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Towards Agents for Policy Making

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Abstract. The process of introducing new public policies is a complex one in the sense that the behavior of society at the macro-level depends directly on the individual behavior of the people in that society and ongoing dynamics of the environment. It is at the micro-level that change is initiated, that policies effectively change the behavior of individuals. Since macro-models do not suffice, science has turned to develop and study agent-based simulations, i.e., micro-level models. In correspondence with the good scientific practice of parsimony, current ABSS models are based on agents with simple cognitive capabilities. However, the societies being modeled in policy making relate to real people with real needs and personalities, often of a multi-cultural composition. Those circumstances require the agents to be diversified to accommodate these facts.

In this positioning paper, we propose an incrementally complex model for agent reasoning that can describe the influence of policies or comparable external influences on the behavior of agents. Starting from the BDI model for agent reasoning, we discuss the effect when personality and Maslow's hierarchy of needs are added to the model. Finally, we extend the model with a component that captures the cultural background and normative constitution of the agent.

In the paper we show how these extensions affect the filtering of the desires and intentions of the agent and the willingness of the agent to modify its behavior in face of a new policy. This way, simulations can be made that support the differentiation of behaviors in multi-cultural societies, and thus can be made to support policy makers in their decisions.

1 Introduction

Effective social simulation and effective support for policy makers depends on our ability to model the adaptive individual decision making process given subjective social norms, individual preferences, and policies. Where policy makers on different levels believe they only act successfully within bounds prescribed by social norms, they struggle to force big changes top-down if they don't seek social support. In fact, social norms have measurable consequences for the environment, e.g. energy intensive consumerism and lifestyles, have led to the ecological near-crisis now at hand [26]. Moreover, Kable and Glimcher showed that social norms vary from culture to culture, by proving that the social discounting factor is not a unique scientific number, but a very subjective value differing from culture to culture [17]. Simultaneously, policies are based on aggregate top-down assumptions of economic behavior, whereas many changes occur bottom-up

due to heterogeneity which is at the basis of cultural drift and adaptivity of a population. Due to heterogeneity, changes may occur that were not foreseen at the introduction of a policy, leading to a low efficacy of a policy, if anything is achieved at all. To support policy makers in their policy design, it is therefore desirable to evaluate proposed policies with models that are not based on economically desirable behavior (equilibrium theory), but on models that take realistic social interaction and cultural heterogeneity into account. Models to evaluate policies, should consequentially include complex agents that more realistically mimic human adaptive behavior. Also the environment in which the agents act needs to be represented dynamically, under the assumption that the environment influences the behavior of agents as well. Because of the magnitude of the world to be modeled, aggregation may still be necessary for sake of computational reduction. The ecological foot-printing method for example is based on aggregate data, which could be coupled back to environment degradation, the notification of which may in return induce stronger emotions in agents to act, as is suggested by statistical data on urban and rural populations.

The above considerations indicate that the design and analysis of policies is a complex task. Many, highly interconnected, and unforeseen factors influence the applicability and result of new policies. This makes it hard to evaluate a (new) policy and foresee its implications. Macro-economic models are often fairly simple and founded on the principle of appropriate risk weighted return. System dynamics approaches [25] are often used for this effect and focus on the understanding of overall behavior of complex systems over time (e.g., causal feedback loops, nonlinearity). However, they are not well suited to study the effects on individuals and groups involved. That is, those models do not provide the instruments to evaluate policy at micro-level of implementation and are not able to handle uncertain situations. On the other hand, micro-models of individuals and groups, usually based on agent models for emergent global behavior, such as ABSS, do not provide the means to specify and regulate normative and regulative global restrictions [20, 24].

Policy makers recognize the need for models that are able to incorporate different levels of abstraction and analysis. For instance, analysis of changes in criminal laws require both the understanding of its political and economic consequences at the macro level, but also the consequences on the working processes of criminal system staff, and the effects on the behavior of different risk groups. The above requirements indicate a need to incorporate macro-, and micro-level models in one simulation. We therefore propose a mediating layer, we call meso-layer, that connects the macro-, and micro-level in a simulation effective way. Basically in the meso layer we specify elements that "influence" the behavior of groups of agents. These are things like norms and organizational (or group) structure. These elements do not dictate behavior as elements on the micro level do, but are also different from the descriptive laws used on the macro level.

