ECONOMIC BENEFIT OF USING LOCATION BASED SERVICES

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Abstract. *A location based service provides location information to the user. This information has an economic value for the user only if it improves his decision-making process. We select driving in a city as an example of a decision-making process; every intersection represents a decision making point where the driver has to decide where to drive. In order to prove our methodological approach for measuring the benefits of using location based services we construct an agent-based model. In this paper we present our methodological approach and the basic elements of the agent-based model.*

1. Introduction

A location based service (LBS) is any service that takes into account the mobile user's actual location [1]. The technology that enables location based services is complex and ranges from wireless carriers, mobile positioning, location infrastructure, location middleware, geographic information systems (GIS), applications, and content. GIS and other tools and services provide instantly access of world maps, spatial data, and geoprocessing capabilities. Through Simple Object Access Protocols (SOAP)/XML programmable interfaces [2] the user can build new mobile applications or enhance ones with maps, routing, points of interest, and geocoding. No other service relies as heavily on so many specialised technological niches. In discussions that mostly focus on LBS technological issues we miss a theoretical and practical analysis of the economic benefits of such services.

In this paper we investigate the user's point of view and the benefits he is able to gather from the use of a location based service. We study a decision-making situation of a driver driving in a city trying to navigate in the street network [3]. A location based service is providing the driver with information about the local situation in the street network, his current location, and suggestions for the shortest route to his preferred destination in the city. The issue that we are interested in is what is the economic benefit of using LBS technology? Is it possible to quantify it? Will the user be willing to pay for the service and if yes in which case and how much?

We explain the methodological approach for quantifying the value of LBS in section 3 of this chapter. We argue that the value of LBS technology is in information it provides to the user and in its use in a decision-making situation. It has an economic value to the user only if it improves his decision-making situation. This improvement can be expressed in different ways such as for example time or distance saved, money saved, or in a reduction of the risk of taking a wrong decision. It can be measured by these parameters and then transformed into a monetary value.

In order to prove our methodological approach we construct an agent-based model for measuring the benefits of using location based service in a driving decision-making process. The model is a simplified real-world situation and it is written in functional programming language Haskell [4-6]. It consists of an environment which is a static geometric place, a street network which is modelled as a graph, a driving agent, and an information provided by a location based service. The agent is rational in the sense that it is trying to find the shortest path to its destination. It is able to reason, deliberate, use the information it gets from the LBS, plan its movements in the street network and learn about the new environment. We focus on information about one-way streets in a city and their effect on the driving in the city.

The agent-based model enabled us to get the first estimations of the value of information provided by a location based service. We conclude this paper with a discussion on simulation as a method for verification of the multi-agent based model for quantifying the value of LBS.

2. Case Study: Driving in a City

Imagine that you are driving in a city with the goal to find the shortest path to the preferred destination. Driving is an example of a decision-making process; at every intersection the driver has to decide which street to take to proceed the driving.

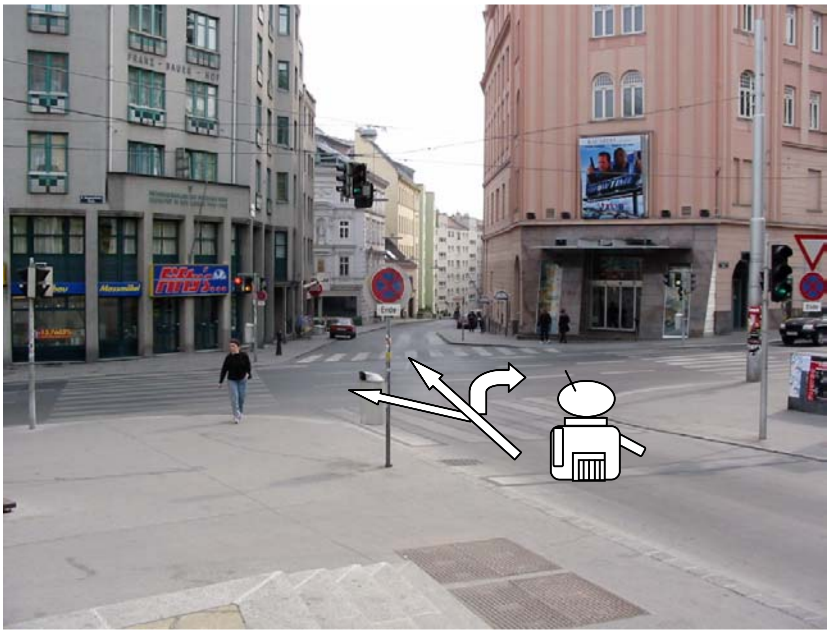


Figure 1. Decision-making process of a driver (Krek 2002)

Decision theory deals with modelling of a decision-making process and ranges from descriptions of how decisions could be made, to the descriptions and specifications of the decisions that are made, finally to those that focus more on how decisions should be made [7].

