Towards Efficient Context-Sensitive Deliberation

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Abstract. We propose a context-sensitive deliberation framework where the decision context does not deliver an action straight away, but where rather the decision context and agent characteristics influence the type of deliberation and type of information evaluated which will affect the final decision. The framework is based on the Contextual Action Framework for Computational Agents (CAFCA). Our framework also tailors the deliberation type used to the decision context the agent finds itself in, starting from the least cognitive taxing deliberation types unless the context requires more complex deliberation types. As a proof-of-concept the paper shows how context and information relevance can be used to conceptually expand the deliberation system of an agent.

Keywords: Context, CAFCA, Deliberation method selection, Dynamic deliberation

1 Introduction

In social simulation we have always striven for more realistic social agents. This is difficult as human behavior is complex and requires elaborate systems that can be inefficient in terms of performance. More realistic agents would allow for more accurate models of human behavior, however it remains a challenge to attain more realism. As sociological and psychological theories of human behavior keep evolving, social simulation models should adapt as well. In the past decades more models conceptualize human deliberation as not only a purely rational or irrational system, but rather as a more dynamic system with multiple ways of thinking. Kahnemann for example proposes a model with two modes of thinking, either simple and quick thinking (system 1), or elaborate and slow thinking (system 2) [15]. Minsky takes this a step further and describes six levels of deliberation that work together to form a solution [16].

Another challenge when modeling is related to efficiency. The trade-off between many simple agents, where patterns emerge from many interactions, and fewer complex agents, where patterns emerge due to both internal deliberation as well as interactions, is of high importance in social simulations (see [6] for a good overview of this KIDS vs. KISS debate). As we have shown in [10], there is no winner for all cases. Going for many simple agents makes it often easier to replicate statistical findings, however with more complex agents we can

often have a more in-depth analysis of what causes changes in behaviour and incorporate critical aspects that require a certain complexity.

For example, the ASSOCC model [10] contains complex need-based agents with a rich social life. This allowed for detailed analysis of the effectiveness of new restrictions. However, this complexity came at the cost of a limit of about 2000 agents since exceeding this number slowed down the simulation significantly. Contrast this with a mathematical model such as the Oxford model [12] which runs one million agents, where on the other hand the agents only have a simple deliberation system and the effects of changes in the situation are not easily explained.

A solution to this problem could be a dynamic deliberation system that uses efficient quick deliberation most of the time and more complex slow deliberation sometimes. The Consumat framework [13] is interesting as it tried to offer a solution for adapting the deliberation to the situation. This could also provide a basis for dynamically compromising between quality and computational costs of decisions, using a utility-driven form of metacognition [14]. It is one of the few framework that uses some sort of dynamic deliberation. The Consumat framework unfortunately lacks social concepts such as normative behavior (e.g., wanting to be part of a group) or theory of mind (i.e. thinking about intentions, needs, goals, etc. of other agents). The deliberation selection mechanism is rational, i.e. utility maximizing, rather than context dependent.

Since dynamic deliberation can help attain both an increase in realism and large scale simulations with complex agents, we propose a context-sensitive deliberation framework spanning multiple types of deliberation for agents. We started from the architecture proposed by Kahnemann [15] but extended this with the Contextual Action Framework for Computational Agents (CAFCA) [7], which has clearer analytical concepts than the Consumat [13] with a richer representation of social concepts. The context-sensitive deliberation framework does not directly deliver an action based on the decision context, but rather the decision context and agent characteristics influence the type of deliberation and type of information evaluated which will influence in turn the final decision. The aim of this framework is not to make a model of human cognition, but rather make a context dependent social agent inspired by work such as that of Kahneman [15] and Minsky [16].

