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MamMoeT: An intelligent agent-based communication support platform for multimodal transport

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ABSTRACT

In this paper, an intelligent agent-based communication support platform for multimodal transport is developed. The rationale for doing so is found in the potential of such a system to increase cost efficiency, service and safety for different transport-related actors. Although, at present several comparable systems exist, their current implementation is far from successful because of technological and economic obstacles. The new expert communication platform put forward here (called MamMoeT) addresses these two issues by using a software agent-based approach. Software agents are pieces of software representing a single user. They are autonomous, communicative and intelligent. The MamMoeT system developed can be described as a real-time decision support system in which intelligent software agents handle communicative tasks, exchange desired amounts of information among different users using common exchange protocols which act as translators between different systems.

1. Introduction

It is commonly accepted that information and communication technologies (ICT) are becoming an increasingly important support tool in managing the supply chain. This is certainly true in light of the intensifying supply chain integration. Besides generating a tangible flow of goods, transportation also causes considerable information flow. Diverse inquiries (e.g. Giannopoulos, 2002; Davies et al., 2007) support the belief that modern ICT applications and accommodating expert systems can contribute to increased cost efficiency, improved service and safety for all actors involved. This view is supported by the European Commission (2001, p. 2) stating: "Europe must bring about a real change in the Common Transport Policy. The time has come to set new objectives for it: restoring the balance between modes of transport and developing intermodality, combating congestion and putting safety and the quality of services at the heart of our efforts, while maintaining the right to mobility".

Achieving these objectives is, however, not an easy task. Promoting the use of alternative transport modes over road transport can only be successful if these alternative modes can meet the shippers' logistical requirements and fit in well into their supply chains. In this respect, research has shown that many different criteria (both quantitative and qualitative) are taken into account in freight modal choice decisions (e.g. Cullinane & Toy, 2000; Jeffs & Hills, 1990; Murphy & Hall, 1995; Witlox, 2003; Witlox & Vandaele, 2005; Dullaert et al., 2005; Blauwens et al., 2006; Vernimmen et al., 2008) such as: freight rate, lead-time performance (i.e. the speed and reliability of delivery), loss or damage (safety), flexibility, infrastructure availability and capacity, regulation/legislation, controllability/traceability, environmental considerations, etc. Clearly, the significance of ICT is omnipresent here, and its potential benefits are sufficiently known. This can also be inferred from the fact that most barge operators are already provided with possibilities for the implementation of ICT applications.

However, the possibility of integrating and sharing operational information in the supply chain is still only limitedly used by transportation actors. Several reasons can be distinguished (http://spb.binnenvaart.nl/):

- Low reliability and quality of mobile data connections (GSM and GPRS), especially when compared to the services offered by 'fixed' connections.
- Low willingness to share information due to confidentiality considerations.
- Difficulties in getting the idea of chain integration adopted: island automation and optimization are prevailing.
- Fragmented knowledge and information on the available communication systems.
- Limited attention given to ICT in training programmes for barge operators.

Broadly speaking, two critical issues arise. First, there is a purely technological problem related to the quality and reliability of

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the communication platform. Second, there is a more managerial economic problem related to the kind of information that needs to be exchanged among the various parties in the supply chain. This paper aims at analyzing both issues, mitigating their effects, and to develop an alternative intelligent agent-based communication platform. Our field of application is multimodal transport (hence the acronym MamMoeT, referring to multimodal transport in Dutch). In particular, the combined use of road transport and inland navigation is used as example, which in Europe is the most common form of multimodal transport.

The paper is structured as follows. First, in Section 2 we briefly discuss two important issues that might impede the implementation of an expert communication system for multimodal transport, and also point to existing initiatives that have been established in inland navigation to identify their limitations. In Section 3, we present a rationale for developing a new agent-based expert communication system capable of meeting the requirements identified in the previous sections. In Section 4, the MamMoeT communication platform is developed and illustrated by means of a set of screenshots depicting its use. Finally, in Section 5, we draw conclusions and identify avenues for future research.

2. Experiences with expert communication systems in multimodal transport

2.1. Technological aspects

It is clear that data transmission is significantly more complex for combined transport than for conventional unimodal transport. After all, the (in)compatibility between information systems is influenced by (i) the size of the participating companies (influencing their level of computerization), (ii) the use of multiple transport modes, and (iii) the international dimension of transportation (Macharis and Verbeke, 1999, p. 51).

