User Intention Market for Multi-Agent Navigation - An Artificial Intelligent Problem in Engineering and Economic Context

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Abstract

We propose an artificial intelligence problem called 'User Intention Market for Multi-Agent Navigation' which is a real problem in engineering context and also should be analyzed in economic context. The purpose of multi-agent navigation is to improve the performance of whole multi-user system without forcing them to make effort for the goal of the whole system. Although some negotiation and adjustment mechanism is needed, we analyze traditional planning techniques in artificial intelligence is not sufficient even when geometric reasoning is joined to it. We think some market mechanism has a possibility to work well. The nature of market mechanism, however, obliges users to take effort to make pricing for a service. Instead of introducing regular market mechanism, does 'user intention market' where exchange of users' intention without currency as catalyst work well for the purpose ? This question is another problem we would like to propose in this paper.

1. Introduction

Artificial intelligence approach such as multi-agent, reasoning, and learning have succeeded to model and simulate complex economic phenomena which are beyond the traditional analysis in economics, i.e., general equilibrium theory. This direction of research benefits economics, especially so-called 'artificial market' provides new analysis tools of financial markets (Arthur 1997). Artificial market is now one of the most active inter-disciplinary research fields between multi-agent and economics.

In the opposite direction, what kind of benefits in artificial intelligence, computer science and engineering do we expect from economics ? Although one of such benefits from economics is single auction mechanism which is used in resource allocation in computer science, we would like to examine the possibility of introducing some economic mechanism in 'user-oriented' or 'human-oriented' context. More precisely, we propose a problem which requires negotiation and adjustment mechanism of users' intention in usual situations, such as navigation and information providing in walking in town, visiting amusement park, shopping, and so on.

2. Difference of Problem Solving in Economics, Engineering, and Artificial Intelligence

Problem solving has different manners in economics, engineering, and artificial intelligence. In economics context, so-called market mechanism has the most importance. The basic structure and constraints of market mechanism is simple. Agents participating in a market offer price and quantity of goods for sell or buy, and these orders are accumulated in the market. The price is determined to maximize the total quantity of trades. This simple mechanism of markets provide a negotiation and adjusting mechanism among agents, because agents have to change their orders in many cases in order to satisfy their intention within fixed finite time. In other words, markets can be regarded to contain a mechanism to oblige agents to make a compromise.

The most important difference of economic problem solving from engineering one is the negligence of space, e.g., orders are assumed to reach instantaneously to a market, or spatial distance is represented as time delay. On the other hand, engineering requires spatio-temporal problem solving. Usually, space is one of the most important part to be modeled and reasoned about in engineering context.

Artificial intelligence has been handling both aspects of negotiation among agents observed in economics context and spatio-temporal entity observed in engineering context. It seems, however, that how economic tools can be used to solve artificial intelligence problem and how they can be formally modeled in artificial intelligence context have not been analyzed well.

In this paper, we propose an artificial intelligence problem that is realistic and useful in engineering context, is interesting in artificial intelligence and psychological context, and can be formalized as a market structure in economics context. The problem is call 'User Intention Market for Multi-Agent Navigation,' where users open

their own information and the whole multi-agent system tries to achieve the higher efficiency.

3. Aim of Multi-Agent Navigation

The aim of multi-agent navigation is information providing service and navigation for multi-users, e.g., providing guidance information, showing the direction, and making visiting plans to users. One restriction is that there is limited number of computational and spatio-temporal resources in the system. If there is infinite amount of resources, the problem becomes simple but it is not realistic. The main problem of multi-agent navigation, therefore, becomes resource allocation and negotiation among agents to maximize the efficiency of the whole system without central control basing on users' information, along with providing better QoS (quality of service) to each user. Another constrains is users' freedom. We should not oblige users to make special effort for the efficiency of whole system. By user information, we mean the following three categories of information.

1) Attribute:
   Stable attribute of users, e.g., gender, age.
2) Preference:
   Stable but changeable preferences, e.g., hobby.
3) Intention:
   Temporal aim or goal in a certain situation, e.g., places to visit on a certain day.

An example of multi-agent navigation in amusement park is illustrated in Figure 1. There several visiting places and several users have their own intention to visit the places.

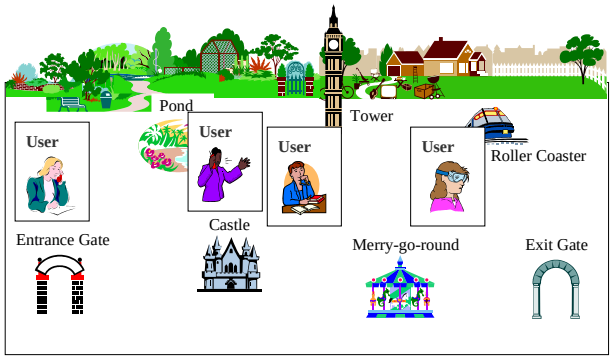

Figure 1: Example of Multi-Agent Navigation in Amusement Park.

