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RFID-Based Intelligent Logistics for Distributed Production Networks

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Presentation Outline

- Introduction
- Proposed Schema
- Case Study & Prototype
- Dynamic Transportation Problem
- Implementation Details
- Conclusions
- Future Work

SPIIRAS

Russian Academy of Sciences

- Founded in 1724
- The research umbrella organization of the Russian Government
- Members of the Academy: Academicians – 458; Corresponding Members - 686
- 363 units (Research Institutes and Centers)
- 116,500 personnel: 55,100 Researchers (10,000 D.Sc., and 26,000 Ph.D.)

SPIIRAS

- SPIIRAS: St.Petersburg Institute of Informatics and Automation of the Russian Academy of Sciences
- Founded in 1978
- Only 1 Russian Academy of Science Institute operating in Northwest Russia in Computer Science discipline
- 210 Personnel: 167 Researchers (29 D.Sc., and 56 Ph.D., 32 Ph.D. students)
- Grants Ph.D and Dr.Sc. degrees

- URL: www.spiiras.nw.ru

CAIS Laboratory: Recent European Grants & Projects

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- IMS-NoE – Intelligent Manufacturing Systems (European Community – Research Program on Information Society Technologies, 2003-2006, – project IST-2001-65001).
- Knowledge Supply for Regional and Inter-Regional Networks of Small and Medium-Size Enterprises (Swedish Foundation for International Cooperation in Research and Higher Education, 2003-2006)
- Information Modelling for Multi-Lingual System Development Across the Extended Enterprise and Multi-Agent Systems (Engineering and Physical Sciences Research Council, UK, 2003-2005)

CAIS Laboratory: Current International Grants & Projects

- ILIPT - Intelligent Logistics for Innovative Product Technologies. Project IST-2002-507592. European Community – Research Program on Information Society Technologies, 2004-2006.
- Knowledge Supply for Regional and Inter-Regional Networks of Small and Medium-Size Enterprises. Grant no. IG 2003-2040. Swedish Foundation for International Cooperation in Research and Higher Education, STINT, 2003-2007

CAIS Laboratory: Selected Current Russian Grants & Projects

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- Methodological and mathematical basis of building context-driven intelligent decision support systems in an open information environment (Russian Foundation for Basic Research, 2005-2007 - project 05-01-00151)
- Theoretical Foundations and Context-Driven Decision Support Systems in Distributed Information Environment (Department of Information Technologies and Computational Systems of Russian Academy of Sciences – Research Program on Fundamental Basis of Information Technologies and Systems, 2006-2008, - project 1.9)
- Context-Driven Methodology of Distributed Systems Development for Intelligent Decision Making Support in Open Information Environment (Presidium of Russian Academy of Sciences – Research Program on Mathematical Modeling and Intelligent System, 2004-2006 - project 16.2.44)

CAIS Laboratory: Current And Recent Collaboration with Industrial Partners

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- Festo
  - Ontology-Based New Order Code Generation for Corporate Product Data Management System (Festo, Germany, 2005-2008)
  - Ontology-Based Intelligent Access to Documents and Catalogues (Festo, Austria-Germany, 2003-2005)
- Ford
  - Ontology Modeling and Knowledge Integration for Supply Chain Management and Product Lifecycle Management (Ford Research Lab, Dearborn, USA, 2001-2007)
  - External Logistics Network Configuring for Russian Assembly Plant (Ford Motor Company – Russia, St.Petersburg, Russia, 2001-2002)
  - Customer-Oriented Management of Vehicles Supply Chain Using Fuzzy Coalition Games (Ford Research Center, Aachen, Germany, 1999–2000)
  - Configuration and Optimization of Global Production Networks in Order to Improve Investment Efficiency over Total Facility Life-Time (Ford Research Center, Aachen, Germany, for 1996-1999)

CAIS Laboratory: European Commission FP6 Integrated Project "ILIPT" (1)

- ILIPT: Intelligent Logistics for Innovative Production Technologies
- Aim:
  - development of new methods and technologies to facilitate the implementation of a new manufacturing paradigm for the European automotive industry
  - this new paradigm, "the 5-day car" will approach the building of 'cars to order' in a reduced time scale
- Approx. 30 members, 15 of them are from industry
- SPIIRAS is the only Russian institute participating in EC FP6 business and manufacturing cluster

CAIS Laboratory: European Commission FP6 Integrated Project "ILIPT" (2)