Section 2 describes our way to connect the macro- and micro-levels using this meso level. Section 3 motivates the need for extending existing agent models with personality, a hierarchy of needs, and a cultural and normative component. It also contains a short overview of existing work. The BRIDGE agent architecture presented in section 4 introduces a high level design for such agents. Ideas for future research and a summary of the proposals introduced in this paper are formulated in section 5.

2 Simulation support for policy making

Every simulation model focusses on the aspects under study and abstracts from aspects that do not (or are not assumed) to significantly influence the aspects under study. Unintended effects are difficult to predict because analysis is mostly based on macro-economic, econometric, models for policy analysis that are not able to represent individual interpretations, and thus cannot provide a clear linkage between structural features of the policy and the individual responses to it. E.g., a tax increase policy, expected to result in an increase of state revenue according to econometric models, may in fact have the overall effect of reducing tax revenue due to individuals' decisions not to earn money that is taxed or to opt for capital flight.

In complex systems, global behavior emerges unpredictably from the complex of individual micro-level behaviors of the autonomous and heterogenous actors, which are in turn influenced by the macro-level, that is, their own perception of the policies, their context, and their perception of the global outcome. Furthermore, the complex and dynamic nature of social phenomena increases due to the inter-actor relationships between the participating actors, which include individuals, groups, organizations and institutions. We claim that any useful simulation tool for policy making should be able to handle current problems faced by policy makers such as:

- representation of dynamic situations
- representation of individual behavior rather than averaged pseudo-rational behavior
- representation of inter-actor interaction
- representation of normative and cultural aspects
- visualization of above aspects and their dependencies

Our proposal for the next generation of simulation models is to create models that provide three layers of description (macro, micro and meso) and the connections between those layers. The most abstract, or macro, layer includes global functionalities and requirements. Macro-level expectations are specified as to enable a natural representation of the overall system that abstracts from (technical) issues. The lower, or micro, layer specifies the characteristics, aims and requirements of the individual entities and/or social groups. The middle layer allows for the coordination between micro and macro and enables the description and measurement of dynamic changes in the context. We will describe it further in the next subsection.

2.1 The meso-level

From the macro level perspective, the meso level offers three types of components. If the macro level has a descriptive component that is empirically valid and which is not in the focus of the simulation (and thus not further expanded in the micro level) then this component is part of the meso level as a kind of "law of nature". I.e. it is assumed all agents (either individually or collectively) abide by this law. If the macro level contains a component like above, but which is in the focus of the simulation, then the component is merely treated as a benchmark to which agent behavior is compared. I.e. the micro level models of the agents should be such that this law "appears" in standard situations,

but it does not have to appear when changes are made in the context (e.g. adding a new policy).

Finally, the meso level contains *new* components that are usually specified at society level in order to influence individual behavior. These components are things like norms, regulations and organizational structures but can also contain cultural biases. These components can be taken as given within the simulation framework. I.e. they do not arise from the agent behavior, but rather influence it top-down. E.g. a norm as “*it is forbidden to drive faster than 100 km/hr*” influences the decision of the agents how fast to drive. However, it depends on the individual agent whether it complies to the norm or not. This decision is in itself influenced by other norms (e.g. being on time at work), culture (e.g. we should all abide by the law) and personality (e.g. if the risk of being caught is low I don’t follow the norm if it conflicts with my desires). This third type of components is really new to the meso level. The other two types actually define aggregation and refinements within the simulation. Together the three types really make for a flexible but simulation-efficient framework.

The overall framework, depicted in figure 1 enables the definition of macro-level analysis instruments and regulations, and the detailed specification of behaviors of individuals and cohes groups and their requirements. Furthermore, it enables the analysis, specification and organization of committed and/or expected collective behavior, as basic concepts that complement existing macro and agent-modeling resources. The rep-

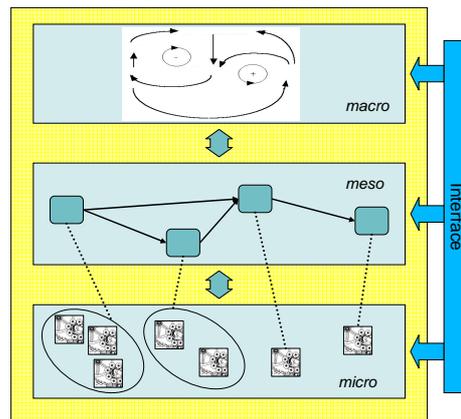


Fig. 1. Policy Making Framework.

resentation must include normative, ontological, organizational and evaluation aspects. Whereas testing the effect of different rules (behavioral assumptions) on the system behaviors turbulence would be one thing, a next challenge would be to test the efficacy of policy strategies. The ideas on policy testing in agent based modeling as expressed in [13, 14] form one starting point for this. The other is the work already done on the connection between meso-level elements such as norms and organizational structure to agents as is done in [28].