In the following section we describe the definition of context from the literature and explains the CAFCA framework. The third section shows our model in detail, starting with the general model mechanism, followed by an explanation of the relevant information from the context per deliberation type and an indication how and when a switch is made to a different deliberation type. In the fourth section an example is shown that serves as proof-of-concept, it uses an existing smoking ban [3] simulation and applies our contextual framework to expand the agent deliberation. This section is followed by a discussion on our framework, the applications and a conclusion.

2 Related work

2.1 Context

The fact that context is important for the deliberation is not new. The relation between time scales and deliberation was posed by Newell and Card in [17]. Although they shows there is some connection between types of deliberation and context, they do not show how an agent can dynamically connect context and deliberation. Similarly there is quite some work on defining aspects of contexts in Human-Computer Interaction. Notably [21] gives a very usable definition of contexts (see Figure 1) when one considers the use of a software system in a context.

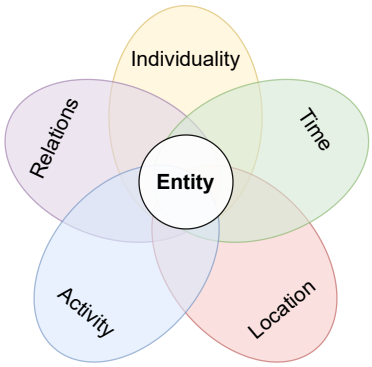


Fig. 1. Categories of context according to Zimmermann [21]

The five context categorizations are not formalized, as they dependent on the domain and 'context' thus can be formalized very differently. To give a better understanding of the categories we give a couple of examples, which is by far not the full definition of the categorizations. *Time* can be a specific point in time, but also a period, it can relate to for example seconds, minutes, days (even working days or weekdays), years, centuries, etc. The *location* can be a physical place, with variety in size, for example larger geographical, building, complex, town, region or country. The *activity* indicates what is done in the context, alone or together, grocery shopping, playing football, having dinner, in a formal meeting or non-formal. The *relations* include the aspects of the context related to other people, groups or institutes. It also includes theory of mind, that can for example relate to goals, intentions, social norms, values of other entities. The *individuality* contains the characteristics of an entity's current interests and goals, value priorities, experience (is the situation known, clear which variables should be salient,...), and needs/motives. These are interesting definitions for context, however they do not aid in selecting a type of deliberation.

2.2 Contextual Action Framework for Computational Agents

The Contextual Action Framework for Computational Agents (CAFCA) is developed to categorize and incorporate different kinds of deliberation for different situations. It is developed specifically for social simulation purposes based on contextual human action and agent action. Figure 2 shows the 3x3 deliberation matrix.

		Sociality Dimension		
		Individual	**Social**	**Collective**
Reasoning Dimension	**Habitual**	Repetition	Imitation	Joining-in
	Strategic	Rational choice	Game Theory	Team reasoning
	Normative	(institutional) rules	(social) norms	(moral) values

Fig. 2. Adopted from [7], it shows the categorization of deliberation methods. In the original version of the matrix in [7] Habitual is named Automatic, the new label is introduced in [8]

This matrix gives a broad categorization of agent deliberation methods. It consists of a social axis (horizontal) which has increased social deliberation when moving from left to right and a reasoning dimension (vertical). In the first column (Individual) the deliberation methods only consider the physical properties of other agents, they are just seen as obstacles or objects rather than social beings with their own behavior and goals. Moving to the second column (Social), theory of mind becomes important, this column is about working together or outsmarting other individuals e.g. game theory. Finally the third column (Collective) focuses on being part of a group and includes all of the aspects mentioned before in addition to group affiliation aspects.

The reasoning dimension starts with the habitual layer which is the least cognitively taxing as it is about following habits or imitating behavior, without plan making or deeper deliberation. The Strategic layer uses deliberation to form plans or theories to choose the best course of action, based on utility. The strategic layer will however see rules and norms as strict and not open to violation. E.g., an agent that wants to steal something will not do it in the strategic layer, but will have to move to the normative layer to deliberate about how bad it is to break the norm (to steal). It is at the Normative layer where it is decided if it is and how important it is to follow the rules and norms.

