Affordance-Based Interaction Design for Agent-Based Simulation Models

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Abstract. When designing and implementing an Agent-Based Simulation model a major challenge is to formulate the interactions between agents and between agents and their environment. In this contribution we present an approach for capturing agent-environment interactions based on the "affordance" concept. Originated in ecological psychology, affordances represent relations between environmental objects and potential actions that an agent may perform with those objects and thus offer a higher abstraction level for dealing with potential interaction. Our approach has two elements: a methodology for using the affordance concept to identify interactions and secondly, a suggestion for integrating affordances into agents' decision making. We illustrate our approach indicating an agent-based model of after-earthquake behavior.

1 Introduction

Identification of interactions plus their particular design in a way that the overall system behaves as intended, is a central challenge when developing agent-based simulation models. This is due to their generative nature [3]; the individual agents' behavior and interaction makeup the system level behavior during simulation. In only few cases, the system level behavior can be a priori determined. Often it just can be analyzed after running the model. Thus, for efficient modeling it is important to determine interactions between agents and between agents and their environment in a systematic and grounded way. This contribution presents an approach for interaction design based on the "affordance" concept. Originating in ecological psychology, this idea ties perception of environmental features to potential agent activity.

We assume that the affordance concept may provide an appropriate abstraction for model development. Appropriate abstractions form the centerpiece for each methodology supporting the development of agent-based simulation models. They provide guidelines what elements of the original system need to be modeled and how those elements can be used in a model. Too low level elements do hardly help – at least not more than a high-level programming language would. Too restrictive, high-level concepts may be confusing for modelers if they leave room for interpretation or do not perfectly fit to what the modeler actually wants to formulate.

In the following, we will first introduce the affordance concept and justify why we think that it is useful for agent-based simulation model development. This is followed by a description of how we suggest to use affordances in Section 4 elaborating on a generic agent architecture and a related environmental model concept. After a short sketch of a development process for designing a model, we exemplify the process with a short glance on a rather complex model capturing how a population of agents may behave after a disaster that radically disturbed daily life. The contribution ends with a discussion of critical issues to be tackled in the future.

2 Affordances

The question how (human) agents are situated in their environment perceiving environmental features and elements and interacting with them, is a central one in psychology. Originally introduced by Gibson ([4]), the concept of "affordances" is the basic element of one of the two major research directions for explaining situatedness. An affordance denotes some perceivable element in the environment that invites a particular activity of an animal or human. This idea forms the basis for a theory of direct perception which states that a perception is tied to a something existing in the environment per se, instead of being produced by sensor data processing that results in symbols that the agent can use for reasoning [21]. The original affordance concept was quite fuzzy and left room for discussions and various more different elaborations. So, for example Chemero ([1]) presents his view on affordances as intuitively perceivable relations between abilities of organisms and features of an environmental situation. A perceivable constellation in the environment with particular features *enables* the execution of a particular ability of the organism. It does not automatically trigger an activity. The organism – the agent – has the choice to actually perform a particular behavior. The idea of affordances can be well illustrated using examples such as a bench that affords sitting on it. But also some horizontal plank which is sufficiently fixed on an appropriate height affords that.

Over the years, the affordance idea has gained importance in several areas in which interaction plays a central role: In human computer interaction it forms the basis for the idea that a user must be able to perceive what he/she can do with a particular element. It also plays an important role in applications of geo-information science where ontologies for capturing potential agent activities and observations are proposed and used for fast and user-friendly information retrieval [16], for enhanced analysis of the spatial environment, as e.g. in the "walkability" or accessibility analysis of [7] or for a methodology to capture "places" based on what humans can do at that place in [9]. Other application areas are natural language understanding and dialog [5] or in studies about autonomous robot control (such as [20]) where the idea of a direct connection between robot and rich environment representations was proposed in the area of behaviour-based, reactive robotics emerging towards the end of the 1980ies (for a recent survey see [6] or not so recent case studies in [15]).