2.2 Interface tools

Policy makers require methods and tools for support of policy design to be able to assess factors such as realization time, development cost, side effects, non-effects, negative effects and resistance to change. Furthermore, tools and techniques should enable participation in the development and analysis to a heterogeneous group of stakeholders, such as, politicians, regulators and the general public.

The policies imposed at the macro-, or mesa-level will be reasoned about at the agent-level, such that the agents are capable making their decisions with respect to the proposed/imposed policies and the mechanisms that are put in play to enforce compliance with the policies. This requires of course that agents need to be equipped with a cognitive representation of their social environment in order to capture the social dynamics in their society. Furthermore, the policies should address the behavioral drives and processes of the individual agents.

In order to analyze and understand the consequences of policies, complexity must be captured at all three levels. It is therefore essential to ensure that the models are easy to use and give interesting, understandable projections that usefully inform scenario development in an engaging and productive framework for stakeholder participation. Such a framework requires interface tools that visualize the dynamics and statistics of the simulation in comprehensive formats and that enable the users to change assumptions and settings quickly and easily, so that policy makers can experiment by running various simulations. Due to space limitations, the focus of this paper is on the underlying model for policy design and not on the interface.

3 Personality, Culture, Norms, Hierarchy of Needs

Representations of human behavior in social simulations entail models for deciding about agents intentions, based on agents beliefs and desires. According to March [21], decision making processes may be rational or rule following. Rational decision making aims to maximize a utility function and is used in economic games and simulations. Human decision making processes often have both rational and rule-following aspects. Rule-following decision making can be seen as imposing moral boundaries on acceptable outcomes of rational decision making. It can also be seen as consolidated experience or an evolutionary outcome of rational decision making [21]. In our opinion, agents in simulations for the purpose of policy making should decide in a more human fashion and apply both types of decision making. This implies that agents must grasp the concept of norms, have cultural scripts, possess a personality, and react based on a hierarchy of needs in correspondence to human nature. In the rest of this paper we will describe how agents can be endowed with these elements, which are introduced below.

3.1 Hierarchy of Needs

Individual behavior follows from basic motivations: the satisfaction of natural needs (hunger, etc.) the difference laying on the way these are satisfied [2]. These motivations (also called source of actions by) make an agent behave either reactively or cognitively

(i.e. adopting a low or a high level behavior). Maslow's Pyramid of Needs synthesizes a large body of research related to human motivation [22] that views all needs as instinctive, but some are more powerful than others. Needs in the lower levels are more powerful, while the highest level is only acted upon when the other levels are met. The bottom levels (Physiological, Security, Social and Esteem Needs) of the pyramid are called "deficiency needs": the individual does not feel anything if they are met, but feels anxious if they are not met. Failure to meet these needs leads to deprivation. The highest-level of the pyramid is called a growth need: when fulfilled, they do not go away; rather, they motivate further. Growth needs do not stem from a lack of something, but rather from a desire to grow as a person.

3.2 Norms

Norms can be seen as constraints imposed by society on the behavior of the individuals. An important aspect of norms is that individuals can decide to violate them. The violation can itself be a trigger of further behavior in order to punish the violation. Thus norms do not directly constrain behavior but influence the decisions to take a certain course of action. They can do this in different ways. A person may be aware of a norm like "one should always give an answer to a request" even though he does not agree with it. He can exploit the existence of the norm by always first requesting information before trying to find it himself. He does not necessarily comply to the norm and if he does it might be an unconscious decision or because it benefits him.

A person can also accept a norm. In that case he agrees that the norm is a good one and he tries to follow it as much as possible. Only in special situations (e.g., if the norm contradicts another, more important norm) will he violate it.

A difference between the notion of norms, as we use them, and the notion of culture is that we assume norms to be explicitly available. Therefore a person can reason with and about them. Reasoning explicitly about norms is included in a number of social simulations, see, e.g., [8, 5].

