Charles University in Prague
Faculty of Mathematics and Physics

BACHELOR THESIS

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Komunikace a paměť pro plausibilní agenty

Communication and memory in plausible agents

Department of Theoretical Computer Science and Mathematical Logic

Supervisor: Mgr. Ondřej Sýkora

Study programme: General Computer Science

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Na tomto místě mohou být napsána případná poděkování (vedoucímu práce, konzultantovi, tomu, kdo půjčil software, literaturu, poskytl data apod.).

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V Praze dne   Vojtěch Kopal

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Abstrakt: V předložené práci studujeme ... Uvede se abstrakt v rozsahu 80 až 200 slov. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Ut sit amet sem. Mauris nec turpis ac sem mollis pretium. Suspendisse neque massa, suscipit id, dictum in, porta at, quam. Nunc suscipit, pede vel elementum pretium, nisl urna sodales velit, sit amet auctor elit quam id tellus. Nullam sollicitudin. Donec hendrerit. Aliquam ac nibh. Vivamus mi. Sed felis. Proin pretium elit in neque. Pellentesque at turpis. Maecenas convallis. Vestibulum id lectus. Fusce dictum augue ut nibh. Etiam non urna nec mi mattis volutpat. Curabitur in tortor at magna nonummy gravida. Mauris turpis quam, volutpat quis, porttitor ut, condimentum sit amet, felis.

Klíčová slova: klíčová slova (3 až 5)

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Abstract: In the present work we study ... Uvede se anglický abstrakt v rozsahu 80 až 200 slov. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Ut sit amet sem. Mauris nec turpis ac sem mollis pretium. Suspendisse neque massa, suscipit id, dictum in, porta at, quam. Nunc suscipit, pede vel elementum pretium, nisl urna sodales velit, sit amet auctor elit quam id tellus. Nullam sollicitudin. Donec hendrerit. Aliquam ac nibh. Vivamus mi. Sed felis. Proin pretium elit in neque. Pellentesque at turpis. Maecenas convallis. Vestibulum id lectus. Fusce dictum augue ut nibh. Etiam non urna nec mi mattis volutpat. Curabitur in tortor at magna nonummy gravida. Mauris turpis quam, volutpat quis, porttitor ut, condimentum sit amet, felis.

Keywords: klíčová slova (3 až 5) v angličtině

Chapter 1

Introduction

In a modern society the amount of information is far behind what one can remember or even process. If we understand that, we realize how important it is to be able to delegate the thinking amongs group. The decision making in groups and teams is a topic covered by several papers. [citation required] Supposing we have limited capacity of memory, we have to distribute the knowledge amongst people around us and communicate with each other so as to gather facts which we currently need to make the decision.

Our decisions are either consciously or subliminaly based on our needs or drives - former term might be rather connected with human behavior, latter term is used for plausible agents. As in microeconomics we can use an utility as a measure of relative satisfaction [10] and see how one manages fulfilling their needs. While attaining the goals we use a knowledge which we store in our memory and which we update regularly. With infinite memory we wouldn't have any problems to store all information and use it when required; however, we don't have such memory - our memory is limited.

What I mean by saying "not to have enough space in our memory" is one is not able to remember everything. Certain pieces of information are fading away as time goes or as one is learning new facts. I want to observer if and how an intensive communication can substitute insufficient memory space with the condition of constant level of utility.

Is it obvious that adding the ability of communication improves the chance

I want to demonstrate that there is a relation between amount of communication and needed space in memory (...)

This thesis is consist of N parts. First, I will introduce the topic of agent and possible memory implementations based on concrete examples. (...)

Chapter 2

Related work

I will use this chapter as an introspecture into the world of agents and spatial memory. I hope that you will not be disappointed, since there is no 007 in following lines.

2.1 Agents

There are several ways how to explain what or who the agent is. Apart from systems of agents used in philosophy or sociology, we can see a first modern use of agency and agents in economy where economists have substited the human with a simpler agent. They intended to simplify their economic models to be able to actually simulate something. Buyers and sellers are typical examples of agents used in simplified market model in microeconomics (see []). In this context agents are entities in the model which can act based on situation in the model.

For area of artificial intelligence we can use the definition of an agent which can be found in [8]. It cannot be more simple:

Definition 1 **Agent** *is just something that acts.*

Of course it is as general as it could be and for my purposes it is too simple, so I will use another definition which meets better the context of my work.

Definition 2 **Agent** *is something that senses the environment and affects it using its actuators.*

Having that defined we continue to specific kinds of agent. In this thesis I use several slightly varying terms about agents: $r$ational, autonomous, plausible and believable.

