Synergistic Team Composition (Extended Abstract)

Ewa Andrejczuk
Artificial Intelligence Research Institute
(IIIA-CSIC)
Change Management Tool S.L
Barcelona, Spain
ewa@iiia.csic.es

Juan A. Rodríguez-Aguilar
Artificial Intelligence Research Institute
(IIIA-CSIC)
Barcelona, Spain
jar@iiia.csic.es

Carme Roig
Institut Torras i Bages
L'Hospitalet de Llobregat, Spain
mroig112@xtec.cat

Carles Sierra
Artificial Intelligence Research Institute
(IIIA-CSIC)
Barcelona, Spain
sierra@iiia.csic.es

ABSTRACT

Effective teams are crucial for organisations, especially in environments that require teams to be constantly created and dismantled, such as software development, scientific experiments, crowd-sourcing, or the classroom. Key factors influencing team performance are competences and personality of team members. Hence, we present a computational model to evaluate proficiency and congeniality of teams based on individuals' personalities and their competences to perform tasks of different nature. With this purpose, we extend Wilde's post-Jungian method for team composition, which solely employs individuals' personalities and gender. We present some preliminary empirical results that we obtained when analysing student performance. Our results show the benefits of a more informed team composition that exploits both competences and personalities of individuals.

1. INTRODUCTION

Some tasks, due to their complexity, cannot be carried out by single individuals. They need the concourse of sets of people composing teams. Teams provide a structure and means of bringing together people with a suitable mix of individual properties (such as competences or personality). This can encourage the exchange of ideas, their creativity, their motivation and job satisfaction and can actually extend individual capabilities. However, sometimes teams work less effectively than initially expected due to several reasons: a bad balance of their capacities, incorrect team dynamics, lack of communication, or difficult social situations. Team composition is thus a problem that has attracted the interest of research groups all over the world, also in the area of multiagent systems (MAS). MAS research has widely acknowledged the importance of competences to perform tasks of different nature [2, 6, 11, 12]. However, the majority of state-of-the-art approaches represent agents' capabilities in a Boolean way (i.e., either an agent has a required skill or not) [3]. This is a simplistic way to model an agent's set of capabilities as it ignores any skill degree. In real life, capabilities are not binary since every (human or software) individual shows different performances for each competence. Additionally, the MAS literature has typically disregarded significant organizational psychology findings (with the exception of several recent, preliminary attempts like [8] or [1]). Numerous studies in organizational psychology [5, 10, 14] underline the importance of personality traits or *types* for team composition. Other studies have focused on how team members should differ or converge in their characteristics, such as experience, personality, level of skill, or gender, among others [13], in order to increase team performance.

In this work, we focus on scenarios where a complex task requires the collaboration of individuals within a team. The task has a task type and a set of competence requests with competence levels needed to solve the task. We have a pool of human agents divided into teams. Agents are characterized by gender, personality, and by competences with competence levels. Our goal is to compose teams to be both *proficient* (covers the required competences) and *congenial* (balances gender and psychological traits). We refer to these teams as *synergistic teams*. We define the *synergistic value* of a team as its competence degree and balance in terms of personality and gender. Each synergistic team works on the very same task. This scenario is present in many real-life settings (e.g. a classroom, crowdsourcing). We empirically evaluate our team composition model using real data in an education scenario. We show that our model predicts better team performance than experts knowing students' social situation, background and competences. The full version of this work can be found in [4].

2. TEAM COMPOSITION MODEL

Our model considers that each agent is a human characterised by a unique identifier, gender, a personality profile (encoded as a 4-tuple of real values in $[-1,1]^4$), and a function $l : C \to [0,1]$ that assigns the probability that the agent will successfully show competence c. We will refer to $l(c)$ as the *competence level* of the agent for competence $c \in C$. We denote by $C = \{c_1, \ldots, c_m\}$ the whole set of competences, where each element $c_i \in C$ stands for a competence. Then, a team is composed of at least two agents. Finally, a *task* has a task type and the required number of agents to complete the task. A task type determines the competence levels required

Appears in: *Proceedings of the 16th International Conference on Autonomous Agents and Multiagent Systems (AAMAS 2017), S. Das, E. Durfee, K. Larson, M. Winikoff (eds.), May 8–12, 2017, São Paulo, Brazil.*

for the task as well as the importance of each competence with respect to the others. Given a team and a task type, a task assignment is a function that assigns all competences in a task type to some team member(s) so that each agent is assigned to at least one competence.

