Modeling Human Behavior in an Artificial Society with MARS

N. Ahmady-Moghaddam[1]

www.haw-hamburg.de nima.ahmady-moghaddam@haw-hamburg.de www.mars-group.org

[1]Hamburg University of Applied Sciences, Department of Computer Science, Berliner Tor 7, Room 04.80, 20099 Hamburg, Germany

Motivation and Problem Statement

How can we model a society of humans? One approach is to design an *artificial society* (AS) – an executable model of a human society to simulate social phenomena [2, 3] – as a multiagent system.

Per definition, an agent is autonomous [8]. Therefore, its reasoning and behaviors should be dynamic, flexible, and adaptive. So far, there exists no standardized approach to agent behavior modeling [6, 9]. Instead, behaviors tend to be designed manually for a given model. This is laborious and often results in low reusability and generalizability.

Solution Approach

To enable configurable and extensible human behavior modeling at the individual and collective level, two **Components** are proposed:

1. *Individual:* A need-driven planning component with an activity plan that can be updated by a `Human` agent when a `Need` arises
2. *Collective:* A graph-based social network to describe relationships and facilitate communication between `Human` agents

Both components will be implemented as core features (see Figure 1) of the Multi-Agent Research and Simulation (MARS) Framework.

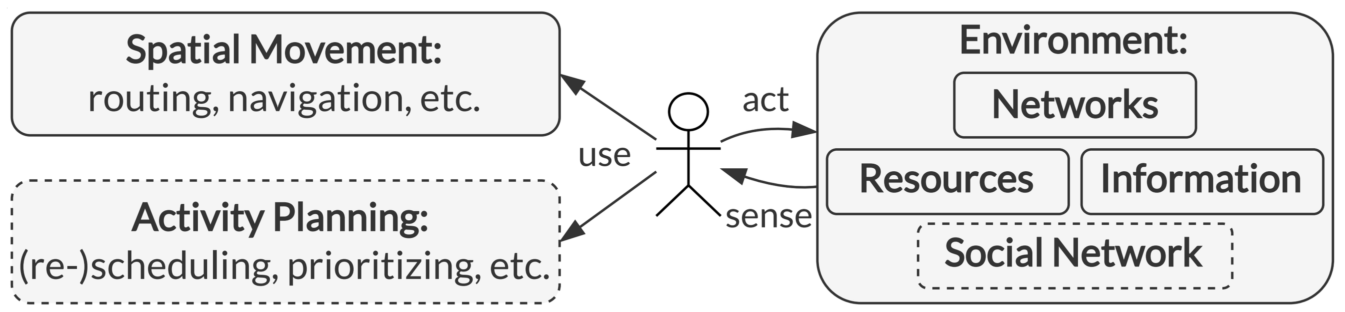

Figure 1. Interactions of a `Human` agent in an AS in MARS with existing MARS components (solid) and proposed MARS components (dashed).

The Environment of a MARS Model

The environment of a MARS model is represented as a set of layers. A *layer* is a subset of the environment that groups together like objects. Layers can contain travel networks, resources, or information (see Figure 2). An agent can use a *network layer* to navigate the environment and to reach a point of interest on a *resource layer*. Furthermore, layers can be distinguished in terms of their activity: An *active layer* can change itself and/or the environment, whereas a *passive layer* cannot.

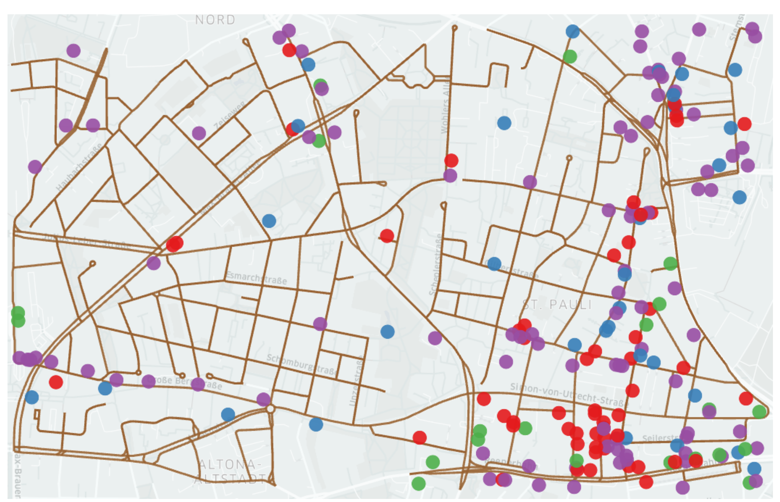

Figure 2. Georeferenced layers representing St. Pauli, Hamburg, including a street network (brown), restaurants (purple), bars (red), cafés (blue), and hotels (green). Data obtained from OSMnx/GeoFabrik. Visualized with kepler.gl.