A rational agent refers back to economics where we can find a definition of rational behaviour. Even though it is rather a hypothetical model, as people are usually irrational in their decisions from the economics perspective, their is yet nice definition whereby a rational agent acts as if balancing costs against benefits to arrive at action that maximizes personal advantage (Milton Friedman (1953), Essays in Positive Economics). So simply he does what is or perhaps might be best for him based on his current knowledge of the world.

On the other hand, the rational behaviour might be understood in a completely different way. Plausible agents are such agents, where the basic approach is to implement human-like internal processes. One of the well-known example is neural networks, although they are usually used in quite simplified way. Since it is really difficult to implement completely plausible agent, one can see research teams focusing on a specific part of the complex human being.

Autonomous agents are those agents which are capable of accomplishing useful tasks or are effective problem solvers [1]. A

Believable agents are personality-rich autonomous agents with the powerful properties of characters from the arts [1]. Now there is just the autonomous agent left. An autonomous agent should be able to accomplish useful task or be an effective problem solver.

2.2 Spatial resource-bounded memory

A memory is something what changes a reactive agent into an agent with ability to learn. It can be used for learing consequances of agent's acts, conditional dependencies in the agent's world (citation for bayesian networks), or spatial information about the environment. The latter one is a kind of memory I used for agents in my simulation.

A spatial memory is used when agent needs to navigate in usually two or three dimensional space. In short it is a component of an agent which says him where to go when he needs or want to do something. There are several different approaches and a couple of examples are going to be covered in this section. I am going to introduce several existing implementations of spatial memory. Mainly I will focus on if and how they have dealt with bounded resources - either due to implementation restrictions, or when approaching plausibility in their models.

2.2.1 Short-term and long-term memories

Generally, when I talk about remembering something I should mention two terms: a long-term memory (LTM) and a short-term memory (STM). Both of which describes a capacity for holding certain amount of information in mind. Apart from the varying amount, the memories differ in availability of such information and a period of time the memories last.

Short-term memory (...)

Long-term memory (...)

2.2.2 Computational memory architectures

Computational memory architectures for autobiographic agents interacting in complex virtual environment suggested by Ho in [5]. works with both short-term and long-term autobigraphic memory, where they have observed agent's ability to survive comparing to purely reactive agency model. Moreover, they researched whether the narrative communication amongst agents somehow positively influence those agents. They have separately experimented with three types of agents: purely reactive (PR), short-term memory (STM) and long-term memory (LTM). Purely reactive agent walks randomly around the environment avoiding obstacles and searching for resource objects to fulfill his needs. What a pure reactivity means is the agent moves randomly until an event occurred such as a collision with obstacle or a resource object detection.

STM agents in [5] further extend the model of purely reactive agents and add a Track-back memory system in addition to the reactive behaviour. Each time an agent deals with an event (e.g. collision, or resource object) he puts such information into his memory. They refer to this as an event-based memory entry making mode. Those events are kept in a linear list of a finite size, whereby the oldest events are cut off. The memory is used when an internal variable is over threshold. That is the moment when agent searches in his memory for an information about relevant resource object. If he succeeded, he retrospectively undoes all memorized states leading to the relevant one. So, what they actually store in memory is an agent's current state: where he was and what he perceived. While attaining imperfection in retrieving information from short-term memory, they introduced noise distortion using Gaussians.

Long-term memory model is mostly based on psychological autobiographic memory models. There are three parts that are involved in the reasoning process: Event specific knowledge (ESK), Event reconstruction process (ER) and Event filtering and ranking process.

2.2.3 Inspirations for my work

Chapter 3

Used methods and algorithms

In previous chapter you have been familiarized with several kinds of agents, how they can be used and also what a spatial memory is. I have briefly prepaired you for the next chapters, where I will explain my contribution to this area. This chapter is going to cover the used algorithms and computational methods I have studied and implemented in my work.

The first subsection disserts on the implementations of agents' memory and in detail describes fundamental parts. Both the Growing Neural Gas and the Quad..blah are used as memory storages to handle spatial information about the environment with bounded resources.

3.1 Growing Neural Gas

3.1.1 Topology learning

Processing an enormous spatial data about an environment is computationaly demanding when for example we want to navigate in that environment. A topology learning or recognition can help us to create a representation such as topological map which can be viewed as a graph and which makes reasoning in that environment much easier. Rather complex understanding of topology in an indoor space using Bayesian programming has been shown in [9]. It goes much farther than I need to.

Based on competitive Hebbian learning (CHL) method [7] and Neural Gas (NG) [6] Bern Fritzke suggested earlier mentioned Growing Neural Gas [4], an unsupervised learning method for finding a topological structure which reflects the topology of the data distribution. Although the combination of both CHL and NG is an effective method for topology learning, there are some flaws in practical application as it requires an initial setup of number of nodes/centers that are used. This fact prevents the method from adequately describing the topology, when a different number of nodes would work better.