Team proficiency. Given a task assignment for a team, a proficiency value measures the degree to which the task assignment covers the task requirements. That is, it measures the distances between the compentence levels required by the task and those offered by the assignment.

Team congeniality. We measure personality using the Post-Jungian Personality Theory [17], which considers four numerical dimensions: Sensing–Intuition (SN), Thinking–Feeling (TF), Extroversion–Introversion (EI), and Perception–Judgment (PJ). The questionnaire to assess personality is a modified version of the MBTI questionnaire [15]. Inspired by the experiments of Wilde [16] we define team congeniality as an additive function that: (1) values more teams whose SN and TF dimensions are as diverse as possible; (2) prefers teams with at least one agent with positive EI and TF dimensions and negative PJ dimension, namely an extrovert, thinking and judging agent; (3) values more teams with at least one introvert agent; and (4) values gender balance.

Team synergy. Given a team, we obtain its *synergistic value* as a weighted combination of its proficiency and congeniality values. The setting of weights depends on each task type, since each task requires different levels of congeniality and proficiency. For instance, while creative tasks require intense communication and exchange of ideas (and hence much congeniality), repetitive tasks require good proficiency but low communication (low congeniality).

Team composition. Given a set of agents, our goal is to split them into teams so that each team, and the whole partition of agents into teams, is synergistic. We refer to [4] for details of the team composition algorithm (i.e. SynTeam).

3. EMPIRICAL ANALYSIS

The purpose of our experiment is to pitch our automated team composition model with the team composition performed by experts. Below, we compare both team composition models in terms of how well they predict team performance in an education scenario. Since we observe that SynTeam outperforms experts at predicting team performance, we argue that it is the method of choice in the classroom.

In current school practice, teachers group students according to their own, manual method based on the knowledge about students, their competences, background and social situation. Last year we have used our grouping system based on personality (only congeniality value matters) upon two groups of students: '3r ESO A' (24 students), and '3r ESO C' (24 students) in a state school "Institut Torras i Bages" near Barcelona. Before measuring team performance, tutors were asked to evaluate each team with a mark within $[1, 10]$ representing the expected performance of the team. Notice that not only know tutors the psychological profile of every student from practice, but also the students' social and cognitive capabilities. Finally, the teams performed "Treball de Síntesi", a collaborative one-week assignment, where students work in teams of size three. This is a creative task, though requiring high level of competences. We have collected each student's final mark for "Treball de Síntesi" as well as their final marks for all school subjects. Moreover, tutors have provided us with a matrix relating

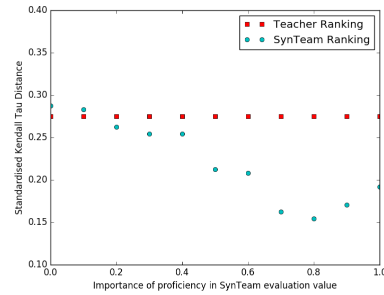

Figure 1: Comparison of Generalized Standardized Kendall-Tau distances between different methods.

each subject to the *intelligences* (competences in the educational context) required for it. There are eight types of human intelligences [9], each representing different ways of processing information: Naturalist, Interpersonal, Logical/Mathematical, Visual/Spatial, Body/Kinaesthetic, Musical, Intrapersonal and Linguistic. Based on the matrix provided by teachers we have calculated values of intelligences for every student by averaging all her final marks obtained for subjects relevant for this intelligence. For instance, for Body/Kinaesthetic intelligence, we calculate an average of student marks obtained in Nature, Physical Education, Plastic Arts and Technology. Finally, based on all students' competences (Intelligences), personalities and actual performances, we calculate synergistic values (for different congeniality and proficiency importance values).

Next, we generate several team performance rankings using the evaluation values obtained through different methods. First, we generate a ranking based on actual team performance, namely the *base ranking* to compare against. Second, we generate a ranking based on experts' evaluations. Finally, we generate several rankings using synergistic values with varying congeniality and proficiency trade-offs. In particular, we want to observe how the rankings change when increasing the importance of competences. Notice that the teachers' and actual performance rankings may include ties since the pool of possible marks is discrete (which is highly improbable for SynTeam rankings). Hence, before generating rankings based on synergistic values, we round them up to two digits to discretize the evaluation space (to generate an ordering with ties, namely a *partial ranking*).