During the last years, the idea of affordances formed the basic concept for a number of approaches and applications in agent-based simulation, mainly for capturing environmental aspects that enable agent mobility: Raubal [18] focuses on identifying the right ontological concepts – determining the elements of the environment – and epistemological concepts – determining what the agent might know. His application is the identification where and wayfinding might be problematic for humans in complex environments such as airports. Clearly, the correspondence between concepts used in the simulation model and the ones used by real humans is essential. Aligned to the original terminology of Gibson and based on interviews with travelers, Raubal identifies categories of “substances”, i.e. environmental entities, and “affordances” which represent what the substances may offer. He analyzed affordances more deeply and categorized them into physical, socio-institutional and mental affordances. Interesting is also that other travelers can afford talking-to. In that way he does not restrict his affordance model to the agent-environment interaction, but also includes simple agent-agent interaction, basically treating other agents as environmental entities. In [19], Raubal and Moratz elaborate these ideas further into a functional model of how affordances could be embedded into the abstract reasoning of an agent. They locate reasoning about them between the skill layer and the deliberative layer of a robotic agent architecture. Joo et al. propose in [8] affordance-based finite state automata for modeling human behavior in complex and dynamic environments. Hereby, they use affordance-effect pairs to structure the transitions between states in which a simulated human may be. In an evacuation scenario, an agent follows a given route to the exit, but checks at every step that necessary affordances are fulfilled using affordances to evaluate different local options. Kapadia et al. ([10]) use “affordance fields” for representing the suitability of possible actions in a simulation of pedestrian steering and path-planning behavior. An affordance is hereby a potential steering action. The affordance field is calculated from a combination of multiple fields filled with different kinds of perception data. The agent selects the action with the best value in the affordance field. A particular interesting approach is suggested by Ksontini et al. ([12]) They use affordances in traffic simulation generating virtual lanes of occupy-able space. This is an important advance for agent-based mobility simulation for capturing realistic human decision making beyond strict adherence to legislation as it enables shared usage of road space, overtaking, avoiding badly parked cars, etc. The agents reason about what behavior is enabled by the environmental situation. The affordances offered by the environment are explicitly represented by those virtual objects that offer driving on them. Papasimeon [17] connects affordances to a BDI architecture for identifying options for space occupation supporting navigation and movement for pilots.

Cornwell et al. ([2]) argue that based on affordance theory a semantic decoupling of the agents’ individual point of view (as necessary for a believable emotional behavior) and the scenario setup can be achieved. Their goal behind using affordances was to easily feed knowledge about how to behave and with whom and why to interact into an emotional agent architecture. An agent may perceive environmental objects in different ways captured by perceptual types. Each of these perceptual types affords actions at the perceiving agent. Those actions have anticipate-able effects on the goals of the agent. Cornwell et al. demonstrate that this concept embedded into the PMFServ agent architecture makes scenario modeling more efficient because fixed predefinition of scenario-specific behavioral and emotional models is avoided and building new scenarios is facilitated.

3 Why Affordances?

Similar to [2], we came across affordance theory not because of theoretical predisposition, but because it helps us to solve an engineering problem. The idea of decoupling and making agent-environment relations more flexible the center of our proposal for interaction engineering. Affordances enable a way of structuring interaction based on the reason why an agent interacts with a particular entity. Thus it lifts the engineering of interactions to a higher level beyond physical interaction of sensing and acting. That higher level may result in using natural language descriptions of particular affordances[1]. We assume that explicitly capturing affordances is suitable for facilitating identification of reasons for interactions in the original system as well as designing the interaction for the simulated environment when formulation based on low-level sensing and information processing appears to be too detailed for modeling. Affordances, as we use them here, enable formulating the reason for interaction by capturing the environmental features relevant for agent decision making and activity. Thus, it is a mean to establish a high-level relation between agent and its environment that then produce actual interactions during a simulation run.

As interaction formulation happens on a higher abstraction level, we assume that this supports

- a higher level of complexity in behavior formulation than would be possible than in reactive approaches. It also helps integrating agent-environment interaction into more sophisticated agent architectures. This supports not only adaptivity of behavior with environmental changes, but also flexibility of modeling as agent and its environment are explicitly coupled with the affordance relation.
- clarity in model design as it lifts interaction engineering from programming to higher, more knowledge-engineering like levels.
- extension of models as interaction is clearly motivated and flexible. Introducing new object types comes with the explicit handling of what role these objects can play in the agents' activities. Knowledge about when and how agents interact is explicit.
- reusability of models, in the same way as their extension. When and where interactions happen is justified based on their connection to agent activity; this facilitates documentation of agent behavior in their environmental context.

The affordance concept – as we understand it – is not connected to a particular agent architecture. So, it is not obvious how affordances could be practically used for producing those positive consequences. This will be elaborated in the next sections.