The incompatibility of information systems can partly be mitigated by using standard formats for communication such as *Extensible Markup Language* (XML) or *Electronic Data Interchange For Administration, Commerce and Transport* (EDIFACT). These systems enable the data exchange between terminals, operators and customers by means of standard messages. These standards improve the quality, reliability and consistency of the information, and advance the compatibility between diverse internal systems.

Besides compatibility, there is also the problem of speed, manageability, and volume of the information to be exchanged. The speed and manageability refer to the flexibility of anticipation to unforeseen events during transport. Assume a sea-going vessel is arriving too late in the port, then a barge operator (who is dependent on the arrival of the sea-going vessel) can decide to sail at a slower speed as a result of which fuel consumption decreases. Related to this issue, there is a need to monitor transport by means of indicators such as Estimated Time of Arrival (ETA) and Estimated Time of Departure (ETD). Using these indicators, company processes (e.g. using Enterprise Resource Planning) can be adjusted. By exchanging accurate data in real-time, also production planning of the parties involved can be optimized and the use of (public) infrastructure can be managed more efficiently.

The volume/intensity of data exchange can be expressed by the amount of bytes that needs to be transmitted. Until recently, data traffic by traditional mobile phone (GSM) has been the best way to transmit data. There are however two major disadvantages to this medium: (i) one has to pay per time unit and (ii) the transfer speed is low (9.6 kbit/s). GPRS already performs better on these two aspects by fixing rates per data unit transmitted and by providing transfer speeds up to 40 kbit/s. This is indeed a significant improvement in comparison to GPS but is still only a tenth of the usable band width provided by UMTS (384 kbit/s). Applications of UMTS in business applications are – to this date – still limited.

Dependent on the location, WLAN (Wireless Local Area Network) technology can also be used. As the term LAN suggests, the use of this technology is spatially restricted, i.e. a user has to be located within a so-called *hot spot* (the reach of the WLAN). Transfer speeds of WLANs are similar to those achieved by fixed networks. When, for example, certain locks and constructions were equipped with such a WLAN network – which is already the case then barge operators would be able to transfer much more information faster and cheaper.

2.2. Managerial aspects

The pursuit of an integration of systems is one aspect; the exchange of correct, reliable, relevant, and if possible real-time information is another vital characteristic. Real-time refers to the speed at which information flows are collected and processed within a network of partners. Companies are after all becoming increasingly part of an "*extended enterprise*", an operational entity consisting of the company itself, its suppliers and its customers. Ranadivé (1999) states that real-time refers to the time frame in which your customer wants satisfaction. In a broader perspective, real-time refers to the time frame in which a partner in the extended company wants its needs to be satisfied. As argued in Dullaert and Van Landeghem (2007), the concept of real-time is of particular importance to the logistic service industry. Not only because some shippers require logistic service providers to integrate into their information system, but also because after stripping away the physical handling and movement of goods, all one is left with is information. So being competitive in logistics and transport means increasingly being able to use information more intelligently, and with less latency.

Real-time transport information such as data on traffic jams, water levels, etc. is usually available on the internet. However, obtaining the right information within a short period of time often remains a complex issue. Moreover, a lot of websites are illustrated by high resolution pictures which increase the amount of bytes to be transmitted. This is considerably slowing down data transmission. In most cases, information is largely available in digital form but conventional means of communication such as telephone, marine telephone, fax and e-mail are often additionally used. Hence, the information (e.g. freighting agreements) has to be exchanged repeatedly. In brief, the chain mostly contains all the information required, but often stores it in the wrong place, at the wrong moment and in the wrong form.

Another important economic aspect is the data privacy of the parties involved. Guaranteeing customer data privacy is often a necessary condition for parties to engage in a communication platform. With regard to ports, a large amount of data on transportation modes and infrastructure is currently being exchanged between multiple agents. This data exchange contrasts sharply with the limited data exchange on freight characteristics. This is due to the fact that the exchange of freight information implies the disclosure of explicit information about the companies involved. Since the success of a communication platform highly depends on the willingness of the participants to share all useful information available, privacy considerations form an awkward obstacle to implementing transport-related ICT applications.

Other factors influencing the performance of ICT applications are the reliability and appropriateness of the transport communication platform (Witlox, 2007). These factors imply a high level of transparency and are at odds with discretion and privacy. The construction of a so-called *trusted third party* (TTP) can stimulate a secure cooperation between different parties which were initially unacquainted.