Role-based and Need-driven Activity Planning

How does a person plan their activities? How and under which circumstances are activities rescheduled? The proposed **Component 1** (see Figure 3) provides (re-)planning capabilities via the following MARS features:

- `Needs`: an active layer that notifies a `Human` agent when a `Need` arises
- `ActivityPlan`: a temporal data structure that enables a `Human` agent to manage personal activities

The `ActivityPlan` holds on a timeline the `Activity` instances that were scheduled by the `Human` agent. A `FixedActivity` is non-reschedulable and arises from a `Role` of a `Human` agent, whereas a `FlexibleActivity` is reschedulable and arises from a `Need` of a `Human` agent (e.g., `Eat`, `Sleep`, etc.).

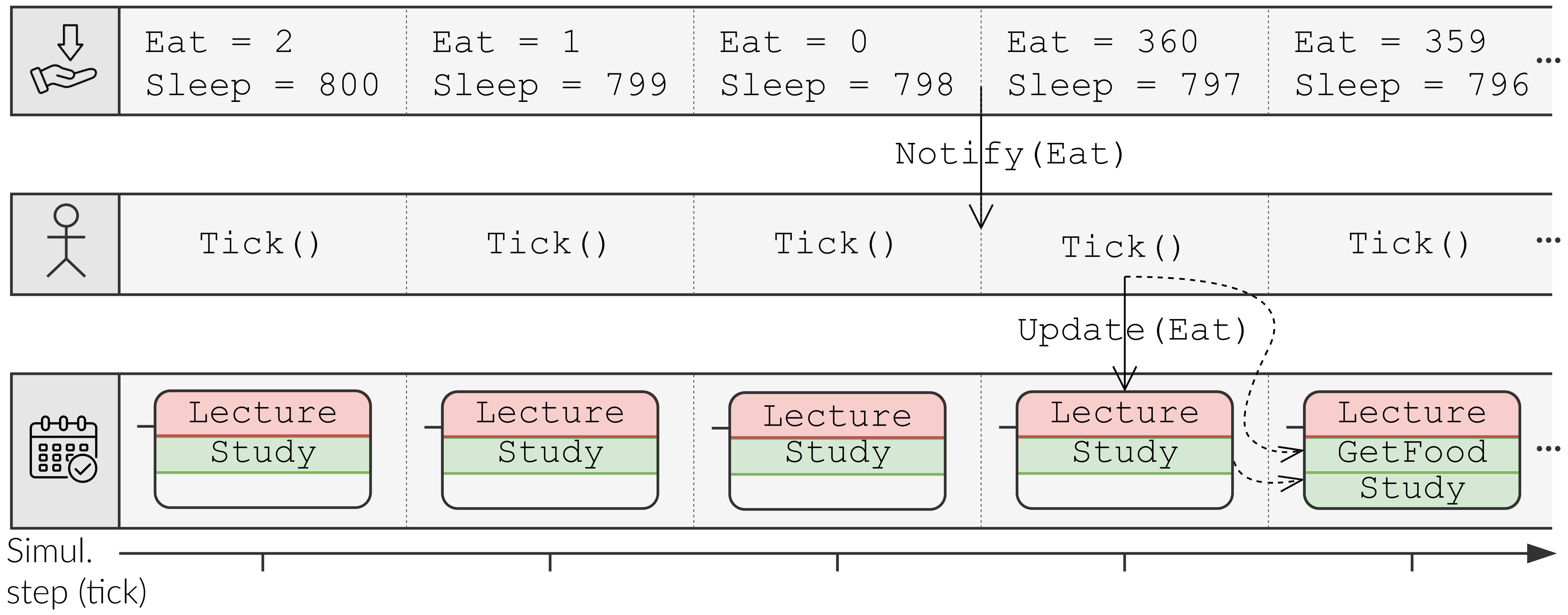

Figure 3. Interaction over five simulation steps (left to right) between an active layer `Needs` (top), a `Human` agent with `Role = Student` (center), and its `ActivityPlan` (bottom) with fixed activities (red) and flexible activities (green). The `Human` agent is notified by the `Needs` layer that it needs to `Eat`, and reacts by scheduling an activity `GetFood` in its `ActivityPlan`. The previously scheduled activity `Study` is rescheduled to prioritize the acute need.