4. Characteristics of Problem

In order to provide better service, we introduce feedback mechanisms of user information which is collected from users and accumulated in a service server. We can summarize the ways of feedback as follows.

1) Free Decision Making:
   Users make decisions by seeing bulletin board that contains the current status of whole multi-agent system and other users' information.

2) Implicit Guidance:
   A planning server collects and accumulates users' intention. The server makes a plan for each user with leaving users' choice, and with making higher efficiency in the whole multi-agent system.

3) Obliged Guidance:
   Such as the guidance in emergency cases, e.g., accident or disaster, a planning server provides a fixed action plan for each user.

The free decision making and the obliged guidance are the both ends of several feedback methods, and an implicit guidance exists at a point between the two ends. The most important problem is how to realize such implicit guidance mechanism, by what kind of negotiation and adjustment under spatio-temporal constraints. This is the artificial intelligence problem that we think has importance in both engineering and economic context. The problem has the following characteristics, compared with the traditional planning and problem solving in artificial intelligence context.

1) Vague Boundary Condition:
   The planner cannot grasp the whole nor entire information about users' intention.

2) Dynamically Changing Boundary Condition:
   Users changes intentions according to the information he/she recieves

3) Compromise of Users:
   The planner should guide users by implicit guidance, including making them compromise.

4) Spatio-Temporal Constraints:
   Unlike traditional planning problem, the planner should handle spatio-temporal constraints in addition to well-formed logical constraints.

5) Small Finite Time and Openness:
   The planner should react in small finite time, ideally real-time response is needed. This is not only computational complexity problem, but it is problem about openness, i.e., the planner should handle dynamically changing constraints mentioned above.

5. Free Decision Making and Obliged Guidance

Multi-agent navigation requires planning or problem solving method under open and dynamically changing

boundary conditions and spatio-temporal constraints. We propose a method for the planning by combining database for spatial extents, especially human flow, and market structure of users' information. The concept of the planning method is shown in Figure 2.

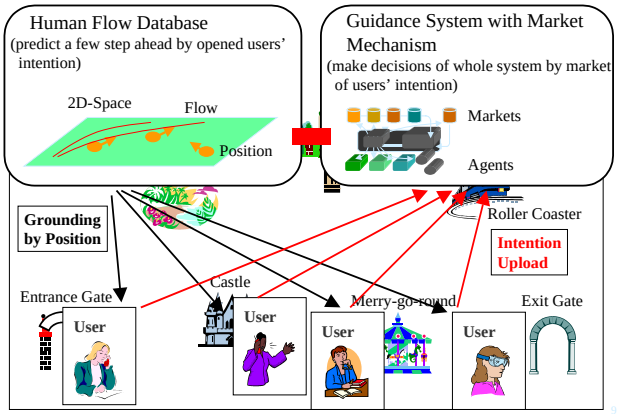

Figure 2: Human Flow Database and Market Structure.

We assume that the position of a user is measured and traced by sensing devices such as video camera, GPS, UWB, or laser radar, and that the track of a user is stored in human flow database. The position and track of a user can be retrieved by the temporal user ID that is issued per person. Human flow as mass users is also stored. Although it is the past data about position and track of users that we can retrieve from the database, we can predict the status after a few steps if we can obtain users' intention about moving.

Another part of the planner is user guidance system with market structure. This planner collects information about users and it serves as implicit mechanism for negotiation and adjustment between users.

In the case of free decision making as feedback mechanism of user information (Figure 3), users see or receive the current state about distribution of users and make prediction for a few steps ahead from the bulletin board in human flow database. In this case, the guidance system (planner) serves as just an information providing server and it does not have the function of negotiation nor adjustment.

We can intuitively predict that oscillation or centralization phenomena will be observed in this system, e.g., people rush in certain popular places or byways. Such tendency of the whole system has been observed in simple mobile multi-agent system, by the simulation of ant colony (Kurumatani 1995, Kurumatani 1997).

In the case of obliged guidance, the planner makes the whole guidance plan in order to save more people, and it provides sub-plan to each user. In that sense, it do not require negotiation and adjustment process between users.

6. Implicit Guidance

The goal of implicit guidance is to provide a mechanism of negotiation and adjustment between multi-users by users' open information as a plug-in to bulletin board mechanism that is realized in free decision making (Figure 4). The important thing is that the system should not oblige users to narrow their action options and should leave choices to them. In other words, the system should not let users notice that they are controlled.

In implicit guidance, collected users' intention is sent to guidance system in addition to human flow database. Users' intention is gathered to information market and will be adjusted. In this process, position flow data, which represents the spatial state in a few steps ahead, is generated by the current state of spatial extents, e.g., users' spatial distribution, and users' current intention in human flow database. The guidance system adjusts all the intentions under spatio-constraints and makes the whole plan of multi-users' behaviors.