The decision making process is the act of tying together all components involved in making a decision. For the analysis described in this paper we decompose every decision of a driver into the following five elements as suggested by [8]:

- *Alternatives* – the available alternatives that may solve the problem

- *Criteria* – which are used to judge the decision quality
- *Outcomes* – predicted outcomes measured by the criteria
- *Preference structure* – preferences over the outcomes and
- *External information* – information that arrives with or without solicitation.

A decision maker has a number of alternatives and has to select one of them. Different streets are the alternatives the driver faces in the driving decision-making process. His decisions directly influence the outcome of the decision-making process. The outcome of the navigation decision-making process is the path selected for the driving. His preference is to find the shortest path to the preferred goal. He gets information about the street network from a location based service.

We take Vienna as an example of the city and consider a situation where a location based service provides information about the street network and suggestions where to drive. We focus on information about one-way streets in the city and its effect on the driving.

3. Economic Value of LBS

In this section we present our methodological approach for quantifying the economic value of information provided by a location based service. We start with a discussion on value of LBS and continue with the explanation of our methodology.

3.1. The Value is in Information

For the providers of the location based service it is important to know which are the valuable features of such service and how much are the users willing to pay for them. The price for the service can then be set in a relation to the value of this service to the user.

We argue that the value of LBS to the users is in information provided by this service. This information is valuable to the users only if it contributes to the improvement of the decision-making process [9] which can be observed in faster and better decisions, or in a lower risk of taking a wrong decision. If, for example, a LBS gives the driver instructions where to drive he is able to choose the right streets for the driving and reach the destination in a shorter time.

The definition of the value of information as presented in our approach is applied from artificial intelligence literature [10, 11] which defines the economic value of a given piece of information to be the difference in (expected) value between best actions before and after information is obtained. It is the difference between acting with and without that information.

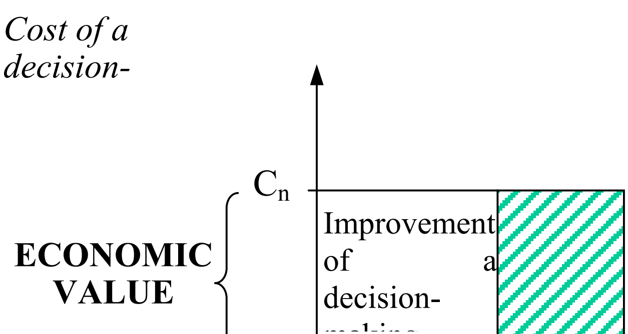
3.2. Cost of a Decision-Making Process

In order to prove our methodological approach for quantifying the benefits of LBS we introduce the cost of a decision making process. Figure 2 shows the cost of a decision-making process which is presented on the y-axis with low values for the cost at the bottom of the axis. C_i is the cost of the decision-making process performed before information is obtained and C_n after this information has been obtained.

The cost of a decision-making process can be expressed in many different forms, for example by time, distance, the number of decision-making points, or in the risk of taking a wrong decision. The unit for the cost and its measurement depends on the decision-making process. If we take an example of the driving we can measure the cost of driving with the driving distance, or the time needed for driving.

3.3. Methodology for Quantifying the Benefits

The economic value of the LBS as presented in our approach is measured by the difference in the cost of the decision-making process which can be translated into a monetary value. This difference shows how much the information provided by LBS contributed to the improvement of the decision making process (figure 2).



Information No information

Figure 2. The economic value of using LBS (adopted from Krek [3])

The metric is linear and we calculate the *economic value of information* provided by a location based service in the following way [3];

$$C_{i,n} = | C_i – C_n |.$$

The difference noted as $C_{i,n}$ gives the quantitative value of the information provided by a location based service. It expresses how much the information contributed to the improvement of the decision making process and with this to the lowering of the cost for the user.

For example, the user of LBS can, due to the information he gets from this service, find his preferred destination in a shorter time. The difference in time gives the value for the provided information which can be translated into monetary value.

4. Conceptual Agent-Based Model

In order to be able to validate our methodological approach we have to test it on a practical case. We decided to use multi-agent systems theory and constructed a model which enabled us to simulate different decision-making situations. In this section we explain the components of the conceptual agent-based model and we focus on the driving agent and its deliberation process.

