Roles and Teams Hedonic Games

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Abstract

We have introduced a new model of hedonic coalition formation game, which we call *Roles and Teams Hedonic Games (RTHG)* (Spradling et al. 2013). In this model, agents view coalitions as compositions of available roles. An agent's utility for a partition is based upon which role she fulfills within the coalition and which roles are being fulfilled within the coalition. The major contributions of the paper include designing the RTHG model, with its corresponding stability and (NP-hard) optimization criteria, designing a heuristic partitioning algorithm and local search algorithm, implementation and testing.

Thesis Summary

When forming a research team, a scientist brings her current ideas as to what type of research to do, what tasks need to be performed and which of those tasks she would do best. The researcher's preference for a type of project may change over time. What is hot in the field may shift focus or the agent may wish to expand her horizons. Short term and long term research needs are expected to change, both for individual scientists and the community as a whole. The goal of the scientist is to be matched with agents who are a good fit to her ideals of the moment.

Research team formation is an example application of a hedonic coalition formation game we introduced, *Roles and Teams Hedonic Games (RTHGs)*. Here the teams are formed to do research, but the formulation of RTHGs does not specify the purpose of the teams. Research on coalition formation games has looked at stability and optimization on a variety of criteria, such as achieving MaxSum or MaxMin utility. A MaxSum partition is one in which the sum total utility is maximized. A MaxMin partition is one in which the utility of the lowest-utility coalition is maximized.

Coalition formation games are *hedonic* when an agent is concerned only with the utility of her own coalition and not others. A researcher in this setting is only concerned with finding a research team that will support her goals and within which she can work well.

An RTHG instance consists of:

- P: a population of agents;
- m: a team size (we assume that $|P|/m$ is an integer);
- R: a set of available team member roles;
- C: a set of available team compositions, where a *team composition* is a set of m *not necessarily unique* roles in R;
- U: a utility function vector $\langle u_0, \ldots, u_{|P|-1}\rangle$, where for each agent $p \in P$, composition $t \in C$, and role $r \in R$ there is a utility function $u_p(t, r)$ with $u_p(t, r) = -\infty$ if $r \notin t$.

Table 1: Example RTHG instance with $|P| = 4, m = 2, |R| = 2$

$\langle r, t\rangle$	$u_{p_0}(r,t)$	$u_{p_1}(r,t)$	$u_{p_2}(r,t)$	$u_{p_3}(r,t)$
$\langle A, AA\rangle$	2	2	0	0
$\langle A, AB\rangle$	0	3	2	2
$\langle B, AB\rangle$	3	0	3	3
$\langle B, BB\rangle$	1	1	1	1

A solution to an RTHG instance is a partition π of agents into teams of size m. The big research problem in RTHG is to identify solutions which satisfy optimization and stability criteria. Criteria include MaxSum, MaxMin, and Pareto optimality and Nash, individual, and core stability.

Similar models include the Additively Separable Hedonic Game model (ASHG) (Aziz and Brandl 2012) and the Coalition Skill Vector model (CSV) (Tran-Thanh et al. 2013). In ASHG, an agent holds a utility value for each other agent within the population. In reality, it is unlikely that any one researcher has worked with every other researcher even once, much less several times over. For a young researcher, the information base may be non-existent. In CSV, each agent possesses a set of skills and is matched to one of many available tasks with a total skill requirement. This grants anonymity among agents, but consider a researcher who wishes to branch out from what she is known for to develop new skills and work with new types of researchers. A robust model for research team formation should allow for agent preferences not only over the roles they fulfill but also over the compositions they work within.

The RTHG model allows for anonymity of the agents. Young researchers seeking to build effective teams while working on a variety of problems could benefit from a team formation method that does not require preformed opinions of other agents in the population. Rather, young researchers could represent their preferences for coalitions as a set of preferences over team compositions and roles within them. More experienced researchers, similarly, could find new connections to previously unknown agents.

Preference for a role within a composition may depend upon the roles available. An agent may prefer to be a writer for project A, but switch to a preference for implementing heuristics when presented with alternative project B. An agent's role preference is taken in context of the composition, not in isolation.

This work was inspired by the popular online game, League of Legends. In this multiplayer online battle arena (MOBA), players form teams, select avatars with different abilities, and compete in 30-40 minute contests against other teams. What makes a successful team composition changes over time and depends upon the skills and preferences of the team members. To have the best experience, players should be matched such that they agree upon the composition of the team and who will fulfill particular roles within the team.