4 Using affordances

Following the ideas of Sahin et al. ([20]), one can identify three perspectives on affordances:

[1] using symbols for capturing a particular affordance – ignoring any potential conflict between approaches from ecological psychology to which original affordance theory was assigned to and representational approaches based on symbolic reasoning

- The perspective of an agent who searches for a particular affordance in the environment: for example an agent have encountered that there is no milk in his fridge and thus searches for a place (environmental entity) where he can get milk.
- The environment perspective which offers a particular affordance to a particular agent. So that is the perspective of the supermarket which may offer to agents buying milk, a neighbor may offer to "borrow" milk or a cow may offer to produce milk.
- The observer perspective ascribing an affordance in an agent-environment system

A modeler must capture all three perspectives: the first two need to be designed and implemented in the simulation model for generating the appropriate outcome of the third. Affordances and interactions of the original system must both be observable in the model. Yet in principle, the modeler faces a similar challenge as without affordances: interaction needs to be formulated from the point of view of an agent and its interaction partners, as interactions originate from their individual behavior; these interactions must end up in an observable (potentially only temporary) relation between the partners. We assume that the gains of lifting interaction design to such an affordance-based level facilitate their systematic development.

To achieve that, we have to consider two questions:

1. How the overall model framework must look like to integrate affordance-based behavior?
2. What is the appropriate process to actually fill such a framework in a particular scenario?

4.1 Agent Architecture

It is obvious that affordances alone do not create agent behavior per se, but they need to be integrated into an overall architecture or process for managing the agent's decision making: An affordance represents an agent-specific offer for action. Consequently it is not hard wired to an actual action. The agent has the choice whether or not to trigger the actions or may select between different actions that are possible at the same time. There is no standard way for integrating the affordance concept into the agent's behavior generation: [17] integrates affordances into a BDI architecture, [20] use affordances for capturing scenario specific information in PMFServ, [12] create options that afford driving on that driver agents evaluate and select, etc. In some models - also shortly described above, affordances are used as preconditions in rule-like structure, etc. Affordance-based robotics is often associated with reactive, behavior-based robotic agents directly connecting perception and action.

On a rather technical level, agents' decision making consists of two parts which are deeply linked: determining what is the next action, and secondly with which entity to interact when performing that action. An agent may decide to now sit down, but on which of the available chairs? If there would be no chair – or no other object that affords the action of sitting on it – the agent may not consider sitting down at all.

These thoughts are summarized in Figure 1 presenting an abstract architecture. Some aspects of this need more explanation: In contrast to affordance-based robotics,

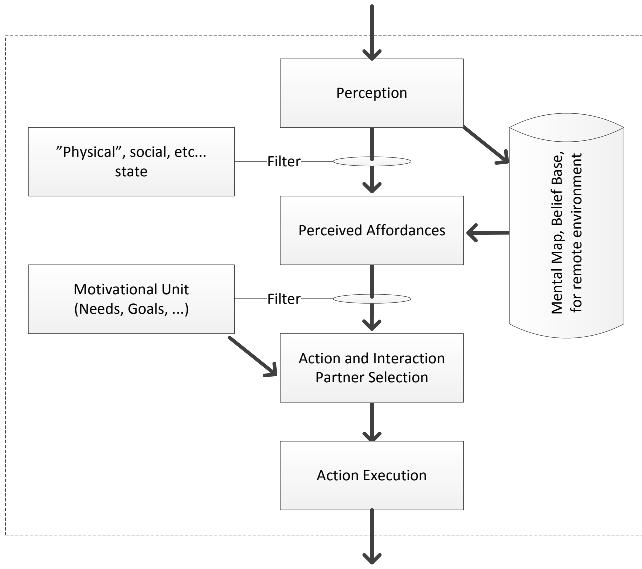

Fig. 1. General Architecture for an agent based on affordances in interaction with its environment

we assume that an agent can remember situations that it has previously perceived as offering some activity. For example, the agent while walking through the museum, may be able to remember that there was a something to sit down in one of the previously passed exhibition rooms. This is not supported by the original affordance concept as it focuses on direct perception. Nevertheless, it makes sense to assume that an agent can memorize what it has perceived in some belief set organizing previous perceptions or communicated information about its environment. Whether an affordance is actually perceived is depending on the agent's situation awareness including its physical, social, emotional, etc. state. Thus, there must be some form of a filter, so that the agent just considers affordances that make sense for it. Whether it actually follows an affordance relation and performs a particular activity with the part of the environment, is depending on what the agent wants to do actually; that means, it depends on its motivational state to evaluate and select the relevant actions and interactions which are then actually performed. In principle, one could need to consider different forms of motivational concepts and their dynamics and combinations for producing rich agent behavior in a rich simulated environment. Yet, this opens an additional thread of discussion about necessary and sufficient complexity of agent architecture to be traded against transparency of produced behavior.