2.3. Existing ICT initiatives for inland navigation

Building upon a brief literature review and several in-depth surveys with shippers, barge operators and government officials, this subsection presents an overview of the most relevant ICT systems for facilitating freight transport. The overview starts at the European level and then moves on to the Belgian and Dutch initiatives which have often been triggered by research projects launched at European level. Belgium and the Netherlands are two key countries when it comes to inland navigation transport.

An important initiative towards the integration and implementation of ICT for inland navigation was taken by the European Union by introducing the River Information Services (RIS) concept. The aim of RIS is to develop harmonized information services to support traffic and transport management of inland navigation in relation to other transport modes. By providing high quality information, RIS aims at improving the efficiency and safety of inland navigation, hence improving the competitive position and professionalism of the inland shipping companies and allowing the waterway manager to better manage infrastructure.

After introducing the RIS concept, the INDRIS (Inland Navigation Demonstrator for River Information Services) project (January 1998–June 2000) was launched. INDRIS intends to (further) gear up diverse national developments with respect to *telematics*, thereby striving for the adaptation to an open European standard for data exchange between ship and quay. In doing so, a ship would only need one single hardware infrastructure and one software product on board to electronically exchange data with the waterway manager in each member state. The sequel to INDRIS was called COMPRIS (Consortium Operational Management Platform River Information Services) and the project ran from September 2002 to December 2005. COMPRIS can be deemed a last step towards a full implementation of the initial RIS functionalities in the Western Europe and Danube countries.

Inspired by the RIS concept, two projects have been set up in Belgium: BIVAS (Binnenvaart Intelligent Vraag en Aanbod Systeem) and IBIS (Informatisering Binnenscheepvaart). BIVAS is a Flemish pilot project belonging to the European INDRIS programme to create a virtual market on which supply and demand for inland shipping could meet by means of modern communication technologies (such as internet, SMS and GPRS). In other words, BIVAS operates as a communication platform for shippers and barge operators and facilitates data exchange by mapping the needs of the parties to each other. The system, however, does not intervene in the negotiation process, i.e. transportation contracts and price agreements are left to the contracting parties. From a technological point of view, the BIVAS system consists of a central server and an internet application ashore as well as on board. Data of multiple parties are stored on the central server. The internet application ashore enables shippers to send information on the freight to the central BIVAS server and to check the availability of ships. The internet application on board is used by the barge operators to check the availability of cargo as well as to pass on information e.g. about the carrying capacity of the ship, or route changes. Furthermore, a shipper is informed immediately by text message (SMS), in case a new load offer or transport order has been submitted to the system. Hence, a shipper is not compelled to be continuously connected with the system, which considerably keeps down communication costs. Suppliers of load space (i.e. barge operators) need a computer with internet connection and Java support. Both shippers and barge operators have to pay communication costs. For a shipper communication costs are negligible given that a fixed internet connection can be used. Barge operators have to rely however on GPRS, or data exchange by GSM. BIVAS was however not successful because of incompatibility problems with existing systems and for privacy reasons.

Similar to BIVAS, another INDRIS project called IBIS was launched by the Flemish authorities (Administratie Waterwegen en Zeewezen). IBIS facilitates the management of the waterways by means of a tracking system. As such, the waterway manager is capable to: (i) gather data on inland navigation; (ii) optimally use the available infrastructure by e.g. (re)directing traffic; (iii) generate statistical information. All local computers at the locks of the waterway network of the Administratie Waterwegen en Zeewezen are connected to the IBIS system since December 1999. This helps optimizing traffic along the waterways through a quicker transferring of information on load, destination, etc. Prior to IBIS this was done using a marine telephone. The IBIS system distributes shipping information via internet to shippers, barge operators, inspectors, etc. The computerization and (central) storage of these reports results in faster information flow between the different parties. The use of IBIS has the advantage that (i) authorization can easily be issued (the barge operator does not have to leave the ship anymore); (ii) the collection of navigational rights happens promptly; (iii) locks can anticipate on the arrival of ships; (iv) statistics can be gathered and processed; and (v) appropriate action can be undertaken faster in case of calamity.

