Introduction and Motivation

**Adversarial Cooperative Path-Finding (ACPF)**
- generalization of cooperative path-finding (CPF)
- teams of agents compete in reaching their goal
- **winner** = the first team to reach the goal

Motivation
- video games
- planning and simulations
- police interventions
- military actions
- security operations

Formal definition

**The ACPF problem**
Instance of ACPF problem is a 7-tuple

\[ \Sigma = (G, A, T, t^*, \lambda_0, \lambda_1, \alpha) \]

Where
- \( G = (V, E) \) an undirected graph
- \( A = \{a_1, a_2, ... , a_k\} \) finite set of agents
- \( T = \{T_1, T_2, ... , T_n\} \) finite set of teams
- \( \lambda_0: A \rightarrow V \) starting position of each agent
- \( \lambda_1: A \rightarrow P(V) \) set of target positions of agents
- \( \alpha \) next placement of agents of teams of adversaries

Agent movement
- Agents move along edges or stay at a vertex.
- An agent can move to an unoccupied vertex or into vertex being left by other agent.
- Swapping along an edge is forbidden.
- Teams alternate in their moves.

Theoretical properties

**Proposition.** A question if there exist a solution for a selected team in ACPF is PSPACE-hard.

Reduction of QBF to ACPF
- QBF known to be PSPACE-complete
- construct an ACPF instance to simulate QBF

QBF – quantified Boolean formula
- propositional formula with quantification
- example: \( \exists x \forall y ((a \lor b) \land a \land \neg b \land \neg y) \)
- question: is the given formula valid?

Can team \( T_i \) chose moves to win whatever \( T_j \) does? (equivalently: is there a solution for \( T_i \)?)

Practical Offensive and Defensive Tactics

**Agent roles**
Various tactics can be used when ACPF is solved in practice. Presented suggestion is motivated by a security operation.

Agents are divided into 3 roles, which are treated differently by the planning algorithm:
- VIA – Very Important Agent
- Guards
- Attackers

Agents with fewer targets should be treated as VIAs and can be protected by guards. Attackers are supposed to harm the opponent by blocking important vertices.

**Target reachability**
The idea is based on effort to find a position, in which it is possible to guide an agent to its target vertex no matter how the opponents behave.

Cooperation of agents of a particular team is important. Consider situations on following figures:

Comments

**Synchronizations and vertex locking**
- agents are forced to follow paths leading to goal areas
- splitting between positive and negative branches need to be ensured
- vertex locking mechanism need to be employed

Conclusion and Future Work

- Presented problem is a generalization of well known cooperative path-finding problem.
- PSPACE-hardness was shown and several solving techniques were proposed.
- The ACPF problem offers new area for research:
  - Future study of the problem complexity
  - Finding a solving algorithm
  - Development of heuristics
  - Special cases (particular types of graph, bounded number of agents/teams, symmetric vs. asymmetric solutions and a lot more)

Bibliography
