INFLUENCE OF COMPETITION-BASED KNOWLEDGE RESTRICTIONS ON AUTONOMOUS ROUTING IN TRANSPORT LOGISTICS

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ABSTRACT

Due to the increasing complexity and dynamics of actual transport logistics networks, traditional algorithms of centralized routing are pushed to their limits. The application of autonomous algorithms leads to a better handling of these increasing requirements. Within this context, the Distributed Logistics Routing Protocol (DLRP) was developed, which enables logistics entities to come to their own decisions. Here, communication between the logistics entities comprising transport vehicles and transport goods is essential to gain detailed knowledge for routing decisions. In previous works on the DLRP, unrestricted knowledge exchange about the current situation in the network was assumed among the participating logistic entities. Within this work, the influence of knowledge restrictions, caused by competitions between actors, will be presented. The effects of different degrees of competitions have been investigated and are presented.

KEYWORDS
Autonomous Control, Distributed Logistics Routing Protocol (DLRP), Transport Logistics, Knowledge Restrictions, Business Competition

INTRODUCTION

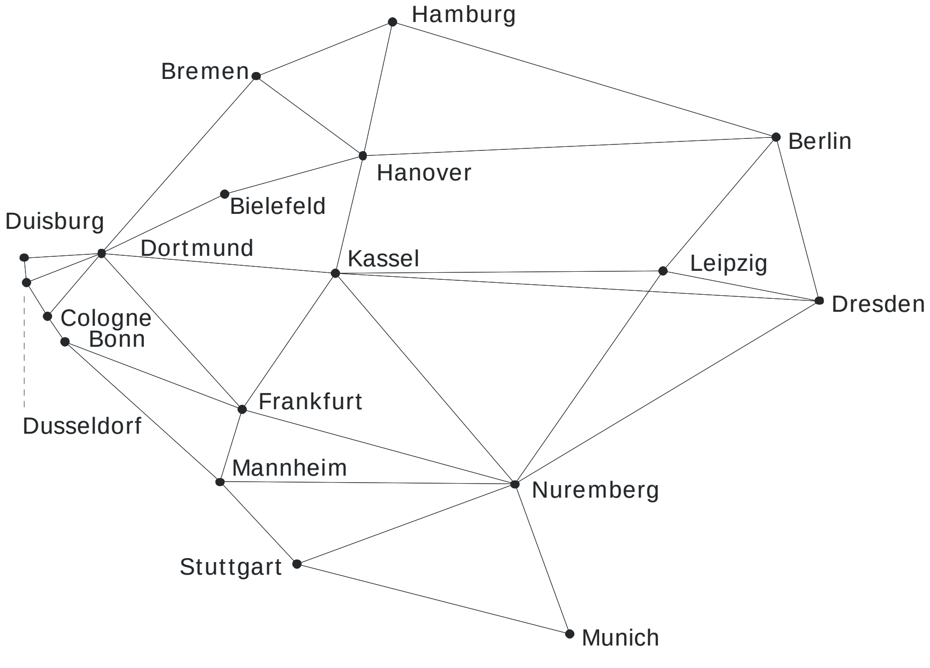
In the field of transport logistics the planning of routes is usually executed centrally, often based on algorithms for the Vehicle Routing Problem (VRP) and the Pickup-and-Delivery problem (PDP) (Laporte, 1992; Savelsbergh et al., 1995). Actual trends in transport logistics exhibit higher degrees of dynamics and complexity. Central control is pushed to its limits when handling the new requirements. An approach for this problem is the Distributed Logistics Routing Protocol (DLRP) which is developed within the Collaborative Research Centre 637 (CRC 637) at the University of Bremen. The research area of the CRC 637 is autonomous control which is characterized by decentralized decision-making. Logistics entities are able to render decisions on their own (Scholz-Reiter et al., 2004; Windt et al., 2007). In the context of the DLRP, logistics entities require knowledge about routing decisions of other logistics entities within a network in order to make well-founded decisions. This is achieved by knowledge exchange between the logistics entities (transport vehicles and transport goods). The occurrence of competitive business relationships limits this knowledge: competition between the actors in transport logistics causes knowledge restrictions which leads to incomplete knowledge for routing decisions. Within this work, the influence of competition-based knowledge restrictions is evaluated for its effects on the logistics performance within the DLRP.