On the initiative of Directie Zeeland van Rijkswaterstaat, BICS (Binnenvaart Informatie and Communicatie Systeem) was introduced in the Netherlands. BICS is a system for barge operators to transmit information about cargo and ship trajectories via computer and GSM to diverse waterway managers and port authorities. These authorities need accurate information to be able to offer a smooth and safe traffic management, especially when dangerous cargo is being transported. At the start of transport, information on the ship and the cargo has to be entered in the system (either by the barge operator or by the shipper). This information is also automatically transmitted to the Dutch National Statistical Office (CBS, Centraal Bureau voor Statistiek). Using BICS, the barge operator can receive specific shipping information (e.g. information about water levels). Interested parties ashore can also retrieve information about the position of specific ships so as to optimize their terminal planning for instance. BICS serves as:

- Registration system: reporting travel and cargo specifications;
- Information system: receiving shipping information;
- Communication system: communicating between BICS users and the helpdesk, and mutually between BICS users.

About 2000 Dutch ships are currently using the BICS system and some European countries make use of protocols, components and software of BICS.

Apart from the Flemish and Dutch initiatives, there exist many more national/regional communication platforms for shippers and barge operators. Without aspiring completeness, we refer to GINA (Gestion Informatisée de la Navigation) in Wallonia; ARGO (Advanced River Navigation), ELWIS (Elektronisches Wasserstraβen-Informationssytem) and NIF (Nautischer Informations-Funk) in Germany; VNF2000 in France; DoRIS (Danube River Information Services) in Austria, etc. A profound discussion of these systems is beyond the scope of this paper.

The list of initiatives generated by the RIS research project is impressive. The commercial success of these systems is, however, rather limited up to this date. Four main reasons can be put forward as possible explanation for their limited adoption:

- The absence of intelligent components and real-time decision support systems.
- The limited willingness to share company sensitive information.
- The lack of standardization and harmonization of systems and information exchange protocols.

– The distrust of inland shipping companies due to privacy related issues. The parties involved only want to participate if privacy of (customer) data is guaranteed. A *trusted third party* is needed to set up a coordinating system that meets the requirements identified above to achieve success.

3. Rationale for a new agent-based expert communication platform

Up till now most communication and negotiation processes related to inland navigation are generally still performed by telephone. It is clear that the speed of this medium is limited compared to the more modern communication technologies available today. Therefore, a prototype of communication platform for multimodal transport has been developed. Three basic goals can be achieved by automating the communication between shippers and transportation companies (in this case, barge operators):

1. Matching supply and demand
Currently, it is difficult for barge operators and shippers to find the most appropriate partner or shipment for inland navigation. Matching supply and demand is the main objective of the communication platform.
2. Tracking and tracing
Telephone contact is a discontinuous medium, meaning that it is impossible to track or trace the position of a vessel or a particular requested freight at any given time. Knowing the exact or approximate positioning of freight would hugely facilitate the management of freight flows further along the supply chain. Therefore, a second objective of our communication platform is to provide basic track and trace concepts to achieve this goal. These concepts are also useful when evaluating transport supply and demand for achieving the platform's first objective.
3. Exception handling
When communication is exclusively performed by telephone, warning about unexpected events is a slow process. As a result, parties involved further along the supply chain might not be informed in time. To facilitate proper reaction to unexpected events, propagation of event messages should be automated. A communication platform does not necessarily have to respond intelligently to each possible event and it might suffice to warn the involved parties in case exceptions occur. Therefore, the third objective of our communication platform is providing tools for latency control and connection to other information systems.

For the prototype of the communication platform, we adopt a software agent-based approach to automate communication. This approach uses one-to-one mapping, meaning that each transport participant gets mapped onto a corresponding agent. More specifically, such a software agent is a piece of software representing a single user. The exact definition of a software agent is subject to many discussions in the literature (see e.g. Nwana & Wooldridge, 1996). However, a wide consensus seems to exist about its main characteristics. Hence, a software agent should possess the following properties:

– Autonomous
An agent is able to perform actions without intervention of the user and is typically configured beforehand according to the user's preferences. At certain moments, an agent can act according to its configuration, without the user having to remain 'on line'. This feature implicitly implies other related properties: the agent exists 'persistently' in an 'environment' which it can alter 'autonomously' through 'actions'.
– Communicative
In the context of a multi-agent system, agents are able to communicate with other agents. This property enables faster communication and reduces the amount of human communication throughout the system. In a dispatching context, more data is readily available for searching better supply-demand matches.
– Intelligent
Agents must possess some business intelligence to function autonomously. In the context of transportation, this means that agents should possess notions of time, capacity, distance, travel speed etc. For example, an agent representing an individual barge operator should 'know' that it cannot accept additional freight if its ship is already fully loaded.