4.2 Model and Structure of the Environment

In the original psychological literature [4, 1], the perceivable "environment" is seen as the scene or situation the agent (human/animal) is in. Affordances is what parts of that situation offer connected to the agent context and potential actions. So, it is not a single object that is to be considered, but a constellation of objects. For example, a cup only affords grasping, if it is accessible for the agent's hand. If it has fallen behind the shelf, the agent may need to move some furniture before the situation affords grasping the cup. Another example that illustrates why it may be too restrictive to associate affordance information to single environmental objects is: A soup in a pot just affords being eaten by an agent, if there are devices available like a spoon (if the soup is not too hot and the pot is too large to be directly attached to the mouth. Clearly, it would be possible to reduce the situation with multiple objects to a sequence of tackling single objects: In such a case, the agent would need to do planning: first it shall take the spoon which affords grasping and then the agent can perceive that the soup alone is now eatable. This would be naturally done in for example robotic applications. Yet, for modeling the scenario in a simulation, it forms a question of the level of detail in which an agents' perception and activities are handled. What is the appropriate level of detail should be handled by the modeler who uses the affordance-based approach and not enforced by restrictive details of the approach.

We assume that a group of environmental objects including other agents together may contribute with different features to an environment constellation. This composition together affords particular actions of the perceiving agent. In the simplest case, such a group contains only one object. Whether a constellation really affords some agent activity is depending on the agent, its configuration and dynamic context. Figure 2 illustrates the overall assumed environmental structure for our affordance-based approach.

An alternative approach would be to generate a particular virtual object for representing the environmental constellation if and when necessary. This is proposed by Ksontini et al. in [12] who generate virtual lanes that an agent may drive on. Virtual objects may be a clean solution for capturing "constellations", but belong to a more technical level than we currently discuss an affordance-based approach. In the technical design of the example model sketched below, generation was not necessary. Yet, the situations in which a virtual lane is generated, contain much more geometric details and constraints to be handled than in our more coarse-grained model.

4.3 Individual Context

The individual agents context influences what action opportunities it actually perceives and which it finds relevant to consider. This is clearly shown in the architecture as well as in the concept of the environmental structure above. The question remains what are the particular influences that are relevant from the agents' side. In principle it can be every detailed feature of the situation and state the agent:

- Physical state of the agent: If the agent has no hands or it may currently not have sufficient energy for lifting things, no affordance of being grasp-able is relevant for the agent.
- Mental state: If an agents' reasoning is overloaded, it cannot process incoming information that information source such as for example a newspaper would afford. If an agent does not believe that a supermarket is reachable, it may not consider the groceries that the supermarket affords to buy. In simulation models that explicitly

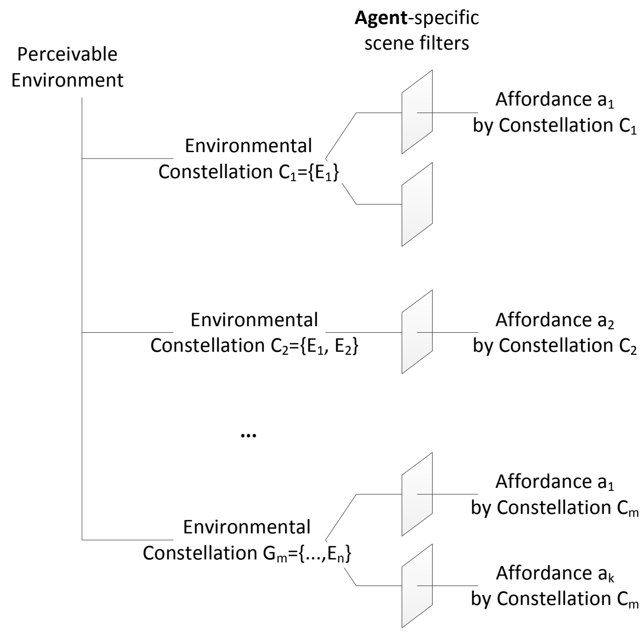

Fig. 2. Illustration of the assumed environmental structure

involve agent beliefs about their environment, the perception of affordances must be filtered based on what the agent believes to be feasible.