3.3 Personality

Personality has been defined as "*the distinctive and characteristic patterns of thought, emotion, and behavior that define an individual's style and influence on his or her interactions with the environment*" [9]. Personality is not something concrete, and existing personality measurements or indicators can just give us an indication of one's personality. A personality inventory commonly used is the Myers-Briggs Type Indicator (MBTI), based upon Carl Jung's theories [16, 18]. According to Jung, people take in and process information in different ways. He characterized individuals in terms of attitudes (extraversion and introversion), perceptual functions (intuition and sensing) and judgement functions (thinking and feeling). Meyers-Briggs extended this classification with a fourth dimension that distinguishes between judgement and perception:

Extraversion or Introversion: Shows how a person orients and receives their energy. Extravert people prefer to acquire their personal energy from the outer world of people and activities, as where introverts prefer to acquire their personal energy from the inner world of ideas and thoughts.

Sensing or Intuition: Describes how people take in information. Sensing people tend to concentrate primarily on the information gained by the senses, creating meaning from conscious thought and limiting their attention to facts and solid data. People who prefer intuition are interested in the “big picture” when interpreting information, taking a high-level view, as opposed to digging into the detail. They concentrate on patterns, connections and possible meanings.

Thinking or Feeling: Indicates how people prefer to make decisions. People who prefer thinking base their decisions on logic, objective analyzes of cause and effect, whereas people who prefer feeling are influenced by their concerns for themselves and others.

Judging or Perceiving: Describes the way you manage your life and how you deal with the outer world. People who prefer judging like to have a planned lifestyle, everything should be in order and in a scheduled manner. On the contrary, people who prefer perceiving are more unplanned, flexible and spontaneous in their lifestyle. They prefer to keep all options open.

Personality determines how decisions are taken and basic patterns of behavior (and therefore will determine the type of reasoning used by simulation agents). E.g. a sensing person needs to have all facts established before taking a decision while an intuitive person concentrates on possibilities.

3.4 Culture

In all aspects of human life, the desires of people, the decisions people make and the procedures for decision making are culture-dependent in several ways. First, the priority of goals depends on culture; for instance “maximize personal wealth” may have priority over “maintain pleasant interpersonal relation”. Second, preferences for rational versus rule following procedures differ across cultures. Third, if a rule following procedure is chosen, the rules depend on culture. Fourth, a decision may be interpreted offensive by an opponent having a different cultural background. Also, the appropriate reaction to inappropriate behavior differs across cultures.

Culture is what distinguishes one group of people from another [11]. This implies that culture is not an attribute of individual people, unlike personality characteristics. It is an attribute of a group that manifests itself through the behaviors of its members. For a trading situation, as analyzed in [12], the culture of the trader will manifest itself in four ways. First, culture filters observation. It determines the salience of clues about the acceptability of trade partners and their proposals. Second, culture sets norms for what constitutes an appropriate partner or offer. Third, it sets expectations for the context of the transactions, e.g., the enforceability of regulations and the possible sanctions in case of breach of the rules. Fourth, it sets norms for the kind of action that is appropriate given the other three, and in particular, the difference between the actual situation and the desired situation. Of course, culture is also created by people and thus generated by the behavior they display. However, we assume that the time scale on which culture changes is much larger than what we are typically interested in during a simulation period. Therefore we assume the culture to be a fixed component rather than an evolving entity itself (for our purpose).

4 BRIDGE Agent Architecture

In order to develop agents that are able to reason about complex social situations, such as determine the consequences of policies to themselves and decide to adapt their behavior accordingly, it is essential to provide agents with constructs for social awareness, 'own' awareness and reasoning update. The fact that these issues are explicitly represented in the agent architecture allows for introspection on the drives of behavior.

Existing agent models can be divided into two types: deliberate reasoning models and unreasoned models³. Both have their strengths and weaknesses. In fact, Silverman states *"no model will ever capture all the nuances of human emotion, the full range of stress effects, or how these factors affect judgment and decision making. However, to the extent that a model provides a valid representation of human behavior, it will likely be useful to those who wish to simulate that behavior"* [24].

Deliberate agent models, such as BDI [3], have formal logic-grounded semantics, but require extensive computational resources. The Subsumption Architecture [4] takes an intentional view, and aims to provide the behavior displayed by lower level life forms which Brook's claims are *"almost characterizable as deterministic machines"*, through a combination of simple machines with no central control, no shared representation, slow switching rates and low bandwidth communication. Cognitive models, such as ACT-R and SOAR [1] aim at understanding how people organize knowledge and produce intelligent behavior based on numerous facts derived from psychology experiments, and employing quantitative measures. However, these models lack realism since they do not incorporate demographics, personality differences, cognitive style, situational and emotive variables, group dynamics and culture. On the other hand, neurological oriented models that mimic the brain, such as neural networks, lack transparency to link observed behavior to the implementation. Realistic agent models should combine the characteristics of the different types.