It should be noted that in our system agents are only autonomous to some extent because they change their environment by changing the distribution of information. The agents do not engage in determining freight rates or concluding transport contracts themselves, rather they provide the user with a list of options. The reason why the system does not interfere with the establishment of contracts is twofold. First, human decision making often involves hidden considerations by which it becomes nearly impossible to simulate good automatic agreements. And second, users are unlikely to fully trust the electronic system to make decisions on their behalf.

We are convinced that the main four causes for the limited success of existing platforms (see Section 2.3) can be tackled with a software agent-based approach:

1. *The absence of intelligent components and real-time decision support systems*: The system is a full real-time decision support system in which burdensome communicative tasks are taken over by intelligent software agents. Instead of contacting all barge operators on a list by telephone and to negotiate in rounds, communication between corresponding software agent provide a cheaper and faster approach to narrow down possible partners.
2. *The limited willingness to share company sensitive information:* Software agent technology allows for a high level of customization so users can decide themselves on the desired amount of information they are willing to share. Indeed, after installing a common protocol for communication among the agents, each party can design or customize its own software agent. Because sharing transport information reveals opportunities for avoiding empty transport, we believe the platform gives strong incentives to share information.
3. *The lack of standardization and harmonization of systems and information exchange protocols*: The asset of an agent-based approach lies in the fact that it does not dependent on some form of standardization. An agent-based system can easily be extended with translations between any standard and the agent system. As long as inside the agent system a common protocol is used, it can act as a translator between different systems.
4. *The distrust of inland shipping companies due to privacy related issues:* The parties involved only want to participate if privacy of (customer) data is guaranteed. A trusted third party is needed to set up a coordinating system that meets the requirements identified above to achieve success.; An agent system can be spread over multiple servers, which rules out the need for a trusted third party.

In short, the main virtue of the communication platform consists of decreasing the amount of required human communication and in increasing the number of possibilities for finding a better match between supply and demand.

4. MamMoeT

In this section, we outline the basic architecture of the MamMoeT platform by means of a series of screenshots for a typical scenario. The platform can be used by shippers and barge operators (transporters), respectively represented on the platform by shipper agents and transporter agents.

Consider the scenario of a shipper (or his agent) placing a transport request and sending it to a barge operator (or his agent). A shipper connected to the MamMoeT platform (Fig. 1) is controlled through a main window from which the user can view and manage transport requests, transport offers, and trusted personal contacts.

As shown in Fig. 1, each shipper has a list of trusted personal contacts (TPC list). In our application, all contacts in the shipper's TPC list are barge operator. A trusted personal contact of a shipper comprises an identification of another registered agent together with an assigned trust figure (TF). This trust figure or index expresses the amount of trust or preference a shipper has towards trading with that particular agent. Trust figures are integers contained in the set TF = {4, 3, 2, 1, 0, −1, −2 and −3}. The higher the TF assigned to a contact, the higher the trust towards that particular contact. A TF = 0 means that the barge operator is unknown to the shipper. Therefore, a zero trust figure typically does not appear in a TPC list. Since an agent platform has a dynamic population, it is only possible for a shipper to know a small percentage of the barge operators on the platform. Whenever the trust figure for some barge operator is not found, a zero trust figure will be used. Afterwards, the barge operator can be added to the TPC list with an adjusted trust figure.

A shipper can enter a new transport request in the system using the window depicted in Fig. 2. All active requests are listed in the main window of the shipper. The shipper can fill in details such as pickup and delivery time and location. After completing this form, the transport request can be confirmed by pressing the *Go* button.

Initially, the request is only sent to the barge operators with the highest trust figure in the TPC list of the shipper (see Fig. 3). Barge operators should be able to react autonomously and without delay. This is the main advantage of agent-based communication: since no human intervention is needed to react to queries, more information can be exchanged and more matching possibilities can be considered. The shipper is automatically notified when a barge operator has reacted to the request.