– Motivational and emotional state: The goals of an agent determine what it finds relevant in its environment. The motivational state is so relevant that it was even shown as an extra component in Figure 1. It determines not just what the agent may select to pursue, but it influences what the agent expects to perceive.
– Social and institutional state: If the agent is member of a group or organization, playing a particular role, this also influences what expectations the agent may have about its environment. Raubal ([18]) found this context so relevant that he introduced institutional affordances in his airport scenario: a border official affords the activity of passport control due to its role in the overall institutional setting.

5 Model Development Process

The idea of affordances is based on psychological theories how humans (and animals) perceive interaction possibilities. We assume that - if interactions are formulated in a way related to how humans think -, this might make this process easier for a human modeler. This might offer a good starting point for identification of both, agent-environment interactions and agent-agent interactions. Additionally, the level of abstraction when dealing with affordances is higher than specifying that an particular protocol is used for realizing interactions. Affordances express not just that there can be interactions, but also why, with whom and under which conditions. So, potential interactions are meaningful and the definition of types and features of environmental entities, which determines the level of detail of the environmental model, are linked to agent activities using those features.

Basically one can interpret this approach as an elaboration of the vague interaction-oriented design strategy for model development sketched in [11]. A process starting from affordances is different from interaction-oriented model development approaches such as suggested in [13]. Focusing on reactive agents, they assume that full behavior can be described based on interactions; complex behavior in which interactions serve a particular purpose and are intentionally selected are hardly supported.

A process centered around affordance-based interaction design might contain the following steps:

1. Specify intentions and/or behavioural repertoire of the agents.
2. Develop a list of affordances that are needed for this behavioral repertoire or to fulfill the intentions, determining what the environment in general must provide to the agent so that it can do what it wants to do.
3. For each affordance, write down the conditions and constraints under which it actually may fulfill its reason to be.
4. Decide what shall be the elements of the environment: What object-types shall be there and assign them to affordances fulfilling the constraints and conditions.
5. fill the behavioral gaps in the agents decision making/behavior program - e.g. planning to move to the locations at which an affordance can be used.

Later phases of such a development process then should deal with data structures, organizations and especially with protocols stating what exactly shall happen if an interaction takes place. Those elements depend on the actual agent architecture.

6 Illustration: The After-Disaster Scenario

We used the described concepts for developing a simulation of civilian behavior during the first 24h after an earthquake. Instead of analyzing evacuation processes, we focus on what people might do and where they might move to after a catastrophic event which dramatically changed their environment. The final vision consists of a decision support tool for disaster helpers enabling them to evaluating the best location for establishing support equipment, distribution of goods, etc. This decision support tool shall be based on predicting how the population might be distributed in the destroyed area. We cannot give a full description of the model here, a more elaborated characterization with simulation results is currently under preparation.

6.1 Intentions and Behavioral Repertoire of the Agents

Starting point is the question what activities the agents could perform. We based our motivational model of the agents onto Maslow's Theory of Human Motivation [14] which formulates a hierarchy of needs. We assumed that directly after a catastrophic event –

that does not require immediate evacuation of the population – basic physiological and safety-related needs (on the two lower levels of Maslow's hiearachy of needs) are the most relevant. After discussions with experts we added needs related to information acquisition. Thus, we came to the following list:

- Need for information about family
- Need for medical help
- Need for self-medication
- Need for food and water (physiological needs)
- Need for security of health, body, safe sleep
- Need for security of property
- Need for general information
- Need for mobile phone charging

Clearly, this is just a first draft of needs and can be easily extended due to the underlying affordance-based approach. For now it is sufficient for illustrating the overall approach. Depending on the particular agent architecture, these needs form the basic goals of the agent or motivate some other form of behavior program. In our case we decide for an architecture of competing needs and associated each need with an urgency, thresholds and functions describing the dynamics of the needs' urgency. So for example the need for food or water linearly increases over time; when the agent executes some activity fulfilling the need, it is nulled again. Each need is connected to a list of potentially satisficing places in the environment, at which the need may be fulfilled.

6.2 Affordances for Needs

The next question is what properties the locations might have that the agents might want to go for fulfilling which need. For that aim, we need to setup a list of affordances describing what an environmental constellation might need to offer so that the agent can perform activities that fulfill each of its needs. For the needs listed above, the list of affordances might look like in Table 1. The relation is not a 1:1 relation. Most of the needs have exactly one affordance. The need for general information about for example the location of the epicenter or the general state of the road network, destructions, etc. can be acquired either by searching in the Internet, more conservative sources such as radio or television or by talking to other agents.