As Fritzke described the algorithm uses a set of nodes and edges that connects the nodes. A simplified describtion of algorithm in context of two-dimensional space follows:

1. Add two nodes at random position onto canvas
2. Generate input signal based on the data distribution (its probability density)
3. Find the nearest node n_1 and second nearest node n_2 to the signal
4. Increment the age of all edges leading from node n_2
5. Moved node n_1 and its topological neighbors towards the signal (according to parametres $epsilon_{winner}$ and $epsilon_{neighbour}$)
6. Remove all edges with an age larger than a_{max}
7. Generate new nodes
8. Go to 1.

For the purpose of this work I want to use this algorithm to learn a topology of data which dynamically changes through the time. In following subsection I am going to introduce you to the experimenting with this algorithm.

3.1.2 Experiments on dynamic data

3.2 Quad

The idea for this data structure representing resource-bounded memory is based on [2]. What differs in my work from their observed environment is agents in my simulation act in a homogeneous space which cannot be differentiated in a way the mentioned simulation does. To solve this issue I have found inspiration in Quad-tree structures [3] which are used, among others, for storaging more dimensional objects.

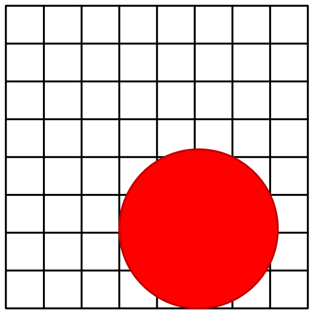

Figure 3.1: Example of a circle in two-dimensional space

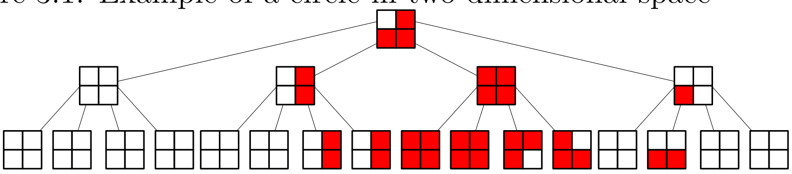

Figure 3.2: Quadtree structure of 3.1

Definition 3 *The* **quadtree** *is a tree structure where each node has exaclty four children.*

In 3.1 and 3.1 you can se an example how is a two-dimensional object such as a circle is stored in quadtree.

Similary I will use this structure to keep spatial information about the environment in the simulation.

3.3 Notes

The tricky think is to determine the negative variable.

I had to realize that an agent listened to an answer about locations which he could see.

Now I had to implement

Chapter 4

Simulation and used memory architectures

In this chapter I will describe the simulation, environment and agent's reasoning and communication how it is used in later experiments.

4.1 Simulation

The **simulation** is consists of a set of agents, a set of generators and a set of pieces of food. According to given settings it sequently processes a number of steps, each of which invokes an agents' life run and eventually generating new food.

It can also contains a couple of monitors which observe the environment or agents.

4.2 Environment

The environemt si a two-dimensional space which contains agents and food. Agents can move around and eat the food which is randomly distributed using the food generators.

4.3 Agent

As I mentioned previously an agent is an entity in the environment which moves and interact with the world around. The interaction is done through eating food which is a part of the environment and through communication with other agents. The latter one actually changes agents' believes about the environment.

Agent has his needs which influences his desicions as fulfilling his needs keeps him alive. When his internal variables of needs is higher than

4.4 Memories

Chapter 5

Implementation

Chapter 6

Experiments

6.1 Notes

The fact is the more an agent actually sees the more successful he is in staying alive.

Too much communication might lead to disorientation of an agent which is subsequently followed by agent's death.

Use 7+-2.

6.2 Experimental settings and methodology

All following experiments are run using a default setup as it is described in this section. Each of the experiments is run on a quadcore Intel Core i5 with 2,4 GHz and 6 GB RAM.

Environment is set to be a square matrix with $6$4 x 64 dimension. All agents start in the middle of the environment. There are $s$ix kinds of food which are randomly positioned in the environment and which generate a piece of food each $5$0 steps.

Since an environment contains of six food kinds, an agent has six internal variable for each such food kind. Defaultly they are set to 0 and are increased by 0.001 each step in simulation. When they are equal to 1, the agent dies.

6.3 Homogeneus agent set comparision

In this experiment I will compare avarage life span and efficiency of groups which contains of agents with only one type of memory. Thereby you can see which of the used memory implementation works better in homogeneus memory environment.

6.4

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