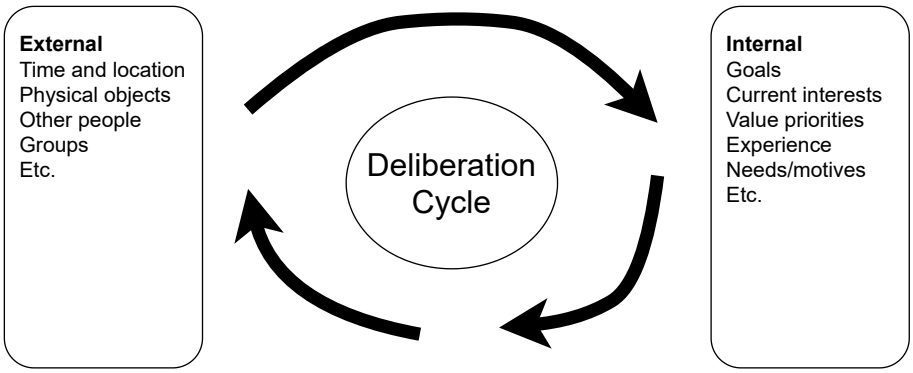
While this contextual framework is interesting, it does not provide the meta deliberation on selecting a deliberation type based on context. The closest formal model on context recognition influencing deliberation is discussed in [5], but it

directly chooses a deliberation type based on context. The main fallacy that the approaches seem to have is that it is assumed that we first determine the context we are in and subsequently determine the best fitting deliberation method. The problem is that there is no loop, influencing which context should be considered based on the deliberation method.

3 Modelling

3.1 Context-dependent deliberation cycle

The context-sensitive framework dynamically explores the decision context as follows, starting at cognitively less taxing deliberation types and context exploration, and adding more complexity until the decision problem is solved. The context exploration should happen dynamically based on the goal of the agent, the information from the context and the deliberation type used, while allowing for adaptation of each of these elements during deliberation. Our solution to achieve this is the following conceptual model (see Figure 3).



	Individual	Social	Collective
Habitual	1.1 Repetition	1.2 Imitation	1.3 Joining-in
Strategic	2.1 Rational choice	2.2 Game Theory	2.3 Team reasoning
Normative	3.1 (institutional) rules	3.2 (social) norms	3.3 (moral) values

Fig. 3. Contextual deliberation cycle

Deliberation for an agent usually (that is, unless there is an important event interrupting) starts with a minimal context (external environment) and a goal or current interest (internal state). The next step is deliberation in the CAFCA matrix using *repetition (1.1)*. When this fails another deliberation type can be selected based on the reason why it failed. Did it fail because there was not enough information? Or did it fail because there was not a pre-existing plan? Does the agent need help from others? With a different deliberation type selected this brings us back to the external and internal elements exploring the context based on the *relevant information* needed for this deliberation type. This deliberation process iterates, expanding the context dependent on the relevant cell, selecting cells based on the context and decision problems encounter or even adjusted the goal of the agent if needed. The general direction of exploration in the matrix is from top-right (e.g. after repetition use rational choice or imitation) to the bottom-right (ending with *'Moral' values (3.3)*). The further to the bottom-right the more complex the deliberation becomes, thus if the problem could be solved by simpler methods this makes the process more efficient as it decreases the cognitive load.

3.2 Information relevance and CAFCA cell transitioning

To make the deliberation cycle (Figure 3) more concrete we describe the information relevance and transitions for each of the cells in the CAFCA matrix. Figure 4 shows relevant information per cell, while Figure 5 shows transitions among the different cells.