In case a shipper does not receive any suitable reactions, (s)he can gradually adjust his/her demands. The button *Decrease minimum trust* invites barge operators with a lower trust figure to react as well. The shipper can sort incoming reactions according to its own criteria. In Fig. 4, the reactions are sorted on the proximity of the barge operator. This principle can be extended towards other

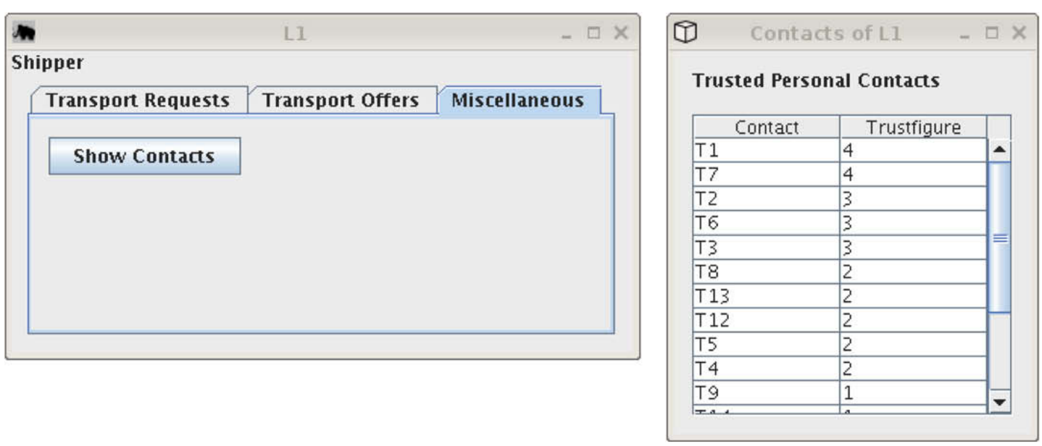

Fig. 1. A shipper's trusted personal contacts.

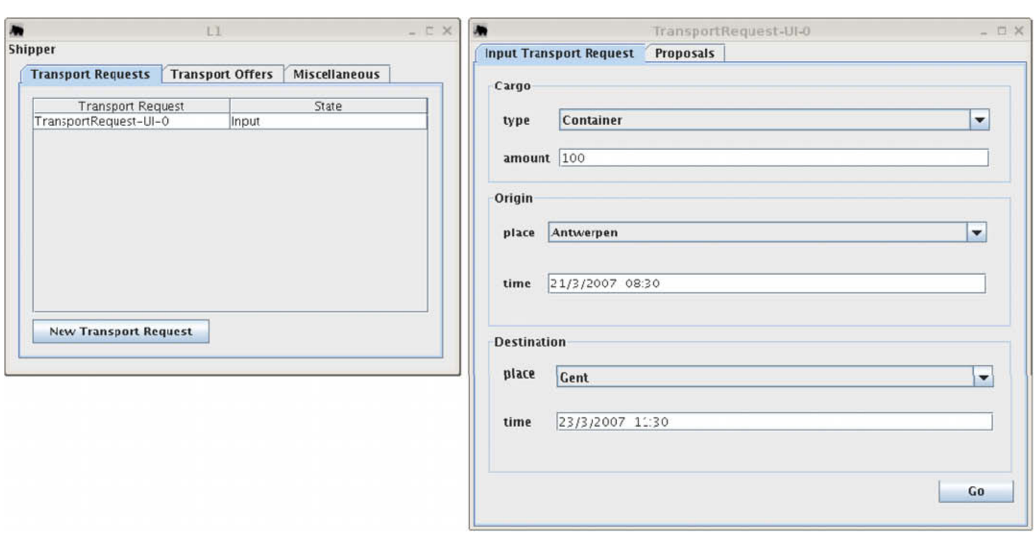

Fig. 2. Shipper requesting transport 1.

