Chapter 12
Embodying Social Behavior

Starting out with human behavior variability in the context of the clock falling off the wall example, we then position algorithmic twin execution for socio-emotional behavior enrichments, utilizing the findings from Part II.

Human behavior is fundamental to human safety and the outcomes of critical situations, such as the clock coming off the wall in a classroom teaching situation. It is correlated with social environments, localization, and other situation-sensitive factors. Once several stakeholders are involved, human-human interactions, i.e., interactions among people or groups of people, and their influence on behavior during critical situations, play a crucial role. They concern interaction with the physical environment, i.e., human-(physical) object interactions, and their handling of critical situations (cf. Zhu et al., 2020). Human-(physical) object interactions involve objects from the environments and their influence on human behavior, such as buildings, including the impact on object performance during critical situations. Handling emergencies concerns human-critical situation interactions, in particular how critical situations impact human behavior and strategies with critical situations. In the following, we apply and adapt the findings by Dovidio (1984) and Zhu et al. (2020) to exemplify the integration of our concepts and modeling approach in Parts I and II.

Critical situations involving physical settings are particularly important, as locations play a key role in people's life, as people tend to spend most of their time in specific locations, such as the workplace, and hence physical settings can be a major factor influencing behavior. For instance, moving along certain routes through the school building can impact how people act in critical situations. They may not be aware that traditionally followed routes need to be reconsidered to avoid disastrous consequences. Due to novel experiences and stress brought about by the critical situation, behavior patterns can emerge that lead to additional fatalities. Thus, a thorough understanding of the relation between human behavior and physical behavior during critical situations is crucial for both critical situation preparedness and response.

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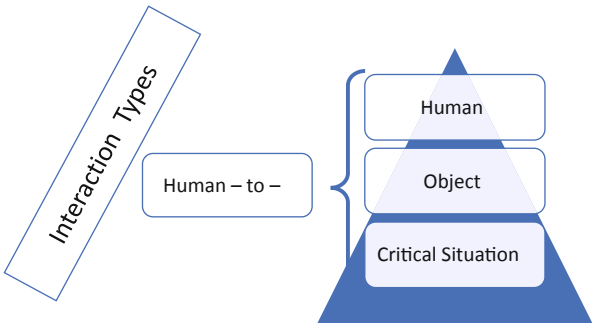

Fig. 12.1 Categories of interactions in critical situations (Adapted from Zhu et al., 2020)

The behavior of an individual during critical situations is interrelated with (1) other people, e.g., classmates, co-workers, and customers; (2) context attributes, e.g., location and visibility of objects, including emergency equipment; and (3) attributes referring to the critical situation itself, e.g., broken glass and smoke. Interaction, as reciprocal action or influence of people and/or things on each other, is the driving force of human behavior and response performance in critical situations. It can be categorized into human-human, human-(physical) object, and human-critical situation interactions according to its formation—see Fig. 12.1.

Human-human interactions refer to the collective behavior among people in the same location and their interactions with people in organization-specific roles, such as students and facilitators in a classroom, staff members, and critical situation response teams. Human-object interactions refer to how various physical attributes (e.g., objects, equipment, exits, or stairs) impact human behavior and how human behavior (e.g., using familiar walking routes to exit, packing things when leaving) impacts the local performance during critical situations.

Human-critical situation interactions refer to how critical situations, e.g., presence of danger in terms of (continuing) damage, fire, and smoke, impact human behavior and how people cope with criticalities, e.g., removing damaged objects and distinguish fire. The actual behavior is a combination of all interaction types and thus referred to as second-order behavior. For instance, rushing to the classroom door encouraging the others to follow while grabbing personal belongings combines all three types of human interactions.

In our modeling approach, we distinguish the aforementioned categories recognizing the interaction variety—human-human, human-object, human-critical situation, and human-object-critical situation interactions. Since all of these interactions can play an essential role during critical situations, both for individuals and for group settings involving different roles, e.g., in facilitators and students in classroom lessons, we need to detail these interactions to make appropriate decisions related to behavior design and processes for critical situation handling.

In particular, with respect to human-human interactions among co-located people, their interactions with people in different roles and the impact of these interactions on the response performance are of interest. For instance, as previously shown, the teacher or facilitator in the classroom is engaged in the knowledge transfer (cognitive

behavior) while also being the caretaker on organizational issues, such as starting and closing in time. In the sample case, people are not alone during the critical situation. They are accompanied by others, such as their peers, the facilitator, and those indirectly in the building, including facility managers.