Figure 4 shows the relevant information that is required from the context to make a decision using that type of deliberation. For example, in repetition (1.1) the agent only needs the accessible objects, people and actions currently performed as this is enough to perform a pre-made plan. If the plan fails different information is needed so a switch to another CAFCA cell is required. In for example the imitation cell (1.2) the agent is interested in other agent's behavior and goals, beliefs, and intentions to determine if their behavior is relevant. By switching cells, the perspective on what is relevant to the decision context changes. The context is explored dependent on what is relevant for the goal and the current deliberation matrix, which creates a focused decision context tailored to the deliberation problem of the agent in the given situation.

For readability purposes, we show relevant information of previous cells (those that are directly above or to the left) in gray. In practice cells more to the right or bottom can always contain the relevant information from preceding (horizontally and vertically) cells. For example in the 'Moral' values (3.3) the accessible objects and people from repetition (1.1) could still be relevant, but only when they are part of the explored context! Using this categorization makes it possible to focus on relevant parts of the context and build a context specifically for the decision problem at hand.

Relevant information for each cell is also information that may hinder achieving the goal even when this is not directly indicated in our matrix. For example, at the strategic level in rational choice (1.2) the agent may consider stealing

	Individual	Social	Collective
Habitual	Accessible objects, Accessible people, Actions currently performed Accessible means being accessible to the DB in the current context.	Theory of Mind: G, B, I Actions performed by relevant people Accessible objects, Accessible people, Actions currently performed Relevant people are those who have a similar goal to the DB. There is a minimal theory of mind.	Theory of Group: G, B, I Expected action as team member ToM: G, B, I Actions performed by relevant people The group considered is the group that the DB wants to join. The DB need information to perform actions to belong to the group.
Strategic	Useful objects, useful people, Utility Accessible objects, Accessible people, Actions currently performed The set of objects and people is extended to include also not directly accessible objects for plan making.	ToM: Mental attitudes ToM: G, B, I Actions performed by relevant people, Utility Useful objects, useful people Relevant people are those who can aid or hinder the DB. Mental attitudes referes to the information needed to make an estimation of the actions that other agents will perform.	ToG: Mental attitudes, roles Agents in my group ToM: Mental attitudes, Theory of Group: G, B, I Expected action as team member The mental attitudes and roles are information needed for the DB to make decisions in the group. E.g. status, structure of team, mental models, roles
Normative	Related rules, Related laws, Useful objects, Useful people, Utility Rules and laws that are relevant for the current context	Related social norms People's opinion towards those norms Related rules, Related laws, ToM: Mental attitudes Social norms related to the current context. That may hinder or lead behavior of the DB.	(Moral) values of self, Theory of Mind: values, Theory of Group: values ToG: Mental attitudes, roles Agents in my group Related social norms People's opinion towards those norms Consider values of self, others, group.

Fig. 4. CAFCA information relevance. DB = deliberating agent, G = Goals, B = Beliefs, I = Intentions, ToM = Theory of Mind, ToG = Theory of Group

something. However, a conflict arises as there is a rule against stealing. To be aware of this such rules should be part of the decision context when they become relevant, even though rules are not explicitly mentioned in rational choice (1.2) but rather in 'Institutionalized' rules (1.3). If a conflict with a rule arises the agent moves from the strategic to the normative layer, where rules are more explicitly part of the context since now they should be evaluated.

Figure 5 shows the trigger of transitioning between the CAFCA cells. When the deliberation type cannot find a solution from the explored context either the context may be explored further or a different deliberation type may be considered. Dependent on the currently selected deliberation type and context different transitions are possible. Ending in the 'Moral' values if the decision drags on.

