LogDynamics
International Graduate School

Graph Transformation as a Modelling Method in Logistics

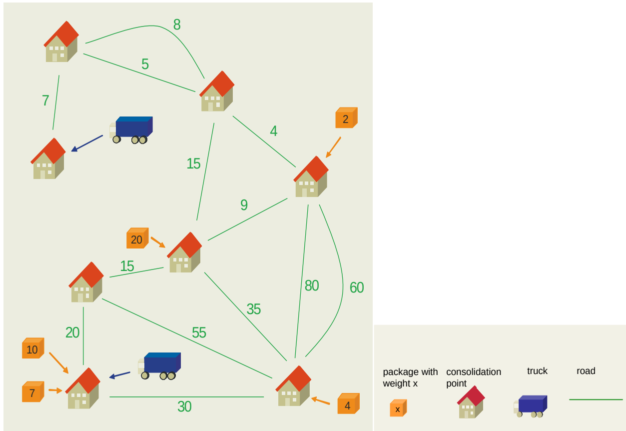
The dynamics of logistics is based on the running and interaction of logistic processes. Therefore, the modelling of logistic processes is a central issue. It is also important to verify properties, e.g., correctness of the modelled process. Graph transformation is a formal framework which offers a basis to analyse and verify properties. It is an ideal tool for modelling the dynamic behaviour of logistic systems. Graphs are very suitable for representing logistic structures and have been in use in this context for quite some time. Rule-based graph transformation can be used specifically to model processes on such graph structures. The objective of the PhD thesis is to utilize graph transformation for modelling logistic processes and to examine their properties, especially termination, as an aspect of correctness. Another aim is to exploit the benefits of parallelism in context of graph transformation.

Research

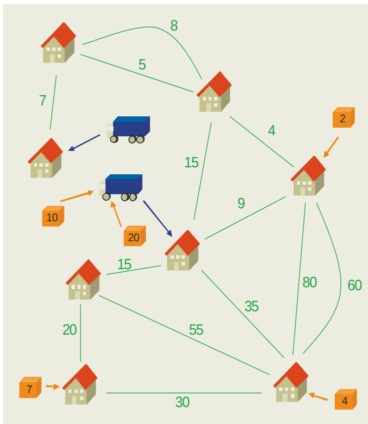
Graphs for modelling logistic data and structures
Graphs are comprised of vertices and edges and can be used to model any structures consisting of entities and the relationships between them. In the logistics environment a graph can represent, e.g., a roadmap with trucks and packages located at consolidation points. Trucks and packages as well as consolidation points are modelled as vertices; the connections between consolidation points (e.g. roads) as edges.

Graph transformation for modelling dynamic logistic processes
Graphs can be transformed by rules, which may either delete something from the graph or add something. Rules can be seen as atomic actions. Given a set of rules, a graph can be transformed by sequential application of rules of the set. Every such sequence of rule applications models a process taking place in the environment.

Figure 1: Modelling transport of packages:



Truck loads package at consolidation point and…



…drives to another consolidation point and loads another package

Transformation units for modelling logistic entities

A transformation unit applies rules in a controlled way. It consists of a set of rules, a so-called control condition to steer the application of the rules and the possibility to describe permitted initial and terminal graphs. It transforms initial graphs to terminal ones by iterated rule application within the bounds set by the control condition.

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There are various sorts of control conditions. The thesis deals with regular expressions extended by an operator called as long as possible. With this sort of control condition one can describe sequential application, choices in application, arbitrary iterative application and iterative application ‘as long as possible’.

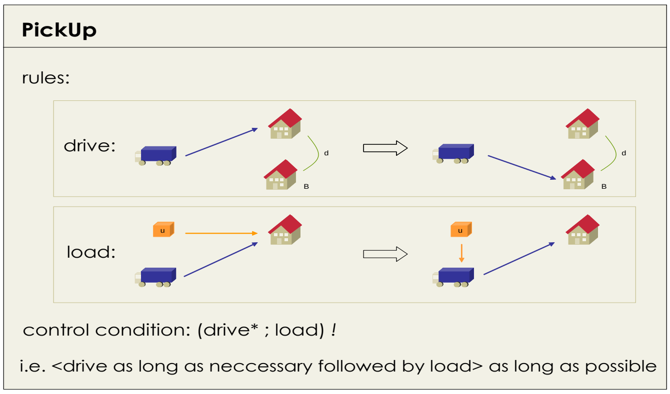

Figure 2: Transformation unit PickUp

1. Examination of the above mentioned control condition with respect to properties and parallelism.

Developing proof methods to ensure properties of the modelled processes:
One crucial property is correctness: Does the transformation unit do what it should do? In practice correctness is often not verified, but merely tested for a set of cases. This is done because the modelling methods do not provide a formal framework and verification is very expensive. But testing could never cover all the possible cases and a certain uncertainty remains as to whether the model works correctly in all situations. In practise, insufficient verification can lead to costly errors and failures which are time consuming to repair. One aspect of correctness is termination: Does the computation of the process terminate?

It was shown that termination of graph transformation systems in general is undecidable. But one can find special cases where termination can be proved. The problem is that there could be infinitely many processes. However, those processes which respect the control condition often share similarities and so some could be subsumed. The idea is to analyse the structure of the control condition and to deduce possible subsumptions in order to get a finite set of processes to be considered. This enables predictions about termination at least for special cases.

Examination of parallelism
Parallel execution saves time in comparison to sequential execution (provided one does real parallel computation). The expenditure of time could in some cases be reduced from exponential to polynomial, i.e. from practically inexecutable to executable. The intent is to implement an operator for parallel rule application at control condition level. In order to apply this operator, one has to analyse the possibilities of parallel rule application, since not all rules can be applied in parallel. Therefore a tool will be developed to analyse these possibilities automatically.

2. Modelling logistics problem-solving algorithms with graph transformation.

In logistics there is a paradigm shift from centralized control to decentralized decision making. The concept of transformation units supports this idea in a very appropriate way. One task of the PhD thesis is to model graph transformational algorithms to solve logistic problems with regard to this new view. In doing so, static problems, e.g. combination of shortest path algorithms with heuristic functions, and dynamic problems, e.g. adaptation of a planned route to changes in the environment, should be considered.

Outcome

In logistics, planning and rescheduling of transport processes is a central issue. Especially rescheduling has to be done on demand and therefore in real time. Non-termination of the rescheduling process and errors would have expensive consequences, which can be avoided by proving respective properties of the modelled rescheduling process.

Computers are ubiquitous – and therefore computer science is ubiquitous as well. As graph transformation is a universal modelling method, the results of the thesis will be applicable in various fields where processes are considered.

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