4.1. Theoretical Background

The theoretical framework for the model is given by multi-agent systems (MAS). MAS consider the behaviour of a collection of autonomous agents aiming to solve a given problem. The literature in multi-agent systems theory [10, 12], [13], [14], [15], [16], [11]) is heterogeneous and offers many ideas and concepts without agreeing on common paradigms or definitions. The same terms used by different authors may mean different concepts and different terms may mean the same concepts. This flexibility resulted in implementation of the ideas on several application areas. It brings innovative approach to the concept of modelling and simulation by offering new possibilities of representing individuals, their behaviour and interactions [14]. The notion of multi-agent systems includes also the case of a single agent existing and operating in the environment.

The latest development in the agent research presents modelling of economic agents. For example, Epstein and Axtell [17] studied economic concepts such as trade and distribution of wealth, and social concepts such as friendship. In their work they critically assessed some basic assumptions of the neoclassical economy.

4.2. Elements of the Model

The model for quantifying the value of a location based service is based on multi-agents systems theory. It is a simplification of the real-world case where the driver uses information from a LBS which helps him to better navigate in the street network. The model ignores certain realistic, but unpredictable situations such as for example traffic jams or traffic accidents and considers only one driver driving in a city.

The major elements of the agent-based model for quantifying the value of LBS are the following;

- An *environment*, that is a static geometric space
- An *agent*, that is a cognitive and rational and is navigating in the city,
- A *street network* modelled as a graph, and
- *Information*, provided by a location based service.

An environment is a static space and includes the driving agent and a street network. The driving agent is navigating in the street network with the help of information provided by the location based service. The features of the street network are modelled as a directed and weighted graph and are defined on the street segments e.g. edges of the graph. The model is formalised in functional programming language Haskell. The complete code and the data for the street network can be found in Krek [3].

4.3. Definition of the Driving Agent

Multi-agent systems literature offers a variety of definitions for an agent. [18] list more than ten definitions of an agent, which range from the simple to the complex, lengthy and demanding. An agent can be “anything that can be viewed as perceiving its environment and acting upon that environment [15]”, a software program or entity, a “hardware or software based computer system [11]”, or simply a physical or virtual “entity which is permanently perceiving, deliberating and executing [10]”.

The definition for the agent used in our approach is “*An **agent** is anything that can be viewed as **perceiving** its environment through sensors and **acting** upon that environment through effectors* [15, p.31].” A sensor is anything that can change the state of the agent in response to the change in the world. Figure 3 shows the car driver agent type with an example of its percepts, actions, goals and environment.

Agent type	***Percepts***	***Actions***	***Goals***	***Environment***
car driver	observations of the	movements (driving) in the	the shortest path to the	street network environment; intersections

	environment acquiring information from LBS	street network	destination	and street segments

Figure 3. The car driver agent type

The agent is modelled as a rational an cognitive agent. It is rational in the sense that it "consistently prefers outcomes with higher payoffs to those with lower payoffs [20]". Russel and Norvig [15, p.33] give the following definition of an ideal rational agent: "For each possible percept sequence, an ideal rational agent should do whatever action is expected to maximise its performance measure, on the basis of the evidence provided by the percept sequence and whatever built-in knowledge the agent has". The goal of the driving agent defined in our model is to find the shortest path to the preferred destination. It behaves in such a way as to achieve this goal.

The driving agent is a cognitive agent (figure 4) which implies that it has a representation of the environment, it is able to draw up models of the environment and of the other agents and predict, explain and understand the changes in the environment and in the other agents. It has the ability to solve certain problems by itself and reason on the basis of its representation of the world. The driving agent has an internal state that defines its knowledge level and the deliberation process.

4.4. Agent's Deliberation Process

The driving agent is able to perceive the environment and act in this environment. It perceives the local situation in the environment e.g. all streets that it can choose from a certain intersection in order to be able to continue the driving. The actions it performs are the movements in the street network; the agent is able to move from one node to the next one.

The agent's deliberation process is defined by the **plan-decide-move architecture** which is applied at every intersection. The driving agent gets the information where to drive from the location based service, makes a plan where to drive, decides on the next node in the street network and moves to the next node.