We are interested in understanding the consequences of macro-level design (policies) on the micro-level decisions of individual agents. This is in some sense the opposite of [24] where the aim is the *"emergent macro-behavior due to micro-decisions of bounded rational agents"*. The model of the human mind CLARION [27] aims to explore the interaction of implicit and explicit cognition, emphasizing bottom-up learning (i.e., learning that involves acquiring first implicit knowledge and then acquiring explicit knowledge on its basis). CLARION's goal is to form a (generic) cognitive architecture that captures a variety of cognitive processes in a unified way and thus to provide unified explanations of a wide range of data. The CLARION model and the BDI model are both excellent candidates for the extension as aimed for in this paper. The emphasis on deliberation in the study of the reaction to new policies, gives us a slight preference for the BDI model over the CLARION model. However, the ideas presented here can also be applied to the CLARION model.

³ We use this word to mean the opposite of deliberate decision making. We refer to such notions as automatic, inborn, inherent, innate, instinctive, intuitive, involuntary, native, mechanical, natural, reflex, spontaneous, unlearned, unpremeditated, unthinking, and visceral. This is thus different from the more usual concept of 'reactive'.

Our aim is to describe, given a new policy, how different people react to it when made aware of the new policy. The decisions made by the agent in reaction to the new policy are the basis for the adaptation of the agents' behavior, which in its turn will determine the emergence of changed macro-behavior, the consequence of the policy. In this view, policy analysis at the agent level is a rational activity, for which agents explicitly reason based on their beliefs, desires and intentions. In this paper we add to this that this decision making process is not only deliberate, but also unreasoned. As a consequence of the above, policy-analysis agents require the extension of the BDI representation to support a description of the agent's personality, hierarchy of needs, and normative-cultural context. For this reason, we propose the BRIDGE agent architecture (Beliefs, Response, Intentions, Desires, Goals and Ego) as depicted in figure 2.

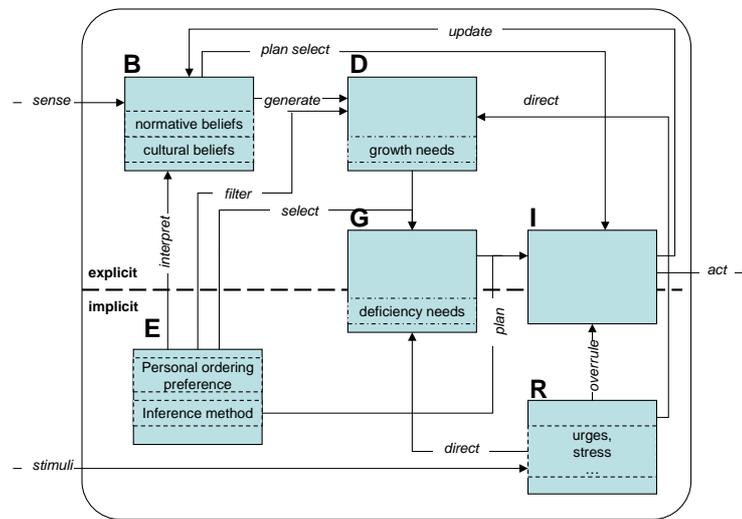


Fig. 2. The BRIDGE Agent Architecture.

4.1 BRIDGE Mental Components

The mental components of the BRIDGE agent architecture incorporate the explicit rational process and implicit (unreasoned) behavioral aspects. BRIDGE is so defined that it can be used in various settings: 'pure' emergent behavior is achieved by using only the subsystems in the lower level of the architecture, purely intentional deliberate behavior results from the top level of the architecture, while the combination of both levels integrate deliberate and unreasoned decision making.

Ego Describes the filters and ordering preferences that the agent uses. Personality type determines the choice of reasoning, e.g., backward reasoning (explorative, goal-based) is associated with intuitive types while forward (belief- or evidence-based) reasoning is typical of Sensing types.

