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Competition awareness

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Understanding decision-making in competitive environments provides useful insight into the dynamics of agent behaviour.

Advances in information and communication technologies (ICT) have dramatically changed the role of users and resulted in unprecedented rates of information generation and diffusion. On the one hand, many different types of sensors are being integrated with mobile communication devices. On the other hand, online social applications are proliferating. Together, these developments add to the heterogeneity of users in terms of interests, preferences and mobility, and enable the collection and dissemination of huge amounts of information with very different spatial and temporal contexts. This information can be intelligently controlled by platforms that collectively enrich people's awareness about their environment and its resources and promote new forms of participatory processes and approaches to managing them.

Aside from contributing to building collective awareness, users may actually exploit awareness of their environment to meet their own needs or achieve certain individual objectives. Overall, users are actively involved in both the dissemination and consumption of the information.

If the disseminated information concerns the availability of some limited resource or service, then competition naturally emerges among entities (both people and networked nodes) desiring to use those resources. In such environments, it is important to understand how the presence of competition shapes decisions taken by these entities regarding the way collective awareness is exploited, if at all, and the specific way these entities participate in disseminating information and creating collective awareness. The first of these very general and fundamental questions amounts to deciding whether a networked entity will *compete* or *not compete* for the available resource. The second amounts to deciding whether a networked entity will deviate from the expected behaviour (*misbehave*) by hiding or falsifying resource or service availability information, to reduce the competition to its advantage.

We investigated these two questions by considering an environment in which parking space is the resource of interest to the users (drivers) and whose availability is disseminated or becomes accessible to the users to some extent. This investigation was motivated by the observation that the availability of information is not always better than the lack of it in competitive environments. In other words, the wider the information dissemination, the higher the effective competition[1,2] and, thus, the larger the congestion penalties experienced (e.g., long car cruising when searching for cheap on-street parking spots in busy urban settings). Consequently, any information about the intensity of the competition should be factored into the decision to go for some available parking space (compete) or not (not compete), and whether to distribute the availability information as expected or to misbehave.

Figure 1. *Competition shapes decisions regarding the way collective awareness is created and exploited. (Copyright Flynt, Dreamstime.com.)*

The parking search environment and the associated congestion penalty that captures the cost of competing but failing (i.e., going for the limited resource but finding it unavailable), appear in various ICT sectors when distributed and uncoordinated high-volume demand appears for some limited service. Other examples include congestion phenomena that emerge in a toll-free road advertised as the best alternative to a suddenly blocked main road (e.g., Google Maps with Traffic Layer) and high access delays when users associate with low-cost wireless access points in hotspot areas.

In a separate study,[3] we investigated how competition awareness affects the decision to compete or not. In essence, this work is concerned with comparing decision-making under full- and bounded-rationality conditions. Fully rational users avail

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themselves of all the information they need to reach decisions and, most important, are capable of exploiting all the information they have at hand. In contrast, users of bounded rationality make their decisions under partial knowledge. Interestingly, counterintuitive less-is-more effects emerge regarding the way information availability modulates the resulting social welfare. Namely, these effects imply that more information does not necessarily improve the efficiency of service delivery but, even worse, may hamstring users' efforts to maximize their benefit.

We have also explored how competition awareness, computational-time constraints and case-sensitive biases (which may lead to perceptual variations or distortions and inaccurate/not rational judgements) jointly shape users' decisions to compete or not.[4] We formulated the resulting interplay between users as an instance of resource selection games,[5] and exploited insights from experimental economics and cognitive psychology (Prospect Theory,[6] Quantal Response equilibria,[7] Rosenthal equilibria,[8] heuristic reasoning[9]) to model agents of bounded rationality. Very simple heuristic reasoning can yield near-optimal results, as shown by comparing equilibria under full versus bounded rationality.

Finally, because competition awareness may induce misbehaviour in distributing the resource or service availability information, we simulated an opportunistic parking assistance service in which the vehicular nodes opportunistically collect and share information on the location and availability of the parking spaces they encounter.[10] Being aware of the competition, the nodes are motivated to defer sharing information or deliberately falsify information to divert others away from a particular area of their own interest. These results show that as long as the portion of misbehaving nodes is not very high, the overall performance does not deteriorate significantly, nor does the misbehaving node enjoy any notable performance improvement. This finding may be attributed to the dynamicity of the environment, which may render falsified data correct or a lack of outdated data advantageous. Our observations suggest that the spatial-temporal-interest diversity in large-scale distributed environments confers robustness against node misbehaviour.

In emerging networking environments, end users perform a dual role as information producers contributing to building collective awareness, and as information consumers exploiting awareness to better serve their welfare. Our research focuses on resource (e.g., parking space) selection environments and explores how awareness of competition affects users' decision-making regarding dissemination and consumption of information. This exploration provides useful insights into the dynamics emerging from users' behaviour and contributes to better understanding of effective information mechanisms.

As ongoing work, we are investigating the emerging challenge of protecting public resources/goods, with a specific focus on the risk of their monopolization by the users of competition-driven resource-management applications.

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