An ideal team is more than a team of ideal agents

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Introduction

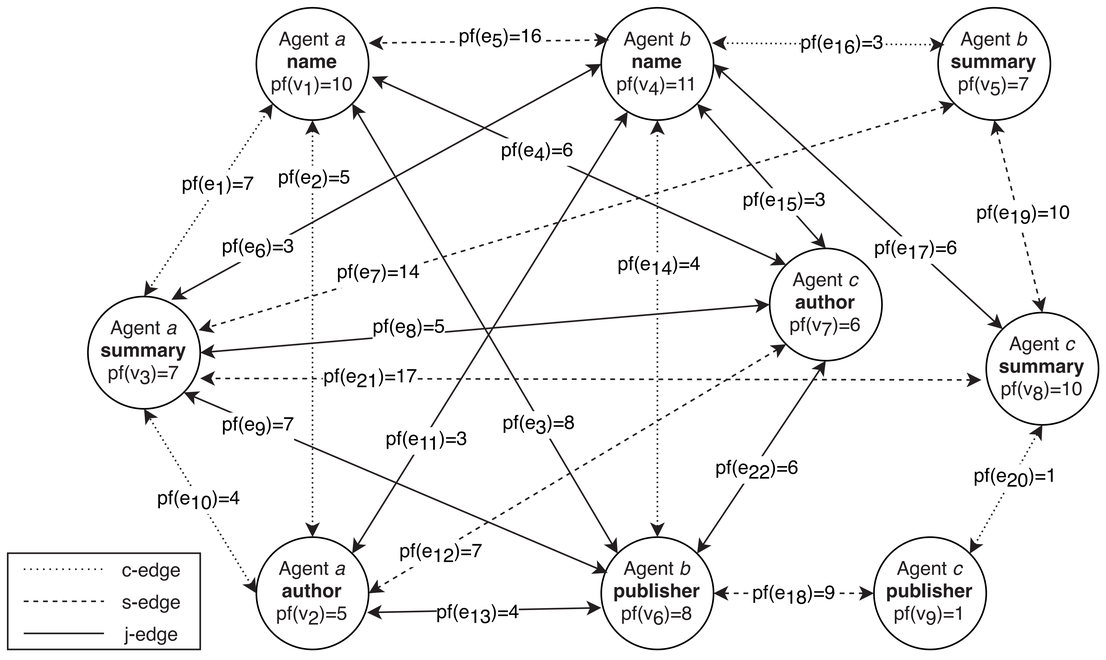
- Finding the best performing team for a complex task is known to be NP-hard
- Subtasks may have subtle relations that affect the overall performance of a team
- Assigning the best performing individuals may not yield to the best performing team
- The individual performance of an agent depends on which subquery the agent is assigned
- Data source agents form teams to answer complex queries by providing parts of the result

Problem Statement

- Task is a conjunctive query
- Capability performance of an agent is the number of entities
- Team is a set of capability assignments
- Performance of a team is the number of entities in the result of a query
- How can we find a team in which agents perform well together for their assignments?

Expertise Graph

$G = \langle V, E \rangle$ is an undirected graph that represents agent-capability pairs (assignments) as nodes V and pair-wise co-performances as edges E, i.e. an edge e between two nodes $v_1 = \mathsf{node}(a_i, c_k)$ and $v_2 = \mathsf{node}(a_j, c_l)$. $\mathsf{pf}(v) = P_{cap}(a, c)$ and $\mathsf{pf}(e) = \mathsf{P_{team}}(\{\langle a_i, \{c_k\}\rangle, \langle a_j, \{c_l\}\rangle\})$.



☞ *Cooperativeness* of a node measures how an agent a would perform c in relation to other capabilities performed by other agents:

$$\mathsf{cpt}(a, c) = \Big(\sum_{e \in E_j} \mathsf{pf}(e) \Big) / |E_j|$$

☞ *Versatility* of a node measures how well an agent a can carry out other capabilities when it is already performing c:

$$\mathsf{vst}(a, c) = \Big(\sum_{e \in E_c} \mathsf{pf}(e) \Big) / |E_c|$$

Team Building

Teams can be built from scratch by selecting assignments based on various metrics:

- **HIP:** Team of the assignments having the highest individual performances
- **HCPT:** Team of the assignments having the highest cooperativeness values
- **HVST:** Team of the assignments having the highest versatility values

Teams can be improved by an *iterative approach*:

- Measure cooperativeness value of the assignments in the team
- Find the least cooperative assignment
- Search for alternatives from the expertise graph
- Select the assignment with the highest
  - cooperativeness if the agent is not in the team
  - versatility if the agent is in the team already
- Continue as long as expected team performance increases

Expected Team Performance

- Expected performance of a team is estimated through set intersections
- The *maximum performance* of a team can be at most the minimum of pair-wise cooperation performances of agents

$$\mathsf{P_{max}}(K) = \mathsf{min}\{pf(e) \mid e \in \mathsf{edges}(K)\}$$

- If the sum of two edge values exceeds the node value, then the entities corresponding to the edges intersect

$$I(K, v) = \sum_{e \in E} \mathsf{pf}(e) - (|E| - 1)\mathsf{pf}(v)$$

- The maximum of the intersections guarantees the *minimum performance* of a team

$$\mathsf{P_{min}}(K) = \mathsf{max}\{I(K, v) \mid v \in \mathsf{nodes}(K)\}$$

Evaluation

Size	HIP	HCPT	HVST	Iterative
3	21.4	20	12.4	16.8
4	9.6	10.5	5.7	14.5
5	5	5.6	2.6	10.8
6	2.3	3.4	1.3	7.7
7	1.3	2	0.9	6.0

- Improving teams results in better performances than building teams from scratch

	Initial			Final		
Size	$\mathsf{P_{min}}$	$\mathsf{P_{max}}$	$\mathsf{P_{team}}$	$\mathsf{P_{min}}$	$\mathsf{P_{max}}$	$\mathsf{P_{team}}$
3	2.5	10.4	6.1	12.6	22.2	16.8
4	0.5	8.3	2.8	10.6	22.8	14.5
5	0.1	6.4	1.2	6.5	20.4	10.8
6	0	5.5	0.6	2.9	18.7	7.7
7	0	4.6	0.3	1.5	17.8	6.0

- Performance of the teams increases significantly with respect to their initial performances

Conclusion

- Building a team by just adding "ideal" agents in does not result in the "ideal team"
- Cooperation is the fundamental factor of the team performance
- Expertise graph can cover the cooperation values
- Expected team performance functions guide the iterative approach to improve team performance

Future Directions

- Distributed approach to build the expertise graph
- Adapting previous teams to different tasks
- Integrating team values, such as privacy

References

[1] Can Kurtan, Pınar Yolum, and Mehdi Dastani. An ideal team is more than a team of ideal agents. In *Proceedings of the 24th European Conference on Artificial Intelligence (ECAI)*, pages 43–50, 2020.