Human-human interactions are one of the most important aspects that determine how people behave and the overall (re-)action behavior and selected behavior patterns. The latter result from people's tendency to observe others' responses to critical situations and select their behavior accordingly. Zhu et al. (2020) could identify several categories of human-human interactions from their study on empirical evidence of behavior: herding, avoiding, grouping, helping and competing, leader-following, and information sharing.

- *Herding behavior* as a specific category of human-human interaction behavior refers to a person following what others are doing, even though the perceived situational information suggests otherwise. For instance, in case of evacuating the classroom, herding behavior refers to a person choosing the most congested route because that route is the most popular choice, instead of alternative routes with less people. Herding behavior can occur when people experience high levels of stress or rationalize as far as they understand the situation. Herding behavior is impacted by both environmental factors, e.g., number of peers, exits nearby, visibility of environment, and personal factors, such as individual attitude.
- *Avoiding behavior* is also related to locality and environmental factors. For instance, in crowded places like lecture halls during lecture time, the level of uncertainty, such as the blocking of visibility through obstacles, is decisive for avoiding the behavior of others. In situations of low uncertainty, e.g., when evacuating classrooms and exits with shorter distance become overcrowded, the majority of people would tend to choose further exits to avoid excessive delays due to heavy congestions.
- *Grouping* is similar to herding and avoiding behavior, but takes into account the connectedness of people. While herding and avoiding behavior may occur among crowds of strangers, grouping behavior requires usually some form of social connectedness. For instance, when people stem from the same peer group, like classmates, they tend to move as a group and look for group members.
- *Helping behavior* is also related to people's pre-existing social as well as emergent collective identities when dealing with critical situations. Thereby, relations among people may be established and might get strengthened through sharing experiences of a critical situation. The latter increases collective identification and, finally, cooperation among people. On the other hand, an increasing level of danger, e.g., when the event of the clock falling off the wall is accompanied by an earthquake, decreases the amount of help.
- *Competing and selfish behavior* can happen when people experience an increased level of stress and loss of personal space. For instance, in case a person feels the need to leave a scene without taking care of others, the behavior could result in competing behavior reaching the exit or another location. The handling of a critical situation for an entire group can be affected by selfish behavior. The

decision on this type of behavior likely depends on pre-existing and/or emerging social relationships, as given in classroom settings.

- *Leader-following behavior* occurs when an occupational and/social role influences people's behavior. Persons can take roles of leaders and followers when critical situations happen. It is based on their knowledge and experience and their personality. It is very common that many people adopt the role of followers during critical situations and less likely that people decide to lead in such situations. Leadership is taken by people with authority who then lead followers according to their individual understanding of the critical situation and the perceived environmental information.
- *Information sharing* is key in critical situations and serves as a medium in human-human interactions. Once a critical event occurs, people start "hunting for information" and make many efforts to grasp more information about the perceived criticality concerning their situation. They start consulting peers or responsible actors, if not forming an ad hoc "crisis committee," to discuss the situation. The information they perceive helps people to evaluate the options when preparing to perform the next activity in a given situation. It can facilitate coping with critical events, but also make handling a critical situation worse for the concerned people. Rather than taking more appropriate actions accordingly, fatalities may be the consequence.

Each of these behavior categories can occur in combination with others and lead to coupled effects. For instance, leader-following and helping behavior can be intertwined, when leaders show helping behavior while guiding people to set specific activities. It may interrupt the leadership function for the sake of completing the support activities. Moreover, persons, when not panicking in critical situations, can process received information, either stemming from the group they have been joining or leading or from the environment.

The environment represents the context of a critical situation. For instance, organizational staff, such as facility managers, can even be first responders to a critical situation, e.g., helping people by leading them to an exit or showing them how to handle emergency equipment. Hence, role-specific behavior not only influences individual behavior but also the relation of interactions, in particular when groups are concerned. Human-object-critical situation interactions play a significant role due to the distinct behavior inputs and patterns of involved stakeholders. For instance, in case facility managers are involved from the beginning in handling the clock case, human-critical situation interaction is influenced by their trained operational behavior. Triggers are trust in role-specific behavior that likely will lead to leader-following patterns.