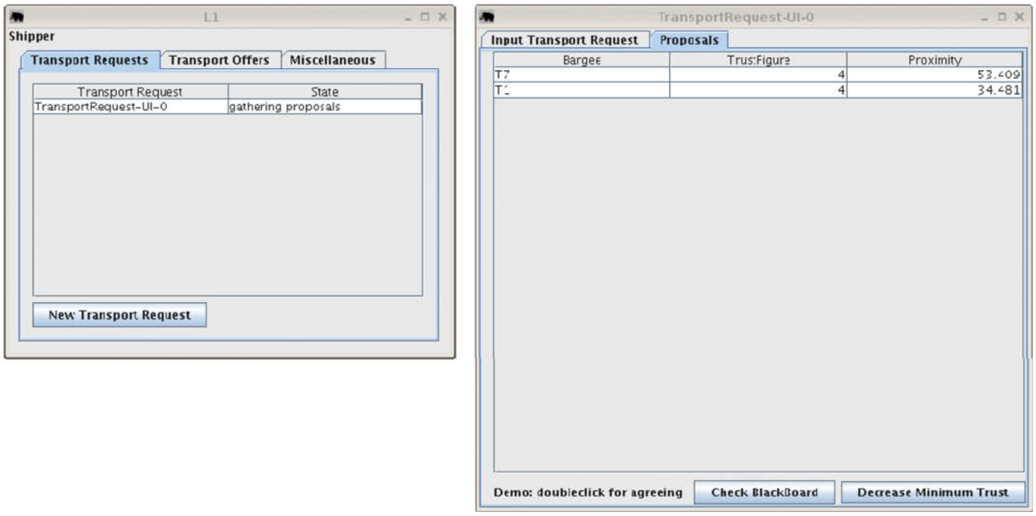

Fig. 3. Shipper requesting transport 2.

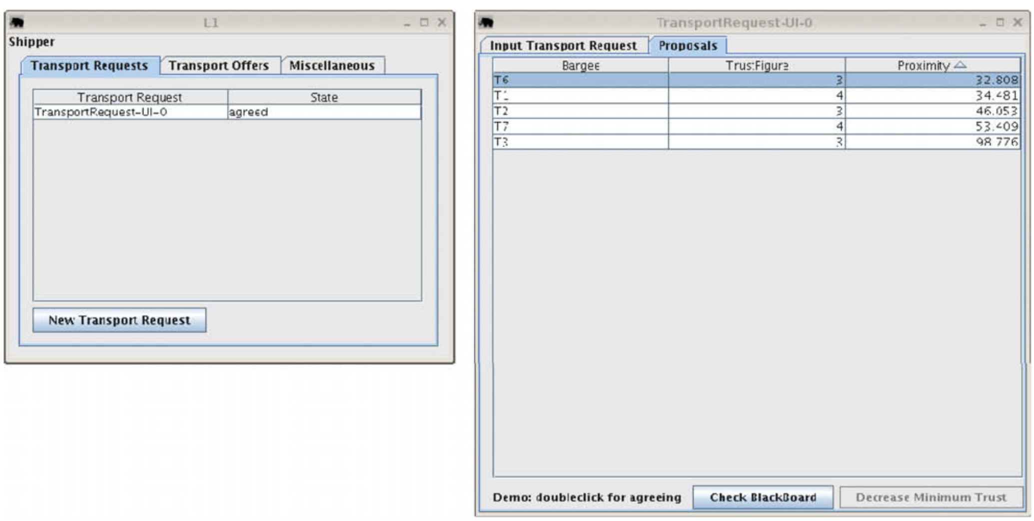

Fig. 4. Shipper requesting transport 3.

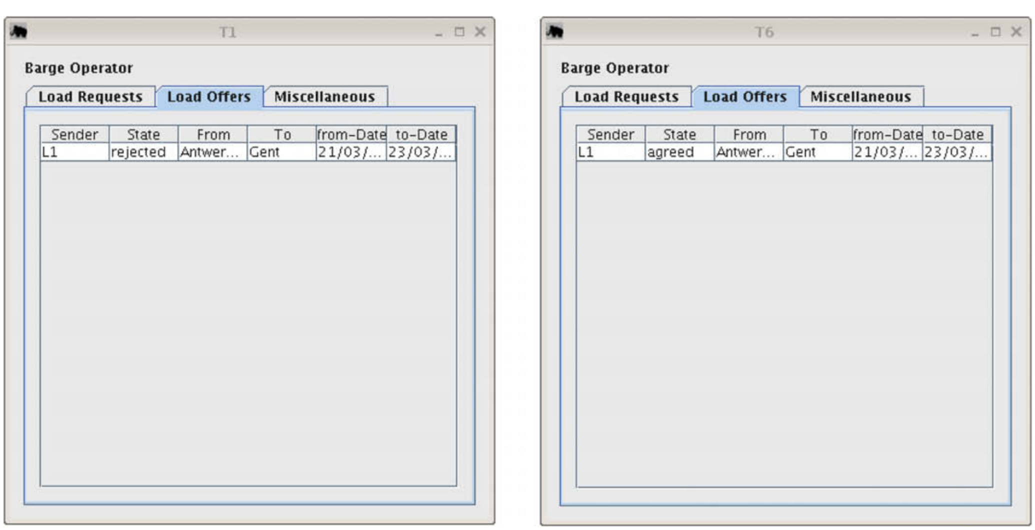

Fig. 5. Barge operator requesting transport 1.