We defined MaxSum and MaxMin optimal partitions for RTHG. We defined Nash stable and individually stable solutions for RTHG in terms of possible moves an agent could make from a given partition. These stability notions are sensible in the League of Legends setting. We are considering further notions of stability for future work. Additionally, we developed proofs of hardness for the related decision problems to finding MaxSum and MaxMin partitions in RTHG. We proved the following:

Theorem 1. Every instance of RTHG has an individually stable partition, which can be found by local search. Not every instance of RTHG has a Nash stable partition.

Theorem 2. MaxSum RTHG and MaxMin RTHG are both NP-complete.

We developed a heuristic optimization method. This method treats agent utilities for roles and compositions as votes in an election. A greedy algorithm selects a composition with the maximum vote, selecting uniformly at random to break ties, then selects the set of agents from the population with optimal utility for that composition. These agents are then optimally assigned to roles within the composition.

We validated the heuristic against brute force optimization with 240 randomly generated RTHG instances, with $|P|$ from 6 to 15, $|R|$ from 3 to 6, and m from 3 to 5. Larger instances made the brute-force calculations too slow, as there are $O(|P|! \cdot (|C| + |P|/m)^{|P|/m})$ possible partitions for an instance of RTHG. We ran the greedy heuristic on each instance 500 times. We implemented a local search algorithm to construct individually stable solutions for those instances. For each instance, we restarted the search fifty times, and compared the mean utilities to the optimal ones.

We found that our heuristic performs best for finding approximately MaxSum utility partitions. We found that, as the population size increases, the MaxSum and MaxMin utility decreases for individually stable solutions found by local search. As the population size increases, the number of local optima increases. Local search simply finds one, which is not necessarily a global optima.

Ongoing work includes new heuristic algorithms, investigation of further notions of stability and of the relationship between RTHG and other hedonic games. We are collecting anonymized real-world data for thousands of League of Legends matches. Data for one match includes the roles and play statistics for each player and the win/loss result.

As societal needs change, projects are completed, and as new researchers join the field, what makes a good partitioning will change. In the game League of Legends, player preferences may change over time due to factors including game updates and a desire to experiment. We will develop online algorithms for social networks, where agents are matched into short-term teams and preferences change over time.

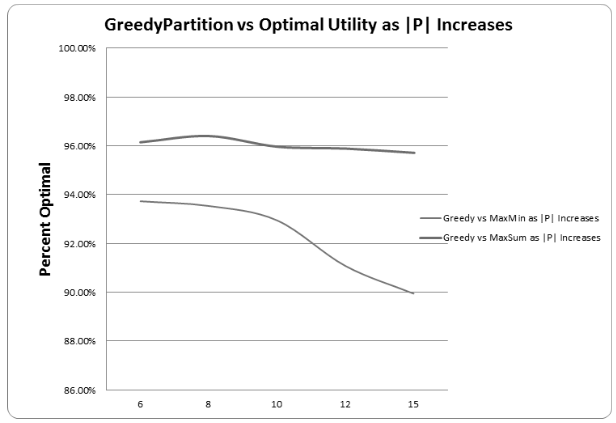

Figure 1: Percent of optimal MaxSum and MaxMin using *GreedyRTHGPartiton* as $|P|$ increases

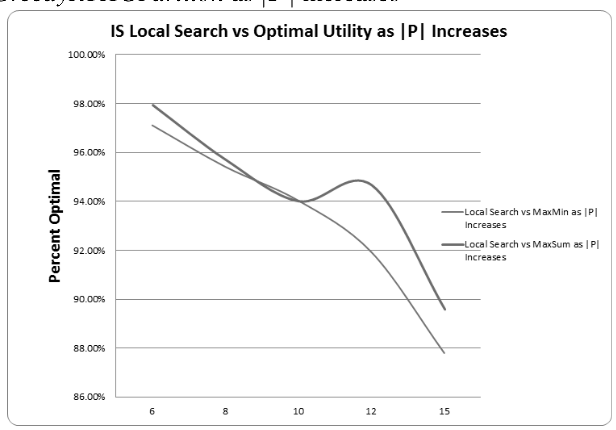

Figure 2: Percent of optimal MaxSum and MaxMin using *ISLocalSearch* as $|P|$ increases

References

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