So, for finding a place where the agent may find need fulfillment, it may identify place that in an environmental constellation provides the corresponding affordance. In the simulation, the agent might not know that a particular place actually affords a particular activity, but if the agent believes, it will plan its way to that place.

6.3 Conditions and Constraints on Affordances

The next step is to determine under which circumstances an affordance can be offered. In our example, most affordances can be realized by a particular place in a particular state, only few affordances needs more than one entity to be fulfill-able, that means they need a true constellation of environmental objects and agents. Table 2 gives an impression about how this could look like informally.

need for	corresponding affordance
information about family	meeting family members
medical help	meeting doctors and nurses
self-medication	provides medicaments
food and water	provides food and water
security of body,...	provides shelter
security of property	enables protection
general information	provides Internet access, enables broadcast listening, provides talking to
mobile phone charging	provides electricity

Table 1. Assigning affordances to needs

affordance	Constraints
meeting family members	other family member(s) must be located at place
meeting doctors and nurses	doctors/nurses are not overloaded, place is not destroyed
provides medicaments	sufficient medication storage available
provides food and water	sufficient storage
provides shelter	building is not destroyed
enables protection	something of value left
provides Internet access	electricity available, Internet accessible
provides broadcast access	electricity available, receiver accessible
provides talking to	other (knowledgeable) person at the agents' location
provides electricity	electricity available

Table 2. Conditions for affordances to be provided

6.4 Environmental Model

The next question is how the environment may look like for providing the affordances listed in Table 2. Thus, the relevant types of objects that should be there – and consequently the level of abstraction of the environmental model – can be derived from that list. It is clear that we may assume that a place of type supermarket or pharmacy is relevant whereas a place of type clothes shop only in its role as a particular workplace. So, the overall environmental model does not need to explicitly show clothes shops. An example list of places that may provide a particular affordance is given in Table 3. Places that are agent-specific are marked with (A).

With that model concept, the coupling between environmental entities (buildings, places, other agents) and the agents is determined, yet not fixed. The agent decides about which is the most urgent need and thus on the related activity it wants to perform. Then, it checks what type of object or particular provides a relevant affordances, and searches for it.

Whether an environmental object affords something, is not necessarily a boolean decision. In our scenario, we assigned a degree of availability to every affordances of an (environmental) entity. This availability may have changed due to disaster-based de-

Affordance	Providing Places
meeting family members	Family Residence(A), Workplace/School(A)
meeting doctors and nurses	Hospital, Ambulance
provides medicaments	Pharmacy
provides food and water	Restaurant, Supermarket, Family Residence(A)
provides shelter	Family Residence(A), Public Building
enables protection	Family Residence(A)
provides Internet access	Family Residence(A), Public Building, some Restaurants
provides broadcast access	Family Residence(A), Public Building, some Restaurants
provides talking to	Other Agent
provides electricity	Family Residence(A), Public Building

Table 3. What affordances need to be satisfied, determines what kind of environmental entities need to be provided

structions or over time depending on the load, tiredness of the personal, available storages, etc. Yet, the agent first assumes that a place with a particular type is fully available, until it perceives (or is told) what the place actually can afford. The coupling between agent and environment is flexible. Affordances are there to match agent activities and location and interaction partner. Also other agents are treated similar to “environmental objects”. They can afford talking to for acquiring more information about the general situation or about blocked roads or unavailable distant places. Interaction to other agents is not only triggered when the need for general information becomes the most urgent one, but when an agent meets other agents.

6.5 Filling the Behavioral Gaps and Next Steps

Affordance theory per se covers perception linked to agent activity. Yet, in a spatially explicit, extended scenario, an agent may not perceive the environmental constellation that would afford the activity it intents to do at a certain time. Also, there might be more than one environmental constellation with which it makes sense for the agent to interact. In the disaster scenario this means, the agent needs to select a place out of the potentially satisficing locations and plan its activities for going there for need fulfillment. This place selection and mobility form behavioral gaps not tackled so far, but that need to be filled for complete agent behavior and interaction.

