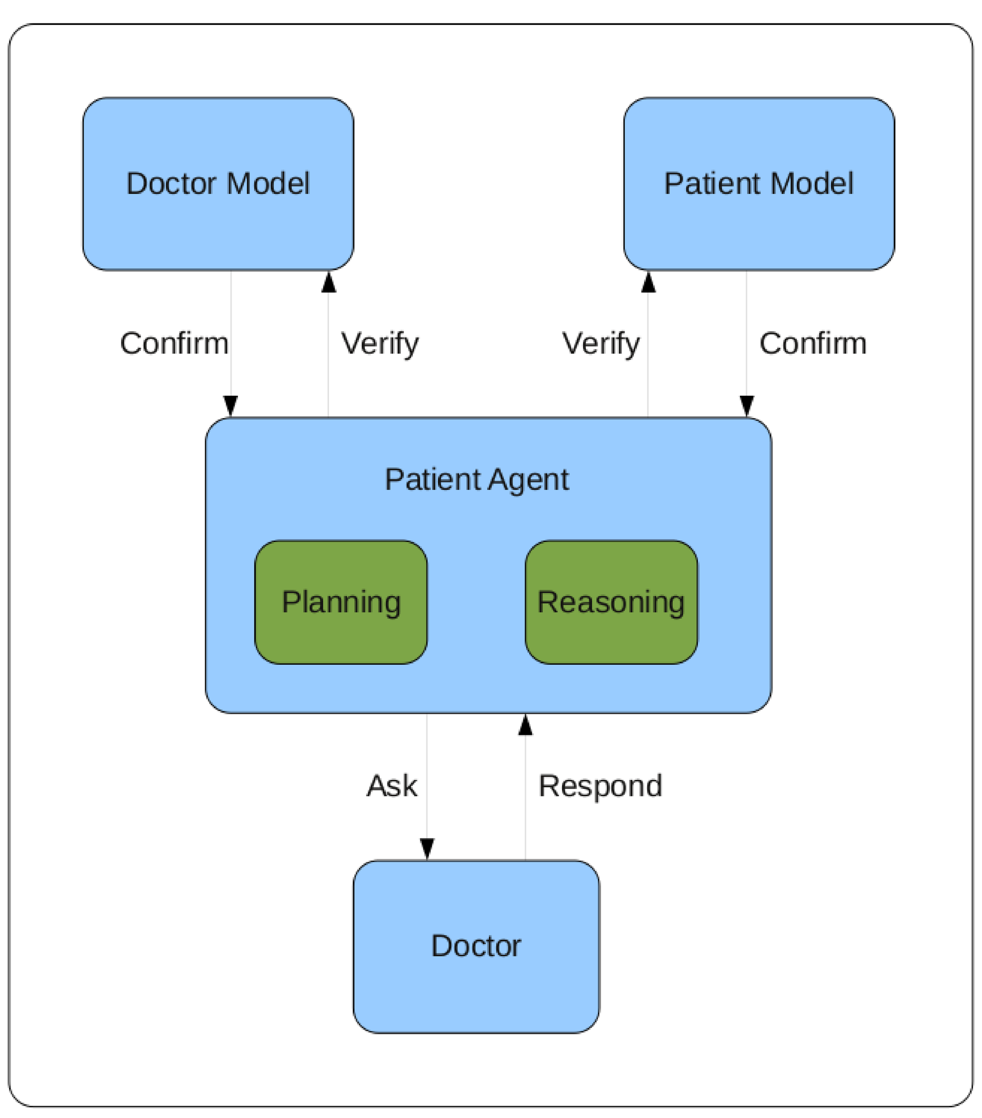
1. Introduction

- We present a novel approach to scheduling of doctors, with a focus on mass casualty incidents.
- The system is based around multiagent resource allocation using Transfer-of-Control strategies.
- The system easily incorporates models of human entities (e.g. doctors, patients) while optimizing schedules against various metrics.

2. Patient scheduling as resource allocation

- The goal of a resource allocation problem is to distribute resources among several interested parties.
- Designing an optimal schedule for patients to be treated by doctors is a resource allocation problem, with appointment times as the "resource".
- Patients will value different appointment times more or less, based both on their personal preferences and on the nature of their condition.
- The schedule can be designed according to any of several metrics. For example, minimizing average hospital wait times or YPLL.

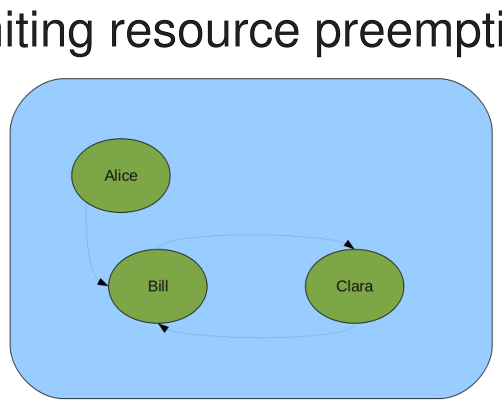
3. Multiagent resource allocation



- Each patient is assigned an autonomous artificially intelligent agent.
- Agents negotiate to transfer time slots, dynamically optimizing the schedule.