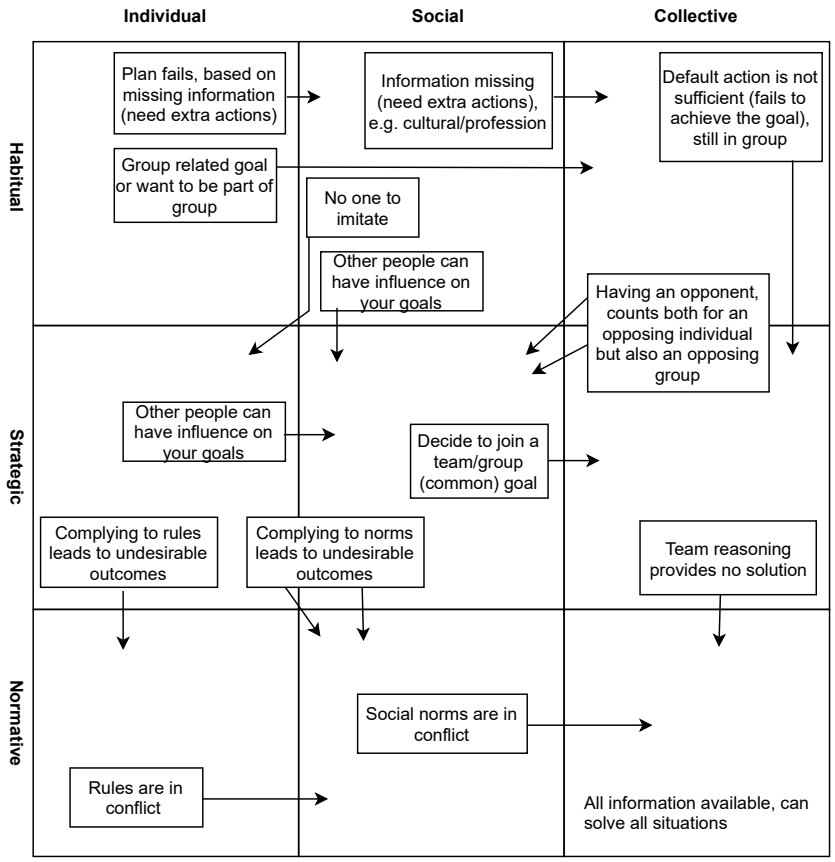


Fig. 5. CAFCA cell transitions.

If the system transitions to a cell while the preconditions of that cell are not met, the system will directly move to the next or previous cell. This process is also dependent on the cell but is related to not meeting the preconditions of the cell. For example, after moving from *imitation (1.2)* to *joining-in (1.3)* because the agent wants to join a group, the agent may become aware he does not share the same goals as the group and move backward to imitation.

In case there are conflicts or when multiple cells may be applicable for transitioning towards, one could base the decision of transitioning on the characteristics of the agent. For example, there can be agents that move quicker to the social dimension to find the solution while other agents will move down (deeper) into the matrix to do more complex but individual deliberation straightaway. There could also be agents that do not even consider breaking the rules or norms, these agents would not even use the normative layer (with the exception of 'Moral' values (3.3)), only in very extreme circumstances.

We refrain from explicitly stating how to implement each of the cells as this is out of scope for this paper. However, we can provide some typical examples of formalizations or implementations shown by the literature. Imitation can for example be imitating the direct neighbors or neighbors in a certain radius in a Cellular Automata implementation or imitating the agents in the same building or same network in other simulation. BDI agent theory can be used for rational choice [18] as this is problem solving that in principle does not consider social aspects. Game theory is a way of solving problems in the social strategic cell and there is enough literature to be found, see for example [1] for an introduction. For team reasoning typical examples are the work of Sugden [20] who explains and formalizes team reasoning, or [4] which is a book formalizing team work in agent systems. Institutions have been formalized by Esteva [9] and legal norms set by a state can be found in [9], both these examples can be used for 'Institutionlized' rules. Some normative frameworks are [19] which gives an overview of norms in simulation, while [2] shows an architecture that uses norms. For values one could consider the formalization by Heidari [11].

4 The smoking ban simulation using the framework

The described framework can assist in making a conceptual model for a social simulation but can also help extending an existing model. In this section we take such an existing model, the smoking ban model [3], and extend its deliberative aspects using the concepts presented in the framework.