Figure 12.2 summarizes the mapping of interaction types to model constructs for digital twin representations. Since we follow a communication-centered approach, the representation is based on role or task behavior. Consequently, human-to-object interaction is based on behavioral entities representing individual procedures handling objects or dealing with objects. Since in our case cyber-physical components

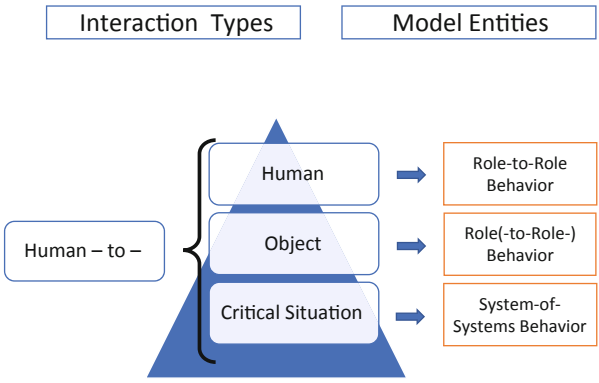

Fig. 12.2 Mapping interaction categories to modeling capabilities

can have dedicated tasks to be accomplished, e.g., pre-processing of sensor data, these interactions can also be of role-to-role type.

Human-to-human interaction is traditionally based on role-to-role behavior. According to the subject-oriented modeling approach, subjects represent role abstractions independent from their actual implementation, and thus, roles can be implemented by physical, digital, or hybrid systems. For human-critical situation interaction, a System-of-Systems mapping is needed, since it requires a baseline, both in terms of what actors are doing and which objects of the environment are concerned in such a specific situation. As such, we consider human-critical situation interaction already as "second-order" interaction, as it implicitly represents human-object-critical situation interaction.

In order to capture the classroom setting, modeling needs to take into account the framing organizational structures (see Chap. 2 in this Part). Students enroll through registration, as shown in the behavior diagrams for course and class registration. Each involved subject, the Student and Course Administration, is modeled by a corresponding behavior diagram (see Fig. 12.3).

Once enrolment has been successful, students attend their classes. The occurrence of a critical situation is captured using Message Guards (1) to decide whether the studying in class can continue as planned or (2) dedicated behavior sequences should be selected for handling the critical situation.

The latter case corresponds to handling a complex event and requires decision-making on behavior options.

Figure 12.4 shows the occurrence of an event from the perspective of a student that leads to a first check whether a critical situation is given or not. This diagram represents human-to-critical situation interactions and implements a System-of-Systems perspective. The Message Guard is activated in case a critical situation is recognized and requires further consideration of the criticality. According to the concept of SoS, the student role triggers the behavior of other actors.

Human-to-object interactions are represented in behavior models as role-to-role interaction when messages report on behavior as a result of object manipulation or location-specific changes. In the first case, data concerning digital or physical objects

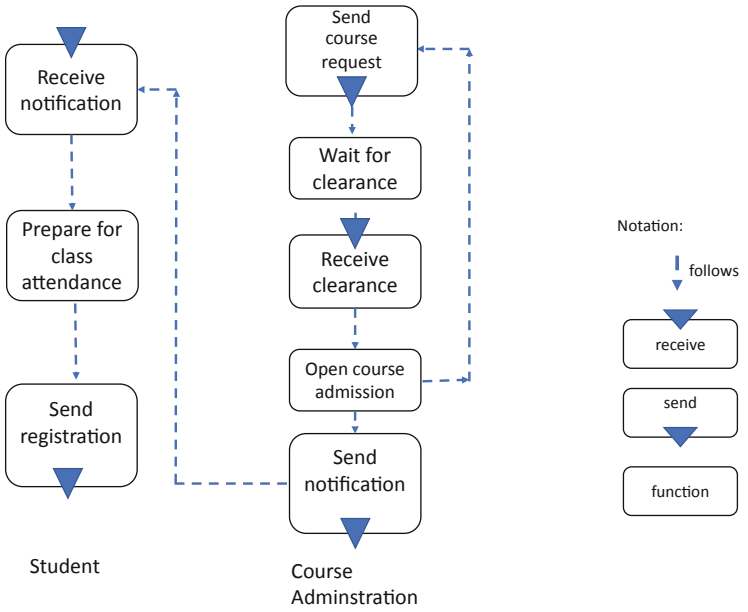

Fig. 12.3 Class registration based on role behavior of the Course Administration and Student