4. Preemption Cycles

- MAS resource allocation schemes adopted by previous researchers [1] cannot properly process *preemption cycles*.
- Agents cannot compute the Expected Relative Value (ERV) of relinquishing their current resource.
- Heuristic estimates of ERV tend to overestimate the value, limiting resource preemption.



Acknowledgements

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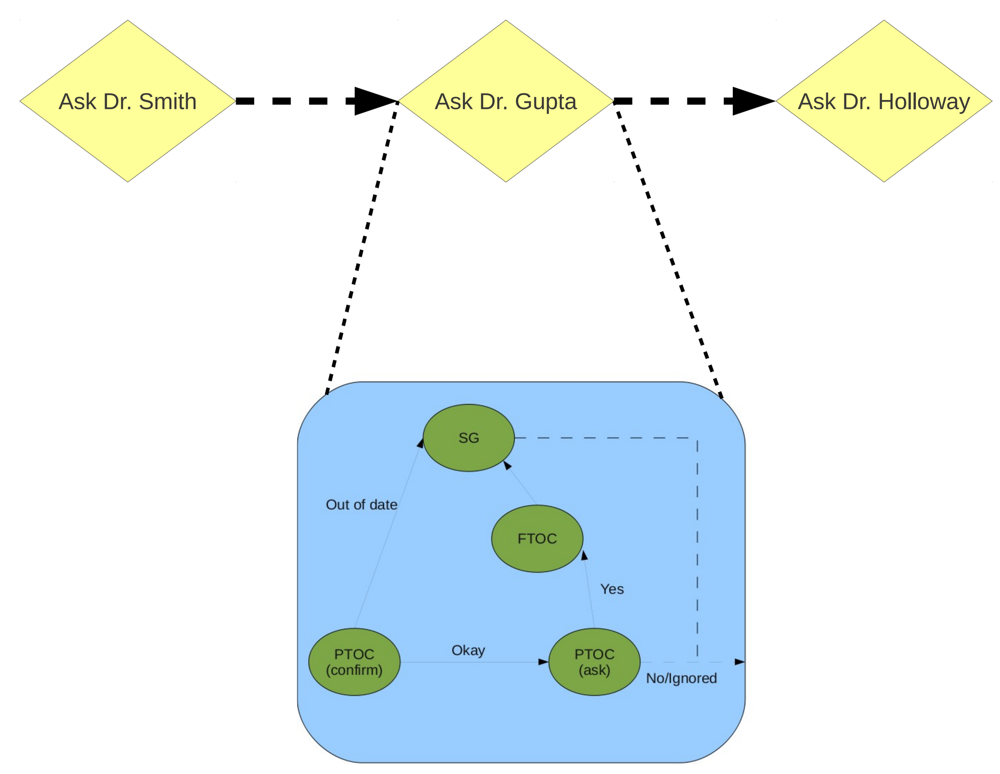
5. Planning

- As in earlier work by Cohen et al [4][3] on Mixed-Initiative multiagent systems, agents use pre-planned strategies in negotiation, called "Transfer-of-Control" (TOC) strategies.
- Strategies maximize the expected utility for the patient under consideration, while minimizing the bother experienced by doctors.
- The system knows what the doctors are doing right now, and weighs the cost of bothering each doctor with the benefit they could provide to a new patient. An emergency patient might be worth bothering a busy doctor, while a routine patient could wait until a doctor is free.
- An example TOC strategy:



- **F**ull **T**ransfer **O**f **C**ontrol (FTOC): Request that the doctor take over treatment.
- **P**artial **T**ransfer **O**f **C**ontrol (PTOC): Ask the doctor a question or confirm that the plan is still valid .
- **S**trategy **G**eneration (SG): Generate a new TOC strategy.

6. Estimating Expected Relative Value (ERV) using Transfer-Of-Control strategies

- To estimate the ERV we find the expected value of the the optimal Transfer-Of-Control strategy which does not contain the current resource.
- If we want to reschedule a patient, the ERV gives us a better estimate of the costs associated with changes in the patient's wait time and quality of care.
- Similar to micro-economic "Opportunity Costs".

7. Example Experiment

- We carried out an example experiment with a simulated prototype of the system.
- The scenario is a mass casualty incident, where 50 patients arrive simultaneously at a hospital with 10 doctors.
- This is not intended to accurately model every detail of a real-world scenario, but to demonstrate an application of the system.

