Modelling Affordances as Emergent Phenomena

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Abstract

Affordances are an important basis for many human-environment interactions such as navigation or geo-design. In this short paper we present an approach to modelling affordances based on treating affordances as emergent phenomena in an agent-based simulation. We use the notion of an affordance schema to represent the setting in which the emergence of an affordance is made possible. We use a case study to show that (unexpected) affordances emerge during the course of the simulation. While the general approach is promising and may be used for other emergent phenomena such as landmarks, we also acknowledge and discuss the problems incurred during the modelling process. The paper closes with a reflection and some ideas for future work.

2012 ACM Subject Classification Computing methodologies → Modeling methodologies; Computing methodologies → Spatial and physical reasoning

Keywords and phrases agent-based modelling, cognitive engineering, spatial cognition, theory of modelling

Digital Object Identifier 10.4230/LIPIcs.GIScience.2023.72

Category Short Paper

Supplementary Material *Software*: `https://github.com/sabinetimpf/emergentAffordance`

Funding *Sabine Timpf*: Funding from the Erasmus+ program is gratefully acknowledged.

Acknowledgements The constructive comments from two reviewers are gratefully acknowledged.

1 Understanding human-environment interaction: the modelling challenge

In this short paper we present our recent work on how to model affordances, which are important for many human-environment interactions such as for example navigation or geo-design. Understanding how humans interact with their environment is part of understanding decision-making. Affordances, according to Gibson [3], are what the environment offers the individual in terms of interaction. Seen from the individual's perspective, affordances represent potential actions tied to specific objects, subjects or groups of objects, but also tied to the current status, knowledge or beliefs of the individual.

Modelling affordances is not a new endeavour and a proper overview does not fit into this paper. Extensions such as [10] introduce cognition into the theory of affordances. However, all implemented approaches so far (see for example [14], [17] or [8]) treat affordances as properties or functions of an object or as properties of the individual-object relationship as a whole. This solution does not satisfy the emergent nature of affordances as described by Gibson.

Sahin et al. [13] define affordances from an agent's perspective within the context of robot control. Their approach is different in that it acknowledges the dynamic nature of the affordance and treating it as a relation between equivalence classes. In robotics,

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12th International Conference on Geographic Information Science (GIScience 2023).
Editors: Roger Beecham, Jed A. Long, Dianna Smith, Qunshan Zhao, and Sarah Wise; Article No. 72; pp. 72:1–72:6
Leibniz International Proceedings in Informatics
LIPICS Schloss Dagstuhl – Leibniz-Zentrum für Informatik, Dagstuhl Publishing, Germany

computational models of affordances have gained a new impetus as evidenced by several overviews in recent years ([19], [1]) and a recent special issue ([11]). However, these approaches do not (yet) provide high-level action information, remaining at the level of interpreting sensory-motor sensor input, which is very different from our focus on understanding and modelling affordances in human-environment interaction.

According to Gibson [3] affordances are perceived immediately without any reasoning, i.e. they emerge from the dynamic relationship between individual and object. While Gibson hypothesised that this perception is inborn, other ecological psychologists such as Neisser [9] argued that the perception of action potentials is a result of a cyclical learning process. While this discussion needs to be solved (preferably by psychologists), our concern is with the modelling of the, let's call it, mechanism of how affordances are supposed to work, assuming that affordances are emergent phenomena as posited by Gibson.

The moniker of emergence originally stems from systems theory, where it describes an observable phenomenon that was not originally visible or predictable by observing the different parts that constitute a system. In our case the system consists of a human and an environmental object (object collection) as well as their interaction. The interaction is the observable result of realising the action potential of the affordance. There may be several affordances providing distinct action potentials in any given agent-object pairing.

From a computational point of view the question arises how an emergent phenomenon may be modelled at all. By its nature a phenomenon emerges during the model run and should not be explicitly represented in our model. Can we then model a system in which we increase the probability of an emergent phenomenon occurring? We approach this question by changing from an analytic (property-oriented) paradigm to an agent-based constructive paradigm.

2 Changing the perspective: an agent-based approach

Agent-based modelling has been shown to be able to capture emergent phenomena resulting from the interactions of individual entities [2]. Emergent phenomena in agent-based models are patterns, structures and behaviours that were not explicitly implemented in the model, but arise through agents' interaction. An agent-based model consists of dynamically interacting agents that use rules for their own behaviour [7]. Such models are commonly used to analyse complex systems that are characterised by a large variety of components that interact with each other. In the case of modelling for emergent affordances, we need to determine the rules agents follow that require some interaction with an entity, the constraints under which an interaction may take place and the entities that may represent interaction partners. This kind of interaction follows a pattern that is akin to a schema in cognitive science [4].

2.1 Using schemata to model affordances

Neisser [9] states that humans use schemata to make sense of their surroundings and to minimise the facts they need to memorise. Rumelhart calls schemata the "building blocks of cognition" [12]. Consider that you know the schema underlying the concept of a "bridge", then there is no need to memorise every bridge that you encounter. You will have learned that a bridge is an instance of the link schema that allows you to connect and move between two areas using a direct path. Schemata are recurring structures we learn that help us to establish patterns of understanding and reasoning.

We will show that the implementation of an affordance schema provides an answer to the modelling challenge, i.e. the emergent nature of affordances. In this implementation the affordance schema serves as a kind of template for generating an affordance at simulation run-time. While the notion of an affordance schema originally served as a means to make interactions visible and tractable [5], we can show in this paper that it also satisfies the question of how to model emergent phenomena. The notion of a schema allows for the required flexibility in matching the needs of the agent with the required properties of the environment, thus not only allowing a single affordance to emerge, but producing a collection of potential actions, including those that are unexpected or may be wrong (false affordances). As Withagen et.al. [18] discuss, there must be a way of capturing that affordances also invite behaviour not merely provide potential actions.