The smoking ban model is a good case study as it incorporates deliberation aspects from multiple cells in the CAFCA matrix such as legal norms, social norms (imitation) and values. The agents have a value priority based on a predetermined distribution. For example, one could have 60% law following, 30% norm following and 10% prefer smoking even when smoking becomes banned. The agents are either smokers or non-smokers. The introduction of the smoking ban in restaurants and bars creates a change in context that may or may not trigger a change of behavior. The simulation has three bars and 50 agents that can switch bars and go home. The agent actions are: Go into bar, leave bar, smoke inside, smoke outside (sub-optimal), and refrain from smoking (very sub-optimal). Considering the CAFCA framework the aspects that are incorporated are imitation (as following the social norm), 'Institutionalized' rules (when deciding to not follow the law) and 'moral' values (as in smoking even though there is a law, hedonism).

Using the model shown in Figure 4 and Figure 5 and the conceptual model of the smoking ban [3] an extension to the agent deliberation can be generated. A smoker can enter a bar they visits regularly. For them this is a normal context allowing for the repetition deliberation method, leading them to smoke inside. However sometimes the context can have changed slightly, leading to different considerations. E.g., if the bartender is not the usual one this might signal a change in management and thus a different smoking policy. Similarly, the introduction of a smoking ban leading to signs that it is forbidden to smoke inside.

Note that these elements of the context are related to the intention of smoking. Thus, this intention leads to picking up certain cues from the context that might influence the intent! Given the change in context the smoker can now take a social view and draw in the presence of the other people present in the bar and see what they are doing. When many others still smoke as usual the smoker might just imitate them and also smoke. However, if they notice their group of friends they usually meet in the bar, and all of the friends are not smoking, they might move to a deliberation including the value of group affiliation and complying to what friends are doing.

All of this behavior is still determined by the first row in the CAFCA matrix. Notice that we first look at the other people as people that have a similar goal of being in the bar and at second instance look at people that one has a special relation to that is worth taking into consideration. Thus the deliberation changed of nature while taking in more aspects of the context.

It can become even more interesting when a person walks up to the smoker and tells it is forbidden to smoke. This will trigger more context exploration as now the smoker has to consider the other person as well, leading to for example game theoretical or (social) norm deliberation methods. If the smoker does not know the other person, they might consider a strategic way out of the situation such as: comply and give up smoking in the bar, go outside to have a smoke, stir up their friends to join in smoking. These possibilities again lead to deliberation methods going from left to right in the second row of the CAFCA matrix.

Finally, the smoker also might consider whether the smoking ban should be followed and thus lead to a more long-term change of behavior. This is the kind of deliberation taking place on the normative row of the CAFCA matrix. Note that this normative reasoning can take place in parallel or even after the deliberation taking care of the present situation. Thus, the deliberation methods are not all exclusive! The more elaborate ones are triggered when more aspects of the context are taken into consideration. And reversely, more social and normative aspects of the context are taken into consideration when more long term influences are expected on the agent's intentions and goals. This flexibility in deliberation processes and interaction with the context is very much like human deliberation. Humans do most things automatically whenever they can (being quick and efficient in deliberation) but in almost any situation they can change to a more complex deliberation if the situation requires.

Figure 6 shows an example of meta deliberation for an agent. Based on the context different deliberation can be selected. This example shows an agent that smokes, is not strict rule following and not a team player. The first terms speaks for itself, but the not strict rule following means the agent can consider going to the normative layer to deliberate about rules and norms, and whether to follow them. Strict rule following could be an agent that never visits the normative layer, except for 'moral' values. The non team player means the agent will not consider visiting team reasoning to get the group of friends together rather the agent will just wait at the bar or leave the bar when friends do not show up. A team player would make an effort to get the group together.