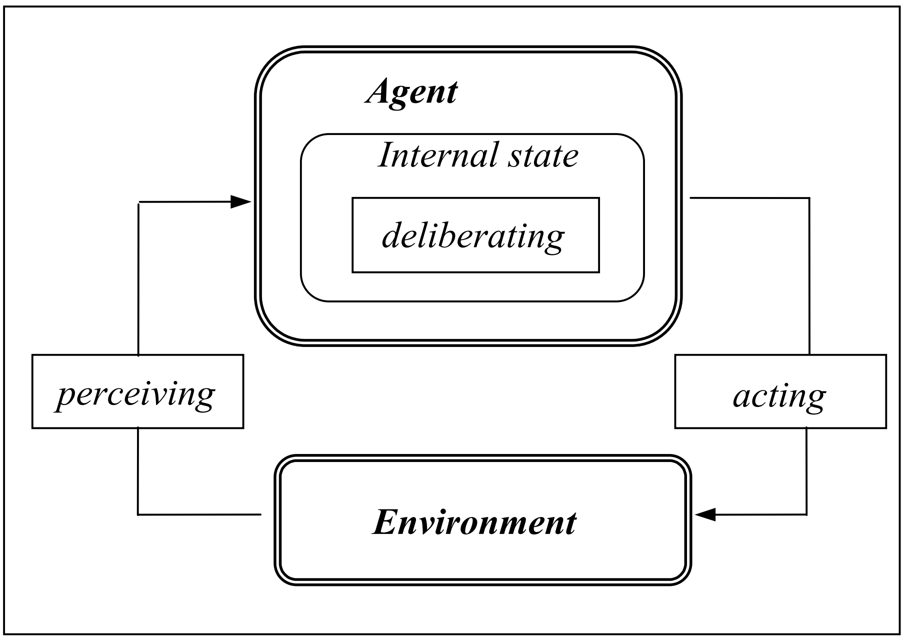


Figure 4. Deliberating cognitive agent

The deliberation process includes also a function of learning. Once the agent has learned about a certain situation on the street it is able to update its knowledge base with this information and acts according to the new knowledge it has about the environment. The deliberation process is repeated on every intersection node.

5. Simulation to Determine the Value of LBS

The agent-based model explained in section 4 enabled us to simulate the behaviour of a driver, his decision-making process and to measure the benefits of using a location based service. The agent-based simulation is based on the idea that it is possible to simulate the behaviour of individuals and their interaction with the environment and other agents as an assembly of agents with their own operational autonomy [19]. It is an imitation of their behaviour. We performed one-hundred-twenty-five simulations and validated the correctness of the agent-based model.

In our analysis we focused on information about one-way streets and its effect on the driver's decision-making process. We simulated situations in which the agent gets incomplete information, or lacks information about one-way streets. The executed agent-based simulations were based on a real street network dataset taken from the map of Vienna in the scale 1:12.500.

The final results of simulations are the paths travelled by the rational agent in the form of visited nodes in the street network and the lengths of the paths. The differences in the lengths of the paths give us the quantitative results for the improvement of the driving decision-making process and with this also the values for the benefit of using this service to the user.

We observed that the complete information about one-way streets in Vienna can improve the driving decision-making process for 32%. The driving distance saved while driving with the help of LBS can be translated into time saved which has an economic value for the driver.

6. Conclusions and Further Work

Discussions on location based services focus very often only on the technical issues and achievements, and tend to neglect the user's point of view. In our approach as presented in this paper we a methodological approach which can help to quantify the benefits of using a location based service. It is based on the idea that location based service provides an information to the user which helps to improve the user's decision-making situation. As an example of a decision-making process we take a concrete example of driving in a city.

The agent-based model as presented in this paper enabled us to model the internal state of the agent, its deliberation process that included planning and learning mechanisms and to simulate the driving process which depends heavily on the quality of information provided by the location based service. The technology that enables the location based services is not of interest to this paper.

The major contribution of the agent-based model presented in this paper is that it connects the information and information source with the process in which this information has been used and consequently with the outcome of this process resulted by the use of information. The innovation of the model is in enabling us to observe and measure the direct impact of the use of information on the output of the decision-making process.

The model was very useful for testing our methodological approach as presented in chapter 3 of this paper. The situation, especially the traffic conditions, for example, traffic congestions, accidents, waiting time at the traffic lights, etc, were excluded from this study.

In our further work we plan to include additional information such as for example information about turn restrictions and observe how it influences the decision-making process of the driver. The impact of both; information about one-way streets and turn restrictions and their impact on the output of the decision-making process would also be of interest to us.

It would also be necessary to analyse how different qualities of location information effect the navigation in the city. For example, to investigate what happens if every second information about one-way street is missing. We would also like to test the methodology of quantitative estimation of benefits resulted from the acquired information on other examples of a decision-making process.

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