DISTRIBUTED LOGISTICS ROUTING PROTOCOL

The development of the DLRP was inspired by algorithms of data communication. Because of the amount of data, communication network algorithms that exhibit a high degree of autonomy are necessary. Due to the similarities of data communication and transport logistics the concepts of data communication algorithms could be adapted (Wenning et al., 2005). This resulted in the development of the DLRP, an autonomous and distributed routing concept for logistics processes. The DLRP can be applied for the routing of logistics objects within scenarios like the one that is presented in Figure 1. Vertices represent logistics centers for the distribution of transport goods. Connections between neighbored vertices represent traffic connections. Figure 1 illustrates a map of Germany with 18 cities and important motorways. Within the DLRP, logistics entities share knowledge in order to perform routing decisions. Whenever a logistics entity has to plan a route, the knowledge transfer is realized by sending route requests through the logistics network. These route requests are transmitted between the vertices. When a vertex receives a request, it adds its local knowledge about the current network status and about routes of other logistics entities to the request. Then the route request is forwarded to the neighbor vertices. When a route request reaches the destination vertex, a route reply is submitted back to the logistics entity. Each route reply contains the knowledge about one possible route through the network. After receiving several route replies, the logistics entity executes its routing decision based on the received knowledge. The concept of the DLRP is described in detail in (Rekersbrink et al., 2008; Scholz-Reiter et al., 2008).

The knowledge exchange within the DLRP was not restricted so far. Whenever a logistics entity has to plan a route, it gains the available knowledge. This leads to complete knowledge for the routing decisions and guarantees the quality. To evaluate the DLRP in scenarios that are more close to reality competition-based knowledge restrictions which lead to incomplete knowledge for the decisions are presented within this work.

FIGURE 1
GERMANY SCENARIO TOPOLOGY

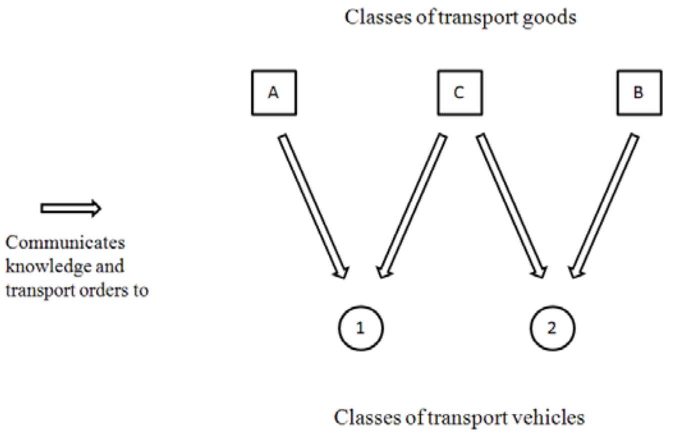


COMPETITION-BASED KNOWLEDGE RESTRICTIONS

For the consideration of competition-based knowledge restrictions, the types of logistics entities are separated into several classes: for the transport goods there are three classes A, B and C, whereas for the transport vehicles there are two classes 1 and 2. The vehicles receive transport orders from the transport goods. Therefore knowledge about announced routes is communicated via route requests.

Because of competitions between the actors, the classes of transport goods do not communicate with all classes of transport vehicles. This leads to knowledge restrictions: Classes of transport vehicles that are not cooperating with a class of transport goods do not gain knowledge about announced routes or transport orders from that class. Figure 2 shows the relationships between transport goods and transport vehicles.