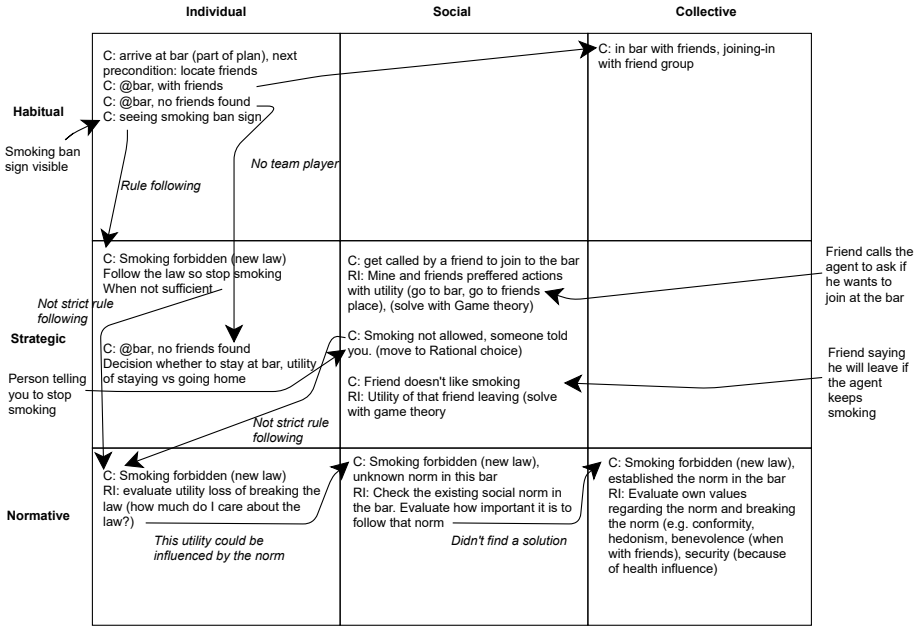


Fig. 6. Smoking ban context-sensitive agent: smoker, non strict rule following, non team player

As shown in the example instead of predetermined preferences as in the original smoking ban model [3], the new deliberation takes context and the agent's characteristics into account to make decisions that could lead to different actions but also the same action based on different reasons. Does the agent stop smoking because the law says so (Institutionalized rules)? Or is it because their friends tell them to (Game theory)? Or because of a value based decision that it is not healthy? (Moral values). With this meta deliberation we should be able to answer these questions. The 'only' thing to do now is to formalize the actual framework so we can actually start answering these questions with our simulations.

5 Discussion & Conclusion

The presented framework is of course not a strict definition of which information should be considered. There are most probably some changes possible to the information written in the cells. However to move forward in this vague, dynamic, and difficult topic of context we need these rougher descriptions. Using CAFCA as a baseline for context already structured our research on context and gave it focus. It should be seen as a guideline for a context-sensitive deliberation agent framework.

While the matrices may be quite overwhelming, when actually implementing we expect that the matrices may be easier to comprehend as the relevant information is limited through the domain that one wants to study. This combined with shortcuts in the implementation can make it feasible to implement a context sensitive system that is able to visit all the CAFCA cells (if needed).

Research on such frameworks also can lead to advances in social science beyond scalable advanced agent models. E.g., which deliberation system to focus on when building a policy to bring about the best effect? Would imitation or changing rules achieve the highest impact? More research questions related to the smoking ban are e.g., Why is the agent following the law? Is this because of the agent's friends who don't want the agent to smoke? Does the agent imitate other people in the bar? Does the agent actually care about the law and follows it directly? Many questions already popup when considering this new framework.

To conclude: contexts are vague, dynamic, and difficult to formalize. The fact that contexts and deliberation are not independent makes this even harder. While deliberating the context should be build, but this context can also influence the deliberation type used which in turn influences the type of context that is considered. With our framework we made a step forward towards unraveling context and in the future using it as an explicit element in agent based simulations. This could be very beneficial as this way of using contexts can help creating efficient simulations which is, key to large scale, complex, socially aware systems. Think of social simulations for crises or policy support, but also social robotics and virtual characters for training and coaching.

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