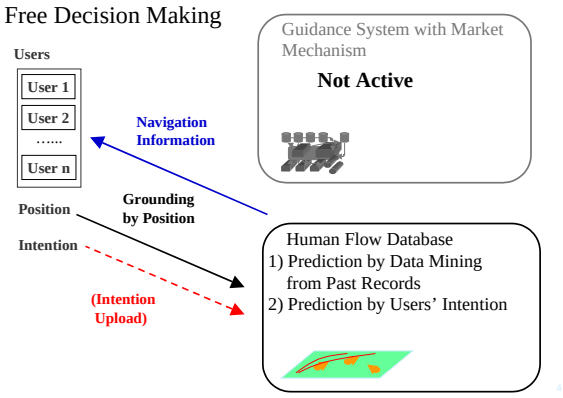

Figure 3: Bulletin Board in Human Flow Database.

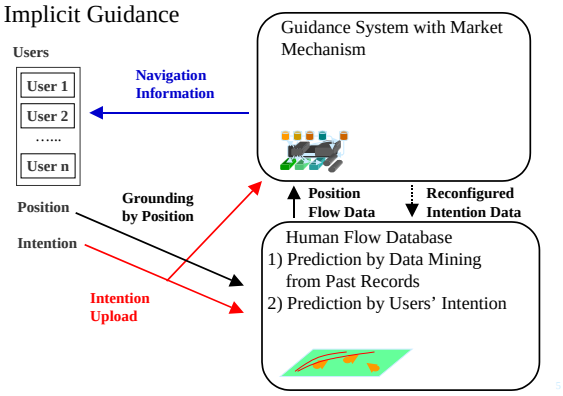

Figure 4: Guidance System with Market Structure.

We can set up several levels of problem instance according to abstraction, assumption, and approximation of the original problem.

1) Traditional Planning:
   If we can assume that all users are satisfied with the plan or follow it obediently, the problem can be seemed as a planning under spatio-constraints. In addition to it, if we approximate spatio-constraints to some symbolic representation (such as logical formula), the problem becomes a traditional planning problem in artificial intelligence.

2) Planning under Spatial Constraints:
   If handling spatial constraints as they are, we need some geometric reasoning techniques in addition to planning. This kind of problem has been raised mainly in robotics and qualitative reasoning, although human users with intention have not been the main concern.

3) Planning under Spatial Constraints with Implicit Negotiation:
   When considering the multi-agent navigation for human users, we cannot expect the obedience of users. That is, some implicit or explicit negotiation or adjustment mechanism is needed.

Market mechanism is one of the candidates for the last purpose. Single-auction or double-auction market mechanism can be introduced to planning under spatial constraints, which means that users can make pricing of reservation for a specific place on a time, i.e., exchange of reservation and currency is carried out in the market. In other words, we bring some 'e-reservation' mechanism into planning in this approach. Because this approach forces users to measure the value of a reservation in currency and to take time for the measurement, it is not suitable for our original purpose.
Another approach is to prepare some market mechanism where exchange of users' intentions themselves is carried out without currency as catalyst. We call this approach user intention market.

To summarize the discussion, we have to take the followings in consideration.

- Traditional planning method in artificial intelligence seems not to be sufficient to achieve multi-agent navigation under spatial constraints with decreasing users' effort.
- Introducing some adjustment mechanism such as market in economic context seems to work for the purpose. A regular market mechanism with currency, however, requires users' effort and does not seem to work well.
- User intention market where users' intentions are exchanged has a possibility to solve the problem.
- At any problem level, it is crucial how we represent and handle spatial extents. In other words, we have to find a suitable way of geometric representation and reasoning for the purpose.

7. Conclusion

We have proposed two problems in artificial intelligence context, which are realistic in engineering and should be considered in economic context. The first one is multi-agent navigation, which requires us to handle planning problem with negotiation under spatio-temporal constraints. The problem has an actual importance in mobile computation scene, such as cellular phone with position information.
The second problem is raised concerning with the negotiation aspects of the first problem called user intention market. Regular market mechanism such as financial one does not seem to work well, because it makes users take time to consider the value or price of service. The basic idea of user intention market is that exchange of users' intentions is carried out instead of measuring the intentions by currency.

References

Arthur, W. B.; Holland, J. H.; LeBaron, B.; and Tayler, P. 1997. Asset Pricing under Endogenous Expectations in an Artificial Stock Market. In *The Economy as an Evolving Complex System II (SFI Studies in the Sciences of Complexity, Vol. XXVII)*, Addison-Wesley.

Kurumatani, K. 1995. Generating Causal Networks for Mobile Multi-Agent Systems with Qualitative Regions. In *Proceedings of the International Joint Conference on Artificial Intelligence (IJCAI'95)*, 1750-1756. Montreal: AAAI Press.

Kurumatani, K., and Nakamura, M. 1997. Qualitative Analysis of Causal Graphs with Equilibrium Type-Transition. In *Proceedings of the International Joint Conference on Artificial Intelligence (IJCAI'97)*, 542-548. Nagoya: AAAI Press.