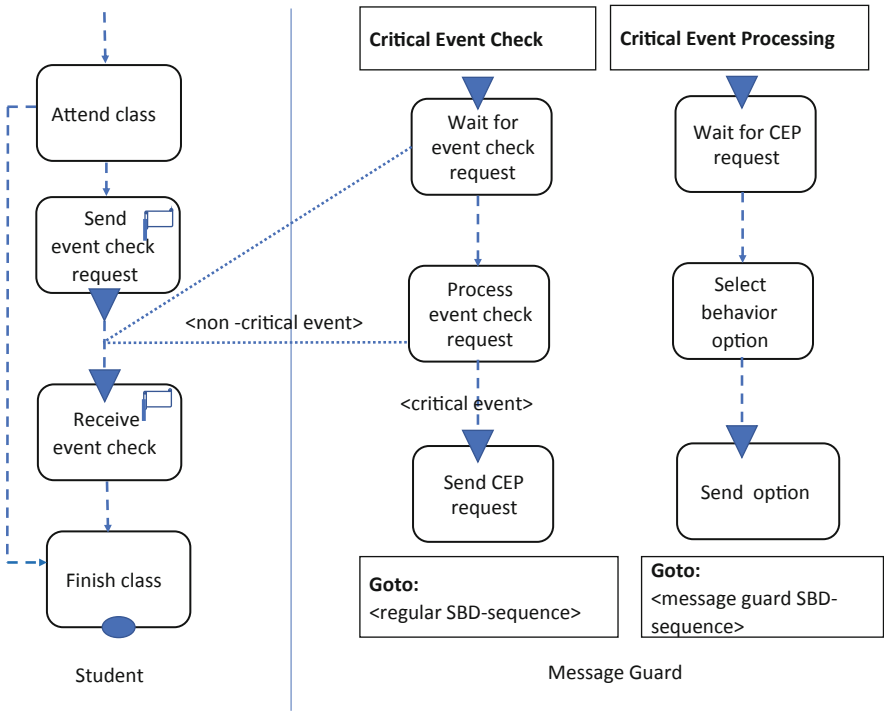

Fig. 12.4 Entering a critical situation and first evaluation of criticality

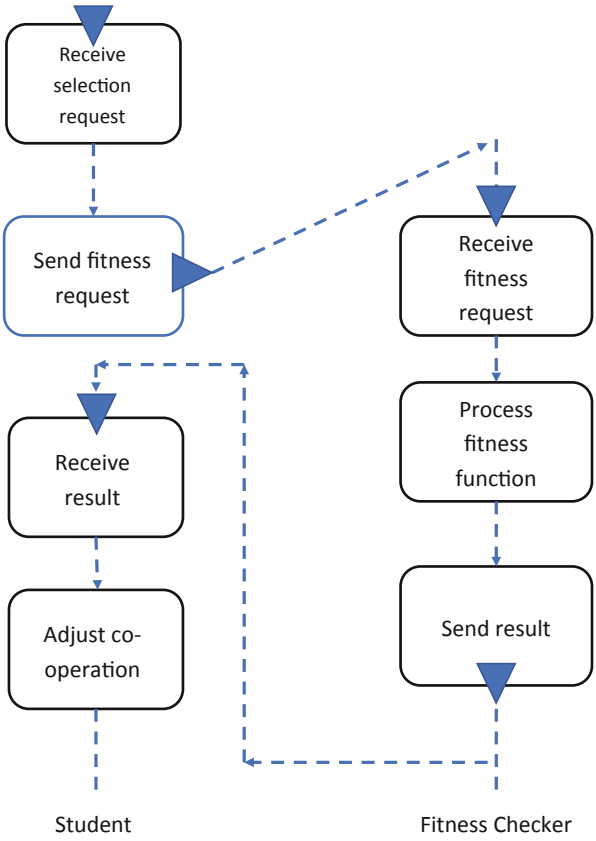

Fig. 12.5 Adjusting cooperation behavior based on fitness of accumulated knowledge

are transmitted via messages to other actors. In the latter case, physical movements or manipulations of either type are reported to other subjects.

For further modeling, in line with the simulations in Part II of this book, we assume a population of unconditional co-operators. When we consider the students as population in which agents can live and work alone or in groups, they can reach a certain fitness, when they have reached the expected accumulated knowledge (calculated with the business transaction function) that the agent (actor) leaves the group.