Using its (individual) “mental map”, that means its believe about location and road network linking places, the agent can start from information about what places exist and potentially provide relevant affordances. Based on that, the agent determines which place is reachable within what time and selects the one at which it believes to reach within the shortest time. Having determined a path, it moves there for need fulfillment. We also used the affordance idea for determining the availability of a road segment for moving across it. Also the road network might be affected by the disaster. The agent takes only the believed availability of links into considerations when determining the route to a place. While moving, the agent updates its mental map with its perceived state of the environment. Interaction for information exchange happens with other agents that it meets during movement or at places. This communicated information is also used for updating mental maps with more accurate information on affordance availability. While moving, the perception of affordances for moving at the different road segments may also trigger re-routing, re-selection of places for relevant affordance or even for need reconsideration (as it does not make sense to search for fulfilling a need that the agent does not believe is fulfill-able). When finally reaching the place that was chosen as destination, the agent starts an activity for the satisfaction of the particular need. Actually, the need for protecting its properties has some low yet constant urgency that will lead the agent to its residence when there is no other important need, unless the home cannot fulfill that affordance any more because it is fully destroyed - that means has no availability for protecting valuable items any more.

Designing data structures and decision making processes, as well as implementing them is rather straight forward given the concepts described here after some more formal and detailed specification. A first prototype of the model is implemented using the standard means and language of the SeSAm simulation system[2]. SeSAm was hereby used on a level of abstraction that also an object oriented programming language would provide in terms of construction of complex data structures. We used predefined plugins for shortest-path algorithms as well as for road network data structures, etc.

7 Discussion and Next Steps

In the example, we illustrated a model design strategy around an abstract coupling between agents and their environment based on a high-level idea of affordances. Given the frame of this contribution, we focused on conceptually showing how agent motivational concepts can be connected with environmental objects. Hereby, we used a more powerful decision making architecture than just simple reactive rule-based structures with affordances in their precondition. Clearly, for understanding how the example really works, a much more detailed description is necessary. Even for giving a precise methodology, a more formally complete description of our particular affordance-based interaction framework would be essential. Yet, this contribution shall give an impression what can be possible and why it is important to have a look onto the affordance concept for developing model design strategies. There are two interconnected aspects that need to be discussed: generalizability and formalization for tool support:

One motivation behind postponing a precise formalization is the issue of whether that what we have presented here, may be transferable to other modeling problems. That means, the question how general the overall approach is, is an open one. Interaction between agents and between agents and a non-agent environment is at the heart of developing and using agent-based simulation models. One can easily think about similar settings in which such an affordance based interaction development may be useful, for example in land use or travel demand – scenarios in which models are spatially explicit and agents have to decide about activities at particular locations.

But, beyond that? An important characteristic is that there must be a particular non-trivial granularity of interaction. Interaction must be intentional and tied to the behavior

[2] *www.simsesam.org*

generation. An essential next step in the development of our affordance-based approach, will be the identification of scenario categories in which such an approach can be useful and test it (maybe still as informally as we presented it here) in very different scenarios. An alternative and additional direction concerns the question whether classes of affordances can be formulated that - during the actual model design - can be instantiated. This idea is related to design pattern for agent-environment interactions. It might be interesting to consider the question how far affordances as a high-level intermediate concept can serve as the basis for interaction patterns connecting agent behavior and environmental structure.

As indicated above, for implementation, we developed all the data structures for needs, affordances, environmental entities as well as mental map structures using the standard toolset provided by SeSAm. That means we made a model-specific implementation that now could be further developed into a toolset by extracting abstractions. A modeler should not need to create his own need structures, affordance data types or environmental structure, but reuse given abstractions on the appropriate level. We did not yet formalize the overall approach, it is currently just formulated in the informal, fuzzy way given here. It would be clearly an important next step to formalize the concepts and make the single steps more precise and clear. This could lead to modeling support starting with simple implementation tools to maybe even support for model-driven simulation engineering. Yet, in relation to the discussion above, we currently do not know whether the model-specific structures as we have used them in a systematic, yet unique way, would be really be sufficient for other, not so closely related scenarios; no matter how well grounded in motivational theory, affordance concepts, etc the particular abstractions are. Giving a formalization of the concepts and steps in a methodology not just makes the approach more precise but also restricts. Such a step should not be done already after the first scenario or simply due to theoretical considerations of what might be reasonable to do. In agent-based simulation model development, abstraction usage and the appropriate level of detail is far more influenced by the underlying simulation objective. Tweeking abstractions where they do not fully fit, is never a good idea. Thus, we plan to use this informal approach in a number of other projects before continuing with the formalization for gathering more experience about its actual usefulness.

Acknowledgements

The author wants to thank Sabine Timpf for introducing her to the affordance idea, as well as Per-Olof Persson and Sepideh Pashami for valuable discussions of the topics addressed in the paper. The work was funded by KKS (the Knowledge Foundation) in the RM4RS (Rapid Mapping for Realistic Simulation) project.