Social Relationship Structures and Communication

The proposed **Component 2** consists of a new layer type `SocialNetwork` that models a social network as a graph. Each agent is represented by a node, and agents with adjacent nodes can communicate via protocols provided by the `SocialNetwork` (see Figure 4). Such communication might be triggered by, for example, the `Need` to `Socialize`. In response, the agents might schedule a corresponding `Activity` in their `ActivityPlan` (see Figure 3).

Which graphs are suitable for modeling social relationship structures? Social scientists found that the number of acquaintances across members of a society follows a power law [4, 5]. Two ways to construct graphs with exponentially distributed node degrees are:

- the Barabási-Albert (BA) model [1]
- the Watts-Strogatz (WS) model [7]

Such graphs are fitting candidates for the `SocialNetwork`.

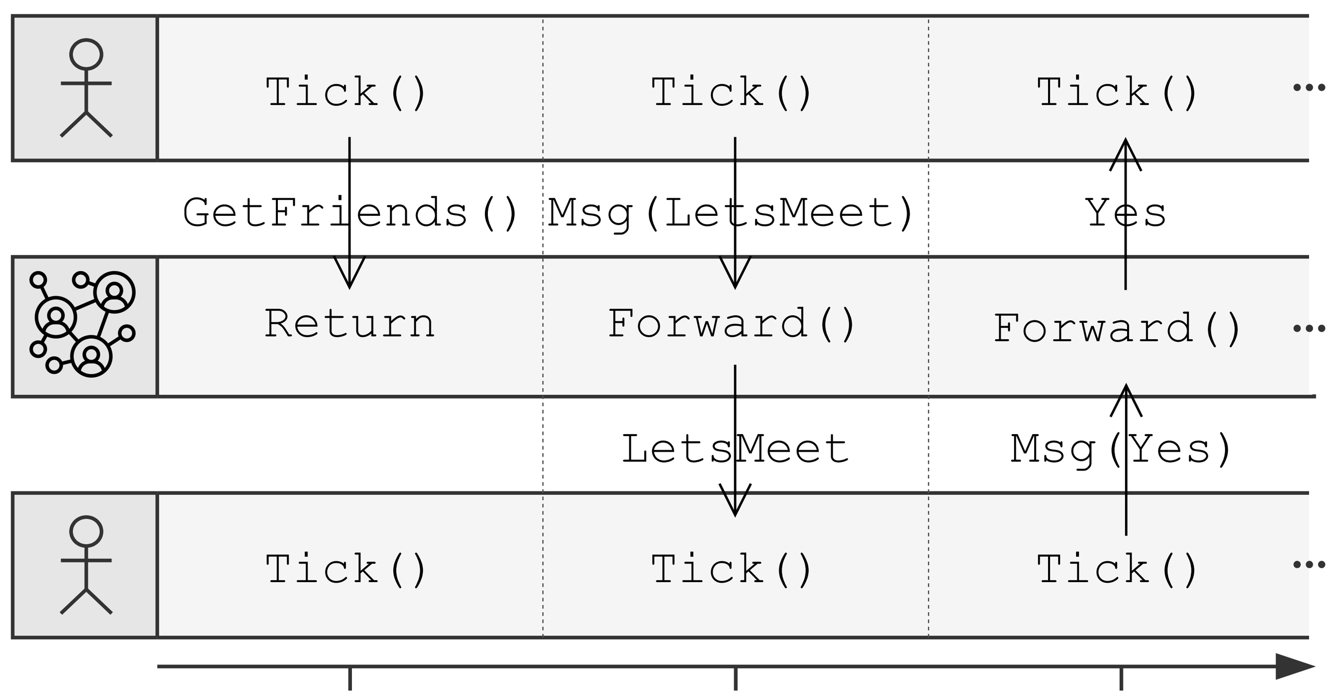

Figure 4. Communication over three simulation steps (left to right) between two `Human` agents (top, bottom) facilitated by the layer `SocialNetwork` (center). The top `Human` agent asks one of its friends to meet at a specified time and location (not shown in diagram), to which the friend agrees.