Figure 12.5 shows the activation of the business transaction function for adjusting the cooperation behavior. The adjustment includes cooperation on a conditional or unconditional basis in a group. According to the already mentioned types of actors:

- *Jealous co-operators* work conditionally and cooperate until a certain level of fitness is reached in their counterparts.
- *Egoists* maximize fitness by working and cooperating only to the extent that the expected fitness cost exceeds the expected cost of defecting.
- *Co-operators* work unconditionally and cooperate in any case.

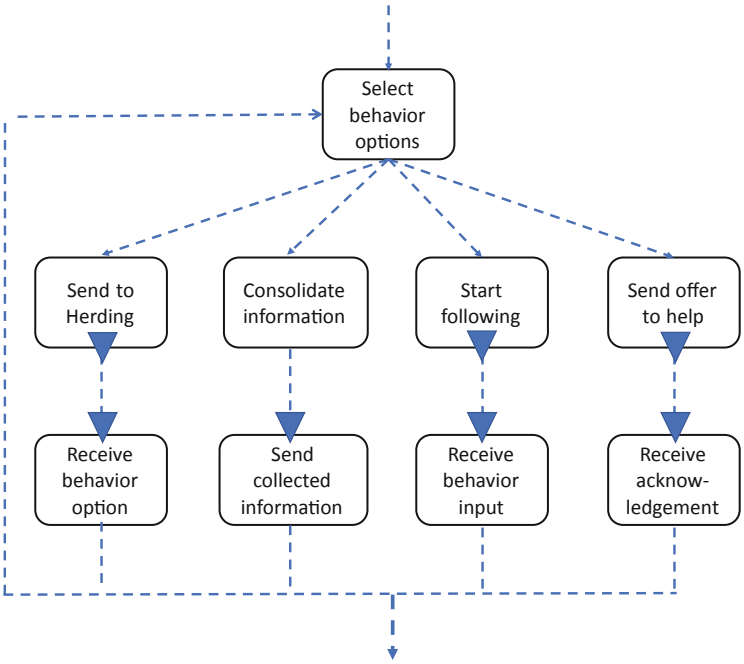

Fig. 12.6 Human-to-human interaction from a student perspective for herding, information sharing, following a leader, and helping

According to these fitness-driven behavior types, (re-)actions in critical situations can be categorized. For instance, the willingness to please others when relating student and facilitator behavior can either be assigned to jealous co-operators or egoists, depending on the fitness threshold to be achieved. Another example is following normative rules, such as waiting for instructions in the classroom, either from facility management outside the room or the facilitator present in the classroom. It can be related to cultural norms including social rewards.

Figure 12.6 exemplifies human-to-human interaction behavior specification when zooming into student behavior after adjusting cooperation behavior based on fitness of accumulated knowledge (see Fig. 12.5). The dotted lines indicated the relative sequence of activities, as there might be additional functions to be performed. However, in this context, only the fundamental patterns of the addressed behavior type are of interest. The examples concern four categories of the aforementioned behavior types:

- *Herding* is further processed to a monitoring subject that reports on all instantiated Student subjects during operation. Once behavior changes can be observed, they are reported and received by the student when selecting herding behavior.
- *Sharing information* requires consolidating individual information which is modeled for that case as function state. Once the information has been consolidated, it can be broadcasted to all other instances of the Student subject at runtime.