- Response** Relates to the bottom layers of the hierarchy of needs and implements the reactive behavior of the agent. It also includes representation of fatigue and stress coping mechanisms [10, 15, 19]. It directly influences current goals and when needed can and will overrule any plans.
- Beliefs** The model includes different types of beliefs and beliefs over beliefs. Beliefs can be acquired through senses, ‘inherited’ from the cultural and normative background of the agent, or indicate the agent’s own judgement on its context. Furthermore, the agent may have beliefs about its own ordering of its beliefs (e.g., believe that normative beliefs are always to be preferred).
- Desires** Besides those desires that are determined based on the agents beliefs and its personal preferences (from Beliefs and Ego), the set of desires also includes the growth needs from the hierarchy of needs. Growth needs are the top of the Maslow pyramid, and can be seen as maintenance goals in the sense that when ‘fulfilled, they do not go away; rather, they motivate further’.
- Goals** Possible goals are generated from the current Desires based on the agent’s preferences, possibilities and current state (from Ego and Response) together with the deficiency needs (bottom layers of the Maslow pyramid) which are always in the set of goals. The intuition behind this, is that deficiency needs are always a goal, but not an intentional one in the sense that ‘the individual does not feel anything if they are met, but feels anxious if they are not met’. Response factors such as fatigue or stress direct the choice and priority of goals.
- Intentions** contains possible plans to realize goals, based on agent capabilities and preferences. However, when Response determines a high level of need, it will overrule any explicitly formed goals with lower level needs.

4.2 BRIDGE Reasoning Process

The BRIDGE reasoning process is carried by the components just described and the interactions between them, see 2. The components and the interactions between them have to work concurrently to allow continuous processing of the input in the form of sensory information and of effects on the body and brain as modeled by the arrow “stimuli”. All these links are discussed below.

- sense** Consciously received input from the environment, such as messages and observations. In the Beliefs subsystem, sensory input is interpreted in the form of belief updates of the agent.
- stimuli** Unconsciously received influences. In the Response subsystem, stimuli are directly processed resulting in an emotional state that prepares for action. In this way we can model unreasoned (involuntary) responses. Note that the actions carried out can have effects that can sensed by the agent, conform [6].
- interpret** Personality characteristics provide different interpretations of beliefs, by adding extra weight or priority to some beliefs.
- filter** Personality (ego) characteristics indicate possible instantiation and ordering of beliefs. This functions as a filter on the desires of the agent at any moment. Different personalities give different priorities to certain types of goals, e.g., based on cultural background (such as the desire to accumulate and show one’s wealth) and determine different ways the agent will interact in its social setting [23, 7].

- select** Possible goals are selected from current desires. Based on personality characteristics (Ego) choice and ordering of goals and deficiency needs is determined.
- plan** The calculation of possible plans is influenced by Ego and Growth.
- generate** Desires are generated from beliefs. This includes desires that are based on the agent's perception of its normative and cultural background.
- plan select** The set of current beliefs has an impact on the plan selection process performed by Intentions.
- update** Beliefs are possible updated.
- act** Plans are performed in the environment through this link.
- direct** Basic urges, the current emotional state, and stress levels direct the order and choice of current goals.
- overrule** Basic urges can become so strong that they overrule any (rationally formed) plans and immediate action is taken corresponding to the basic urge.

5 Conclusions

In this paper we have set out a preliminary framework for building simulation support for policy making. We argued that such a simulation tool needs to combine both macro- and micro-level models. In order to combine these two levels we introduced a meso-level, which serves on the hand as a place to aggregate some micro-level data for the macro-level models as well as give macro-level input for the micro-level agents. However, we claim that an at least equally important function of the meso-level is to specify society level elements, such as norms, that influence the agents on the micro-level. These elements do not emerge from the micro-level neither are they used as laws of nature from the macro-level. Rather they are used as inputs for the deliberation process of the agents.

In order for the agents to realistically simulate human behavior, we argue that they should also incorporate mechanisms to cope with these meso-level elements. Our proposed BRIDGE model provides for potentially very rich agents. They might also be very computationally inefficient if every action would require deliberation over all these components. However, we also provide a "unreasoned", reactive layer that can be used to bypass the deliberation. This provides the opportunity to use the deliberation only for those elements that are of prime importance for the simulation while having reactive behaviour for standard situations.

Although a new framework is easy to specify, the question is how this framework should be implemented. In our case we envision the agents to be implemented in an extension of 2APL which can be connected to an existing simulation tool such as Repast to provide a proper simulation environment. Finally, we will use the the OperA framework to define the meso-level elements, and generate patterns to be used by the simulation tool at the micro-level. Thus we have a basis for starting to actually build the simulation tool for policy making.

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