FIGURE 2
COMMUNICATION BETWEEN THE CLASSES OF TRANSPORT GOODS AND TRANSPORT VEHICLES

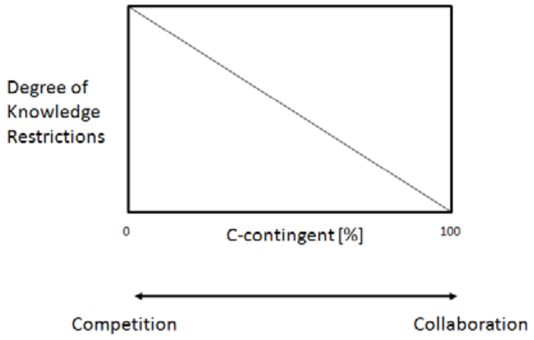


According to Figure 2, the transport goods classes A and B cooperate with one class of transport vehicles whereas the class C cooperates with all classes of transport vehicles. The transport vehicle classes have the opportunity to cooperate among each other when they receive orders from the transport goods class C. Within the DLRP it is possible that a transport good can be transported by more than one vehicle. Hence, cooperation between the vehicle classes is possible for transport goods of class C.

The influence of competition-based knowledge restrictions has been evaluated within the scenario illustrated in Figure 1. The scenario contains 18 vertices. For the delivery of transport goods 12 transport vehicles, each with a capacity for 12 transport goods, are responsible. The vehicles are equally allocated to the transport vehicle classes 1 and 2. 1000 transport goods are generated within the scenario. In contrast to the transport vehicles the allocation of the transport goods to the classes A, B and C varies.

For each simulation a different contingent of the transport goods is allocated to the class C. This value is called the C-contingent in the following. The value for the C-contingent defines the degree for the competition-based knowledge restrictions. The higher the C-contingent, the lower is the degree of knowledge restrictions. This is illustrated in Figure 3.

FIGURE 3
DEGREE OF COMPETITION-BASED KNOWLEDGE RESTRICTIONS



The transport goods within class C are able to communicate with all transport vehicles. This leads to a high degree of collaboration between the transport goods and the transport vehicles and allows a high degree of communication. A C-contingent of 100 % causes full collaboration. In previous work on the DLRP, the effects of full collaboration has been investigated. In contrast, a high contingent of transport goods allocated to the classes A and B causes a high level of competition. This leads to a high degree of knowledge restrictions and to incomplete knowledge for routing decisions.

The influence of competition-based knowledge restrictions was evaluated in different degrees. The C-contingent was increased in intervals of 10%. Remaining transport goods that are not allocated to class C were equally allocated to the classes A and B. For each degree of knowledge restrictions 5 allocations has been evaluated. Each simulation run has been terminated after a given time period in order to measure the logistics target values. The results are presented in the next chapter.

EVALUATIONS

The figures 4 – 8 show the results for the investigation about competition-based knowledge restrictions within the DLRP. The x-axis of the figures presents the C-contingent. The y-axis of the figures presents the average values of 5 simulation runs for the particular target value.