References

1. A. Chemero. An outline of a theory of affordances. *Ecological Psychology*, 15(2):181–195, 2003.

2. J. B. Cornwell, K. O'Brien, B. G. Silverman, and J. A. Toth. Affordance theory for improving the rapid generation, composability, and reusability of synthetic agents and objects. In *presented at 2003 BRIMS Conference (Behavior Representation in Modelling and Simulation, available online via http://repository.upenn.edu/ese_papers/291*, 2003.
3. J. M. Epstein. *Generative Social Science: Studies in Agent-Based Computational Modeling*. Princeton University Press, 2007.
4. J. J. Gibson. *The Ecological Approach to Visual Perception*. Houghton Mifflin, 1979.
5. P. J. Gorniak. *The Affordance-Based Concept*. PhD thesis, School of Architecture and Planning, MIT, 2005.
6. T. E. Horton, A. Chakraborty, and R. S. Amant. Affordances for robots: a brief survey. *AVANT*, 2012.
7. D. Jonietz and S. Timpf. An affordance-based simulation framework for assessing spatial suitability. In *LNCS 8116 - Proc. of COSIT 2013, Spatial Information Theory*, pages 169–184, 2013.
8. J. Joo, N. Kim, R. A. Wysk, L. Rothrock, Y.-J. Son, Y. gwang Oh, and S. Lee. Agent-based simulation of affordance-based human behaviors in emergency evacuation. *Simulation Modelling Practice and Theory*, 13:99–115, 2013.
9. T. Jordan, M. Raubal, B. Gartrell, and M. J. Egenhöfer. An affordance-based model of place in gis. In T. Poiker and N. Chrisman, editors, *Proc. of 8th Int. Symposium on Spatial Data Handling, Vancouver, CA*, pages 98–109, 1998.
10. M. Kapadia, S. Singh, W. Hewlett, and P. Faloutsos. Egocentric affordance fields in pedestrian steering. In *Proceedings of the 2009 symposium on Interactive 3D graphics and games (I3D '09)*, pages 215–223, New York, NY, USA, 2009. ACM.
11. F. Klügl. Multiagent simulation model design strategies. In *Proceedings of the Second Multi-Agent Logics, Languages, and Organisations Federated Workshops (MALLOW), Turin, Italy, September 7-10, 2009*, volume 494 of *CEUR Workshop Proceedings*, 2009.
12. F. Ksontini, R. Mandiau, Z. Guessoum, and S. Espi'e. Affordance-based agent model for traffic simulation. *Journal of Autonomous Agents and Multiagent Systems*, online first, 2014.
13. Y. Kubera, P. Mathieu, and S. Picault. Ioda: an interaction-oriented approach for multi-agent based simulations. *Autonomous Agents and Multi-Agent Systems*, 23(3):303–343, 2011.
14. A. H. Maslow. A theory of human motivation. *Psychological Review*, 50(4):370–396, 1943.
15. R. R. Murphy. Case studies of applying Gibson's ecological approach to mobile robotics. *IEEE Transactions on Systems, Man and Cybernetics - Part A, Systems and Humans*, 29(1):105–111, 1999.
16. J. Ortmann and W. Kuhn. Affordances as qualities. In A. Galton and R. Mizoguchi, editors, *Proceedings of the 2010 Conf. on Formal Ontology in Information Systems (FOIS 2010)*, pages 117–130, The Netherlands, 2010. IOS Press.
17. M. Papasimeon. *Modelling Agent-Environment Interaction in Multi-Agent Simulations with Affordances*. PhD thesis, Melbourne School of Engineering, University of Melbourne, 2009.
18. M. Raubal. Ontology and epistemology for agent-based wayfinding simulation. *Int. Journal of Geographical Information Science*, 15:653–665, 2001.
19. M. Raubal and R. Moratz. A functional model for affordance-based agents. In E. Rome, J. Hertzberg, and G. Dorffner, editors, *Towards Affordance-Based Robot Control*, volume 4760 of *Lecture Notes in Computer Science*, pages 91–105. Springer Berlin Heidelberg, 2008.
20. E. Şahin, M. Çakmak, M. R. Doğar, E. Uğur, and G. Üçoluk. To afford or not to afford: A new formalism of affordances towards affordance-based robot control. *Adaptive Behavior*, 15(4):447–472, 2007.
21. R. Shaw. The agent-environment interface: Simon's indirect or Gibson's direct coupling. *Ecological Psychology*, 15(1):37–106, 2003.