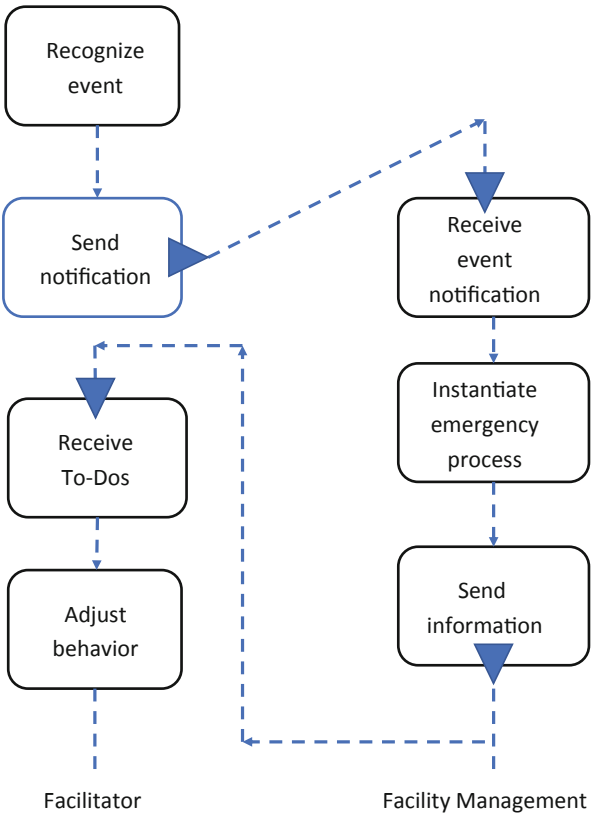

Fig. 12.7 Role-specific behavior of facilitator in critical situation

- *Following* triggers a Leader subject that can be a member of the peer group, i.e., a student, the facilitator, or another role carrier (e.g., facility manager, other community members), that can be addressed at runtime.
- *Helping* is bound to informing others that they can ask for support whenever needed. It is also modeled as broadcast message to instantiated subjects at runtime.

Together with students, a teacher or facilitator is situated in the classroom. Figure 12.7 shows the human-to-human interaction behavior specification for facilitators. Besides adjusting behavior on the fitness of accumulated knowledge, functional interaction with the facility manager is required for further instructions in critical situations. In case of interruption, the facility manager receives a timely report and feeds back the regime to follow.

Figure 12.8 exemplifies some human-to-human interaction zooming into the facilitator behavior specification, including the different types of cooperation behavior on fitness of accumulated knowledge:

- *Egoistic behavior* is encoding when asking for repair, since the facilitator wants to keep a clock in the classroom and asks for prompt replacement.
- *Delegating* expects somebody else, either facility management or even a student to take care about the entire critical situation. It can be trigged by non-cooperative motives.

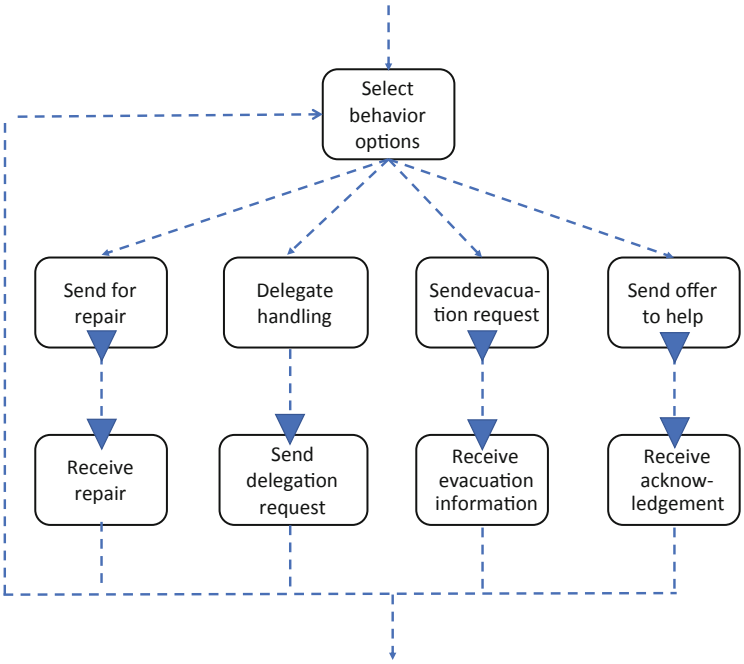

Fig. 12.8 Human-to-human interaction from a facilitator perspective for keeping time control (repair), delegating the further handling, evacuating the room, and helping

- *Evacuating* the room concerns all instantiated subject at runtime and leads to leaving the room according to evacuation principles of the facility. In a way, it corresponds to take leadership making others following.
- *Helping* informs students in the classroom whether they need support handling the critical situation, e.g., when helping to organize another clock or removing broken parts from the classroom. Like the evacuation call, it is modeled as broadcast message to instantiated subjects at runtime.

Now, imagine a combined system. Suppose the teacher is an artificial agent and the crowd consists of humans. If the agent wants to know how the crowd will react when the clock fells down, then the agent asks an oracle. The oracle is a simulation of the crowd, and provided that the individual properties (egoists, conditional co-operators, co-operators) of the humans are known, the oracle will present an answer. Egoists will probably wait until facility management takes over. Conditional jealous people will need some incentives to help. Co-operators will help immediately without waiting for facility management.

In the sense of Daniel Kahneman (2011), the oracle can be seen as the system 2. Similar to people using system 2, when deeper energy-consuming thinking is necessary because pre-learned concepts are not available, machines will use oracles once the machine-learned mental models are not sufficient to solve a problem.