Human-Agent Collaboration for Disaster Response

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Ramchurn, S. D., F. Wu, W. Jiang, J. E. Fischer, S. Reece, S. Roberts, T. Rodden,
C. Greenhalgh, and N. R. Jennings (2015).
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Overview

- Introduction
- Background
- Problem
- Proposed Solution
- Method
- Results
- Discussion and Conclusions

Introduction

- Why human-agent collaboration?
- How does this help?
- Why is this important?

Human-Computer Interaction has three parts: the user, the computer, and how they work together. We hope to answer all three of these questions by showing how agents and humans work together to handle emergency situations.

Background

- It is possible to have create a system that have multi-agent coordination and human-computer interaction (HCI) for disaster ?
- Why?
    - In any disaster the most important thing is organization.
        - Good organization = More lives saved.
    - Disaster are impossible to prevent, but using such systems can improve the change of help people in a disaster.
        - (Improve organization)

Obstacles

- Each disaster has unique characteristics
  - There are some that we can get prepared (2017 hurricane in Florida), other arrive without notice (earthquakes).
- In all disaster there are limited resources.
  - Safe places
  - Limited personal
  - Food
  - ! TIME !
    - Time is the most important resource.
- Organization
  - It is not that simple to have a good organization, people are not that predictable.

Previous solutions and problems

- Solutions
  - Do Drills
  - Create Algorithms for optimal teams of emergency responders
  - Train as many as possible for every possible disaster (Brute force)
- Problems with previous solutions
  - Assume the environment is Deterministic
  - Human factor (take into account their capabilities and preferences, performance ...)
  - Ignore difficult of team coordination
  - Not enough money for the training.

Solution: Actors

- Members of the system
  - **FR:** First responders (military, medics, transportation)
    - Each type of responder has unique skillset
    - Can choose to accept or deny given task
  - **H:** Human Coordinator
    - Communicates instructions to the FR
    - Receives updates from the FR
  - **PA:** Planning agent
    - Communicates instructions to the FR

Note: The FR and the H are humans.

Solution: Definition

- Which disaster to choose?
  - Satile powered by radioactive fuel, has crashed in a suburban area.
  - Radiation spreads over time
- Solution from paper:
  - Algorithm for team coordination that captures the uncertainty in the scenario
  - Allocate responder to best task (efficient timing and skills needed)
    - Develop a Multi-agent Markov decision process (MMDP)
  - Planning agent, working alongside a human commander.
    - Intersection between multi-agent coordination and human-computer interaction (HCI)

Formal Model

- G is the disaster space, (x,y) ϵ G
- Radioactive level, L ϵ [0,100]
- Safe zones, G' ⊆ G
- FR, I = { p1,..pi…,pn } where | I | = n
    - Each FR has a health level , hi ϵ [0,100]
    - hi decreased by 0.002 x L per second
- Set Θ types of responders
    - Θi ϵ Θ the type of responder pi
- Targets to be rescued T = {t1,...,tj,..tm} where | T | = m
    - Ti required a set sub set of I
    - Specific responders needed

MMDP model

- **M**ulti-agent **M**arkov **D**ecision **P**rocess
- M= <I, S, {Ai }, P, R>
    - I: Set of all actors
    - S: State space
    - {Ai}: Set of actions
    - P: Transition function
    - R: Reward function
- Bellman Equation: $V^{\pi}(s^{\tau}) = R(s^{\tau}, \pi(s^{\tau})) + \sum_{s^{\tau+1} \in S} P(s^{\tau+1} | s^{\tau}, \pi(s^{t})) V^{\pi}(s^{\tau+1})$

Team Coordination Algorithm

Algorithm 1: Team Coordination Algorithm

Input: the MMDP model and the current state s.
Output: the best joint action $\mathbf{a}$.

```
   //The task planning
1  {t^i} ← compute the best task for each responder p_i ∈ I ;
2  foreach p_i ∈ I do
       //The path planning
3      a_i ← compute the best path to task t^i ;
4  return a
```

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Team Value Calculation

Algorithm 2: Team Value Calculation

Input: the current state s, a set of unfinished tasks T, and a set of free FRs I.
Output: a task assignment for all FRs.

$\{C_{jk}\} \leftarrow$ compute all possible teams of I for T ;
foreach $C_{jk} \in \{C_{jk}\}$ **do**
    //The N trial simulations
    for $i = 1$ *to* N **do**
        $(r, s') \leftarrow$ run the simulation starting at state s until task k is completed by the FRs in C_{jk} ;
        if *s' is a terminal state* **then**
            $v_i(C_{jk}) \leftarrow r$;
        else
            $V(s') \leftarrow$ estimate the value of s' with MCTS ;
            $v_i(C_{jk}) \leftarrow r + \gamma V(s')$;
    $v(\bar{C}_{jk}) \leftarrow \frac{1}{N} \sum_{i=1}^{N} v_i(C_{jk})$;
return the task assignment computed by Eq. 3.

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Solution in Practice

Results

- It was fun!
- 8 Targets rescued in Non-Agent condition A, 12 and 11 Targets rescued in Agent conditions (B & C respectively)
- Health was 40 in A, 91 in B and 72 in C
- Agent re-planned 14 times in B and 18 times in C
- The Non-Agent HQ allocated 43 tasks. Only 15 were responded to.
- Only 2 HQ Directives led to task completions. The last 6 were without HQ.
- Agent allocated 52 tasks on average. 24 were accepted.
- 15 accepted Agent Directives were completed. 6 Non-response completed. 2 tasks completed with no direction.
- 11 total Agent task rejections

Discussion and Conclusions

- A new approach to evaluating Human-Agent Collaboration
- AtomicOrchid
- Agent had successful planning and effective re-planning
- Based on results the design recommendations include
  - Adaptivity
  - Interaction Simplicity
  - Flexible Autonomy

Questions