FIGURE 4
DELIVERED TRANSPORT GOODS OVER ALL CLASSES

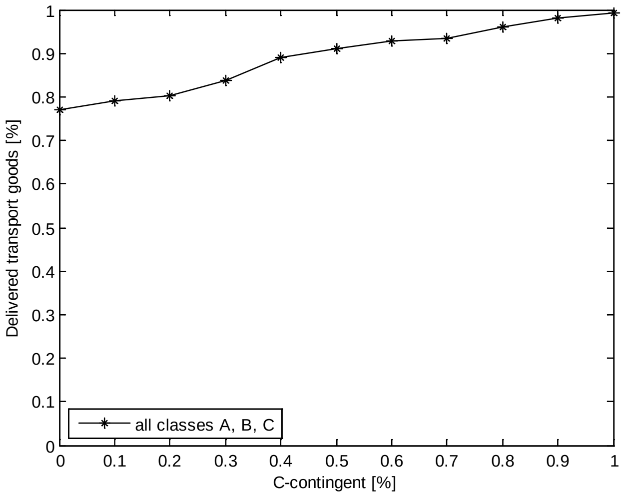
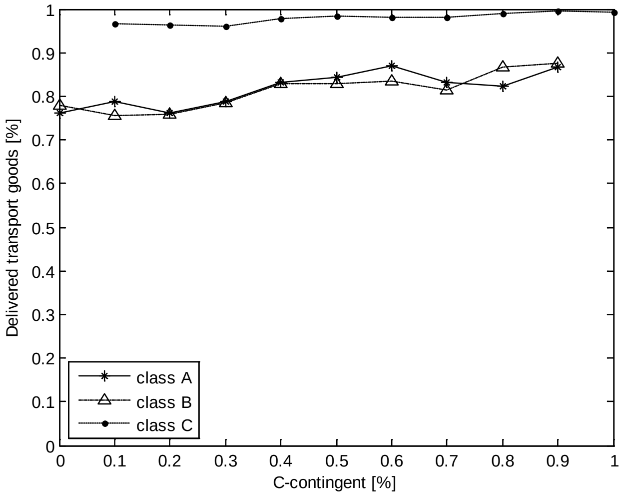


Figure 4 shows the average contingent of transport goods that can be delivered within the simulation time, regardless of the transport goods classes. The higher the C-contingent the higher is the number of delivered transport goods. At high rates for the C-contingent almost 100 % of the transport goods can be delivered. The rest of the transport goods cannot be delivered within the given simulation time. High delivery times for the remaining transport goods lead to the non-delivery within the simulation time. The reason that many transport goods at high values of the C-contingent can be delivered, is the communication of transport orders for class C to both transport vehicle classes. Transport goods of class C can be transported by every transport vehicle. In contrast to transport goods of the classes A and B, the goods of class C are not dependent from defined transport vehicles. Furthermore, the vehicle classes are able to cooperate. These aspects have positive influences on the probability that class-C transport goods can be delivered.

FIGURE 5
DELIVERED TRANSPORT GOODS FOR THE CLASSES A, B AND C



In Figure 5 the average values for the transport goods classes are compared. The line charts with lower values show the results for the classes A and B. The third line chart shows the values for the class C. It can be seen that almost every transport good of class C is delivered, regardless from the value for the C-contingent. This shows that the transport goods of class C have a high probability to be delivered. The line charts for the classes A and B show also better values at a high C-contingent. Hence, if there is a low restriction degree the probability to be delivered increases for the transport goods of the classes A and B.

FIGURE 6
DELIVERY TIME OF TRANSPORT GOODS OVER ALL CLASSES

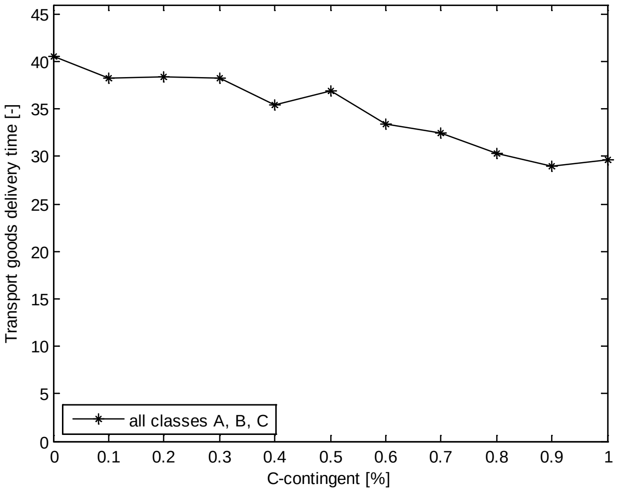
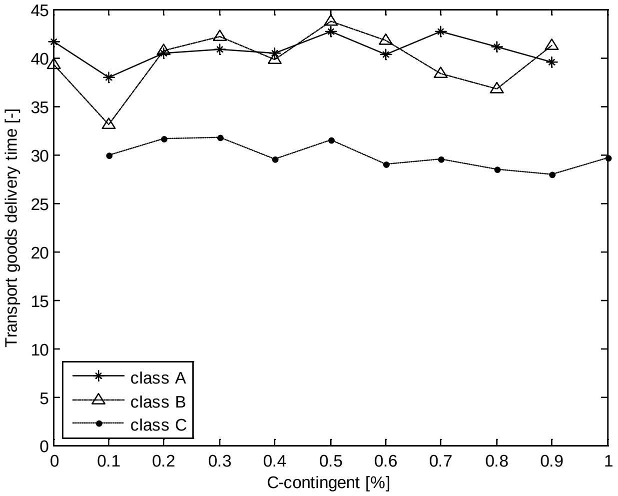