In our implementation, agents possess a list of affordance schemata for each of the activities they may carry out. We define an affordance schema as a 3-tuple ⟨EType,condition,fpriority⟩ composed of

- an Entity type EType,
- a condition that expresses constraints under which the affordance can be generated, and
- a number called fpriority that assigns a priority or preference to the combination of agent and potential interaction partners.

During run-time an affordance ⟨a, e, act, p⟩ is generated, where a stands for the agent, e stands for environmental object, act describes the activity the agent intends to perform and p stands for preference, allowing a means of differentiating between otherwise equivalent affordances.

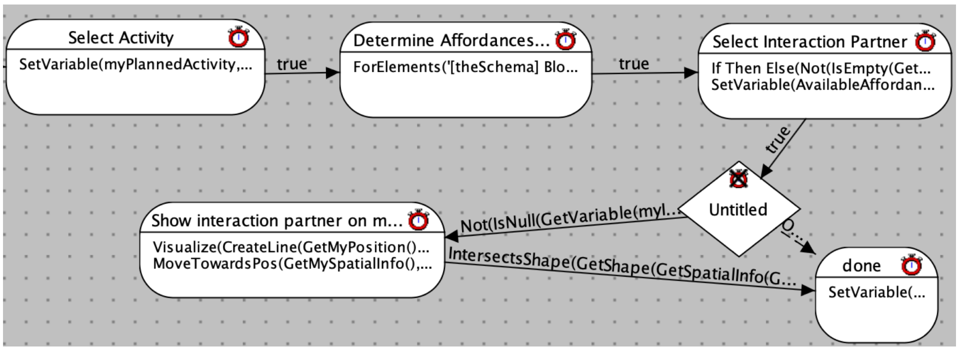

Figure 1 Activity graph of affordance-enabled agent.

Figure 1 shows the activity graph of the agent where, after selecting an activity, first the affordances are determined and then the interaction partner is selected. A detailed account of the implementation may be found in [6] and on github[2].

2.2 Case study: a visit to the park

We are applying the approach discussed above to a case study of visiting a public park. We focus on the act of walking into a park and needing to find a place to perform a specific activity there ([15], [16]). As an example we take the specific activity of sitting to take a break with the option of drinking some water. The question arises which objects in the park offer the affordance for sitting as well as drinking some water. As shown in [6] it is necessary to break down the conditions for the activity in terms of attributes of the environmental object tempered by knowledge about the agent. For example, in order to be able to sit, there

[2] https://github.com/sabinetimpf/emergentAffordances

must be an object or configuration there that affords sitting, which means a relatively flat, stable surface with a certain minimal size. There should be a differentiation into required and optional properties.

In contrast to an implementation based purely on an object's properties, in our implementation the properties are expressed as a function of the agent's properties, i.e. the 'certain size' is expressed in terms of an agent's size, the 'stable surface' may take the agent's weight as parameter, and the 'relatively flat surface' may take preferences of the agent into account. Please note that this customisation is only possible because of the agent-based approach that allows tying agent and interaction object together at run-time. This allows for the affordance to truly emerge as an individual trait between agent and object.

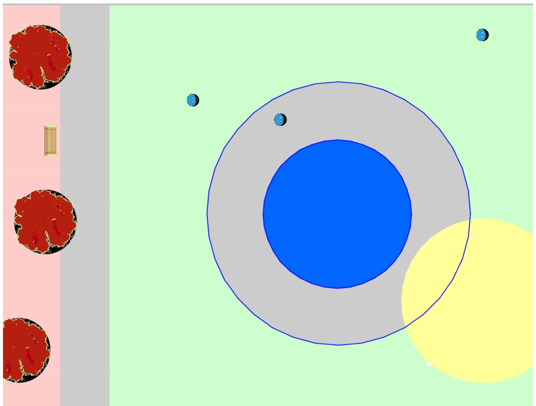

Figure 2 Situation of park scenario at run-time.

Figure 2 shows a detail of the simulation situation, where an agent has chosen to sit on a relatively low concrete band surrounding a water feature. This interaction partner is unusual but perfectly fine for the purpose of sitting and drinking some water. Of course, we did not specify that the water in the water feature might not be safe to drink for humans.

While the current results of the implementation are encouraging, we must note that it is quite time-consuming to put into constraints all required and optional properties of agent and objects within an activity context for physical affordances; And as the example shows, it is easy to forget specific aspects. However, we believe that this example shows the flexibility of using affordance schemata to model human-environment interactions that also allows the emergence of affordances in the original sense of Gibson, as we interpret it.

3 Reflections and future work

In this research-in-progress we have used affordance schemata as patterns that generate affordances during an agent-based simulation. This version of modelling affordances seems to be closer to the original idea of Gibson, who saw affordances as emerging phenomena. We have implemented this approach, thus showing proof of concept. We are currently working on a more detailed and extensive implementation of the park use scenario. However, there should be a better way of defining the constraints and ensuring their completeness.

One endeavour for the future is to formally define activities and their actions as well as the needed properties for an activity to be carried out successfully. While we have extensive observations of park behaviour to help us with the formalisation, this might not be true for other spatial behaviours. Our approach using schemata is promising also for modelling other emergent phenomena such as landmarks or resilient objects, which is an avenue we would like to explore in the future.

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