Summary

The two proposed **Components** aim to support AS modeling with MARS at the individual (intra-agent) and collective (inter-agent) level.

1. *Individual:* Management of a personal `ActivityPlan` with `Role`-based and `Need`-driven activities (see Figure 3)
2. *Collective:* Communication via a `SocialNetwork` that provides protocols to facilitate agent-agent interaction (see Figure 4)

Both components will be made available to MARS modelers for configuration/parameterization and extension (see Figure 5).

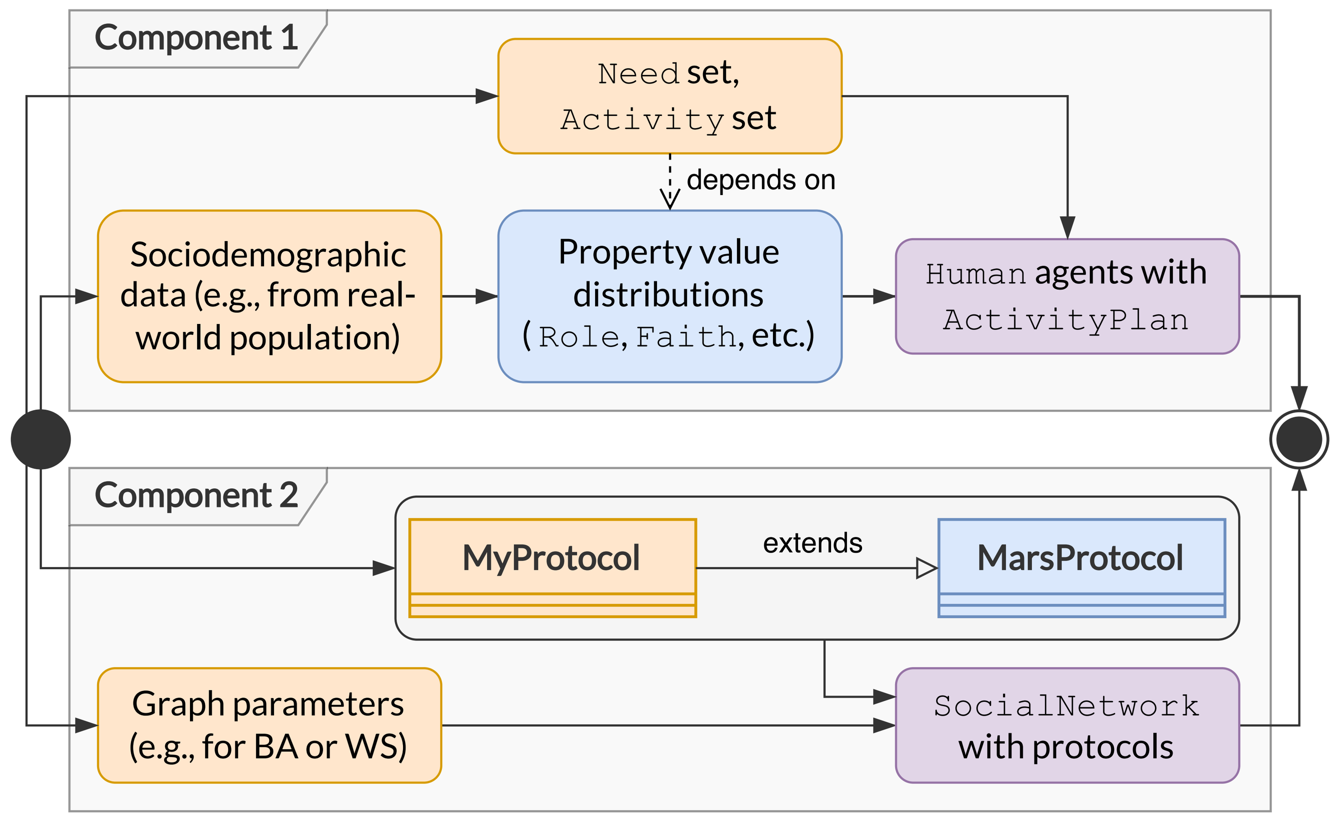

Figure 5. Steps to parameterize and extend **Component 1** (top frame) and **Component 2** (bottom frame) and initialize an AS in MARS. The modeler provides input parameters (orange), which are associated with and processed by the MARS Framework (orange) to produce AS components (purple).

References

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