FIGURE 7
DELIVERY TIME OF TRANSPORT GOODS OVER ALL CLASSES

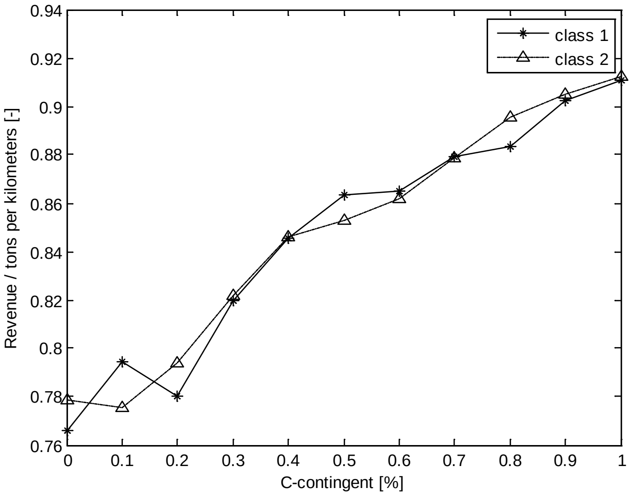


In

Figure 6 the average delivery times for the transport goods are presented. Here, the average delivery times decrease with a growing C-contingent. Regarding the delivery times for the transport goods classes A, B and C (Figure 7) it can be seen that the delivery times of transport goods of class C are lower than the delivery times for the other classes. A high C-contingent leads to lower delivery times over all transport goods.

The reason that the values for the delivery times decrease and the values for delivered transport goods increase (Figure 4) lies in the routing decisions within the DLRP: the routes for the transport goods and for the transport vehicles can be planned in a more effective manner if full knowledge is available.

FIGURE 8
REVENUE / TRANSPORT GOODS PER LENGTH UNIT
FOR THE PARTICULAR TRANSPORT VEHICLES CLASSES



An important value to evaluate the influences for the transport vehicle classes is the ratio between the revenue and the effort. Revenue is gained for delivered transport goods. The effort is regarded as transported goods per length unit which can be indicated as tons per kilometer. Figure 8 shows the ratio of the two target values. It can be seen that the ratio for the two classes 1 and 2 increases with a growing C-contingent. This finding correlates with the target values for the transport goods. Low delivery times lead to low costs whereas a high contingent of successfully delivered transport goods increases the profit. These effects can be realized if transport orders are communicated to all transport vehicle classes.

CONCLUSION

The results show that a high degree of competition-based knowledge restrictions has negative influence on the logistics target values, for all logistics entities within the DLRP as well as for the particular classes. When the logistics entities are able to exchange full knowledge about transport orders, better values can be achieved. In the future several investigations about the influences of competition-based knowledge restrictions will be performed. Especially the influences of unequal allocations of transport goods to different supplier are subject to further research.

ACKNOWLEDGEMENT

This research was supported by the German Research Foundation (DFG) as part of the Collaborative Research Centre 637 “Autonomous Cooperating Logistic Processes - A Paradigm Shift and its Limitations”.

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