Finally, we compare the teachers' and SynTeam rankings with the actual performance ranking using the generalised standardized Kendall Tau distance [7]. The results of the comparison are shown in Figure 1. Notice that the lower the value of Kendall Tau, the more similar the rankings. We observe that the SynTeam ranking improves as the importance of competences increases. A standardised Kendall Tau distance for the teachers' ranking is equal to 0.28, which shows that SynTeam predicts the performance better than teachers, when competences are included. We also calculate the values of Kendall Tau for random (0.42) and reversed (0.9), which shows that both teachers and SynTeam are better at predicting students' performance than the random method.

Acknowledgments. Work supported by projects CollectiveMind (TEC2013-49430- EXP), Collectiveware (TIN2015-66863-C2-1-R MINECO/ FEDER), and 2014 SGR 118. The first author is supported by an Industrial PhD scholarship from the Generalitat de Catalunya (DI-060).

REFERENCES

[1] J. M. Alberola, E. Del Val, V. Sanchez-Anguix, A. Palomares, and M. D. Teruel. An artificial intelligence tool for heterogeneous team formation in the classroom. *Knowledge-Based Systems*, 101:1–14, 2016.

[2] A. Anagnostopoulos, L. Becchetti, C. Castillo, A. Gionis, and S. Leonardi. Online team formation in social networks. In *Proceedings of the 21st international conference on World Wide Web*, pages 839–848, 2012.

[3] E. Andrejczuk, R. Berger, J. A. Rodriguez-Aguilar, C. Sierra, and V. Marín-Puchades. The composition and formation of effective teams. computer science meets psychology. *arXiv preprint arXiv:1610.08804*, 2016.

[4] E. Andrejczuk, J. A. Rodriguez-Aguilar, C. Roig, , and C. Sierra. Synergistic team composition. *arXiv preprint arXiv:1702.08222*, 2017.

[5] J. Arnold and R. Randall. *Work psychology.* Pearson Education Limited., Harlow, England, 2010.

[6] B. Chen, X. Chen, A. Timsina, and L. Soh. Considering agent and task openness in ad hoc team formation. In *Proceedings of the 2015 International Conference on Autonomous Agents and Multiagent Systems, AAMAS 2015, Istanbul, Turkey, May 4-8, 2015*, pages 1861–1862, 2015.

[7] R. Fagin, R. Kumar, M. Mahdian, D. Sivakumar, and E. Vee. Comparing and aggregating rankings with ties. In *Proceedings of the Twenty-third ACM SIGMOD-SIGACT-SIGART Symposium on Principles of Database Systems*, PODS '04, pages 47–58, New York, NY, USA, 2004. ACM.

[8] M. Farhangian, M. K. Purvis, M. Purvis, and B. T. R. Savarimuthu. Modeling the effects of personality on team formation in self-assembly teams. In *PRIMA 2015: Principles and Practice of Multi-Agent Systems - 18th International Conference, Bertinoro, Italy, October 26-30, 2015, Proceedings*, pages 538–546, 2015.

[9] H. Gardner. The theory of multiple intelligences. *Annals of Dyslexia*, 37(1):19–35, 1987.

[10] M. K. Mount, M. R. Barrick, and G. L. Stewart. Five-factor model of personality and performance in jobs involving interpersonal interactions. *Human Performance*, (11):145–65, 1998.

[11] T. Okimoto, N. Schwind, M. Clement, T. Ribeiro, K. Inoue, and P. Marquis. How to form a task-oriented robust team. In *Proceedings of the 2015 International Conference on Autonomous Agents and Multiagent Systems*, AAMAS '15, pages 395–403. International Foundation for Autonomous Agents and Multiagent Systems, 2015.

[12] S. S. Rangapuram, T. Bühler, and M. Hein. Towards realistic team formation in social networks based on densest subgraphs. *CoRR*, abs/1505.06661, 2015.

[13] M. A. West. *Effective Teamwork: Practical Lessons Learned from Organizational Research.* Wiley-Blackwell, West Sussex, 2012.

[14] K. B. White. Mis project teams: An investigation of cognitive style implications. *MIS Quarterly*, (8(2)):95–101, 1984.

[15] D. J. Wilde. *Teamology: The Construction and Organization of Effective Teams.* Springer-Verlag, London, 2009.

[16] D. J. Wilde. *Jung's Personality Theory Quantified.* Springer-Verlag London, 2011.

[17] D.J. Wilde. *Post-Jungian Personality Theory for Individuals and Teams.* SYDROSE LP, 2013.