8. Example Experiment: Patients Model

- Patients are modeled by their conditions (determines deterioration rate $\boldsymbol{D(c)}$) and criticality ($\boldsymbol{c}$).
- Scenario goal: Minimize treatment costs ($\boldsymbol{T(c)}$) and suffering $\boldsymbol{S(c)}$ incurred by patients as a whole.
- Total cost incurred by a single patient between T1 and T2 is:

$$Cost(T_1, T_2) = \int_{T_1}^{T_2} S(c_t) + T(c_t).dt$$

with $D(C) = \frac{dc}{dt}$, so

$$c_t = c_{t_{init}} + \int_{t_{init}}^{t} D(c).dt$$

9. Example Experiment: Doctor Model

- Following [3] doctors are modeled by their specialization and degree of busyness.
- A bother model [4] is also utilized to track the impact of previous system interactions on doctor willingness to respond.

10. Example Experiment: Algorithm

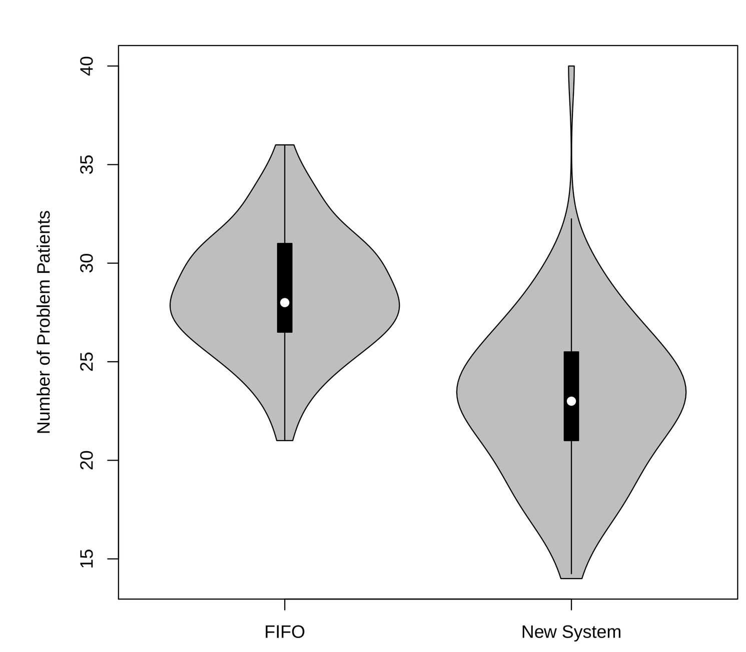
```
WHILE( there are still untreated patients )
  FOREACH Agent A
    //Let each agent take the next step in its TOC strategy
    execute_plan(A)
  ENDFOR

  //Patients deteriorate based on their conditions,
  //Doctors treat assigned patients
  update_simulation()
ENDWHILE

//Subroutine for executing the next step in a plan.
SUB execute_plan(Agent A)
  IF( A has no plan)
    generate_plan(A)
  ELSE
    execute(A->plan->next()) //execute the next TOC world.
  ENDIF
ENDSUB
```

11. Example Experiment: Strategy Generation

- Strategies are generated using a new dynamic programming approach.
- This approach requires only O($\boldsymbol{2^n}$) steps for n doctors, instead of the O($\boldsymbol{n!}$) steps used in previous work [3].

12. Results

- We compared our method to a simple First-In-First-Out allocation system.
- The evaluated against 100 randomly generated sets of patients and doctors, the new system produces a significant decrease in the number of problem patients, and total costs.



13. Conclusions

- Initial results are promising, but further work is needed:
  - Direct comparisons with previous authors (e.g. [1]).
  - Ablation studies.
  - Work in other problem domains.

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[1] T. O. Paulussen, A. Ziller, A. Heinzl, A. Pokahr, L. Braubach, and W.o Lamersdorf, *Dynamic Patient Scheduling in Hospitals.*, Agent Technology in Business Applications, 2004

[2] Hyunggu Jung, *Reasoning about Benefits and Costs of Interaction with Users in Real-time Decision Making Environments with Application to Healthcare Scenarios*, Master of Mathematics thesis, University of Waterloo, Waterloo, Ontario, 2010.

[3] Robin Cohen, Hyunggu Jung, Michael Fleming, and Michael Y.K. Cheng, *A User Modeling Approach for Reasoning about Interaction Sensitive to Bother and Its Application to Hospital Decision Scenarios*, Special Issue on Personalization in e-Health, User Modeling and User-Adapted Interaction: The Journal of Personalization Research, January 2011.

[4] Robin Cohen, Michael Y.K. Cheng and Michael W. Fleming, *Why bother about bother: Is it worth it to ask the user?*, AAAIâ05 Fall Symposium on Mixed-Initiative Problem-Solving Assistants, 2005

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