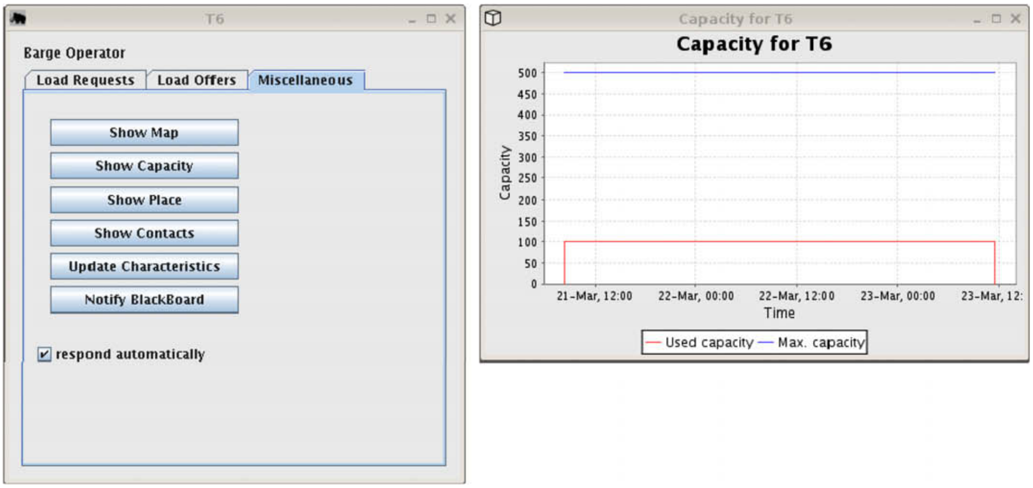

Fig. 6. Barge operator requesting transport 2.

criteria like properties of the ship or previous shipment of the ship. Finally, the shipper makes his/her choice and the barge operator(s) are informed.

From the transporter or barge operator perspective, an incoming transport request of a shipper is called a load offer. Barge operators addressed by the shipper can follow the state of the load offer in the main window of the barge operator, as shown in Fig. 5. Following states are possible: *received*, *refused*, *reacted with proposal*, *rejected*, and *agreed*. The initial state of an incoming load offer is *received*. If a barge operator wishes to refuse a load offer, (s)he can acknowledge this to the shipper and the state becomes *refused*. If the barge operator reacts positively with a proposal, then the state of the load offer becomes *reacted with proposal*. Depending on the barge operator's choice of the shipper, the final state becomes *rejected* or *agreed*.

Each barge operator maintains a schedule which monitors occupation and capacity over time. Such a schedule enables the system to automatically decide on availability. The destination and departure of the accepted transport requests can be used to estimate future locations and availability of the ship (Fig. 6).

5. Conclusions and avenues for future work

This paper discusses the development of an intelligent agent-based communication support platform for multimodal transport. The rationale for developing such a platform was found in the potential of such a system to increase cost efficiency, service and safety among different transport-related actors. Today, several communication systems do exist, but they are unsuccessful because of two important impediments: (i) the quality and reliability of the communication technology, and (ii) confidentiality and trust concerns on the data to be exchanged.

The MamMoeT communication platform developed in this paper addresses these two issues by using of a software agent-based approach. Software agents are pieces of software representing a single user. They are autonomous, communicative and intelligent. The MamMoeT communication platform is able to offer its users real-time decision support system by having intelligent software agents taking over strenuous communicative tasks in real-time. Moreover, it also allows for high level of customization so that users can decide themselves on how much information to share (trust issue), and produces and uses common exchange protocols which act as translators between different systems.

Although, the MamMoeT prototype has obvious advantages over existing platforms, there is still room for further improvement when implementing the system. For instance, distances are now calculated based on Euclidian distance, whereas in future, they should be graph- or network-based. Detailed information on ship type and possible waterway constraints should be added as well. Finally better, more transparent control on sending/receiving of requests and proposals is needed. Note also that although hardware issues are lessened by the distributed nature of multi-agent systems, in practice there will be issues with wireless communication, servers, etc. to be dealt with.

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