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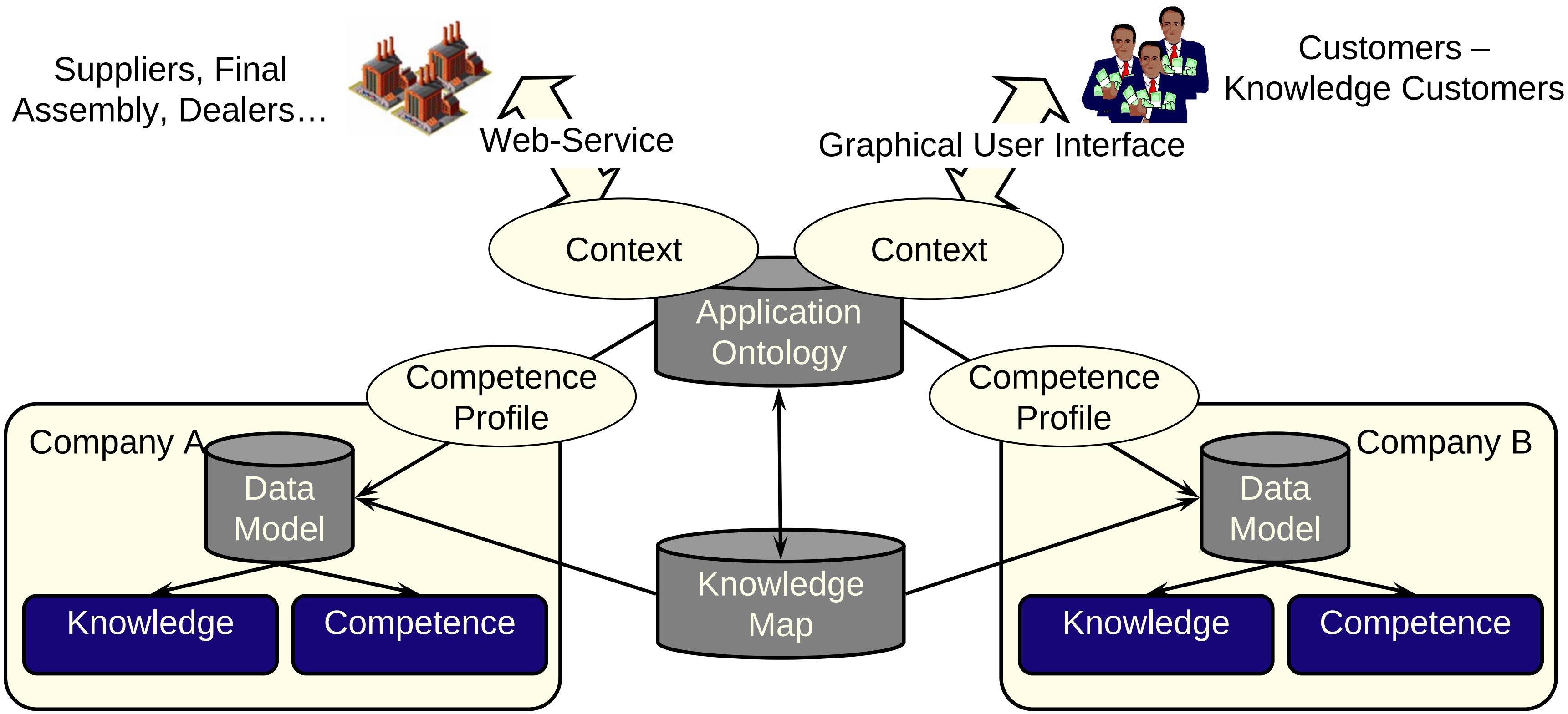
Participant . Role*	Participant Number	Participant name	Participant short name	Country	Date enter project**	Date exit project**
CO	1	THYSSENKRUPP AUTOMOTIVE AG	TKA	DE	1	48
CR	2	CLEPA - EUROPEAN ASSOCIATION OF AUTOMOTIVE SUPPLIERS	CLEPA	BE	1	48
CR	3	UNIVERSITY OF BATH	UBAH	GB	1	48
CR	4	FRAUNHOFER GESELLSCHAFT ZUR FOERDERUNG DER ANGEWANDTEN FORSCHUNG E.V.	FHG	DE	1	48
CR	5	VDI/VDE TECHNOLOGIEZENTRUM INFORMATIONSTECHNIK GMBH	VDI/VDE-IT	DE	1	48
CR	7	DaimlerChrysler AG	DC	DE	1	48
CR	8	TRW DEUTSCHLAND GMBH	TRW	DE	1	48
CR	9	SIEMENS VDO AUTOMOTIVE AG	SIEMENS VDO	DE	1	48
CR	10	SAINT-GOBAIN SEKURIT	SAINT-GOBAIN SEKURIT	FR	1	48
CR	11	LEAR AUTOMOTIVE (EEDS) SPAIN S.L.	LEAR	ES	1	48
CR	12	PLATOS PLANUNG TECHNISCH-ORGANISATORISCHER SYSTEME GMBH	PLATOS	DE	1	48
CR	13	4FLOW AG	4FLOW	DE	1	48
CR	14	DANA SPICER EUROPE LIMITED	DANA CORPORATION	GB	1	48
CR	15	THE CHANCELLOR, MASTERS AND SCHOLARS OF THE UNIVERSITY OF CAMBRIDGE	UCAM	GB	1	48
CR	16	ST. PETERSBURG INSTITUTE FOR INFORMATICS AND AUTOMATION OF THE RUSSIAN ACADEMY OF SCIENCE	SPIIRAS	RU	1	48
CR	17	UNIVERSITY OF PATRAS	UOP	GR	1	48
CR	19	TECHNISCHE UNIVERSITAET DRESDEN	TU DRESDEN	DE	1	48
CR	21	FEV MOTORENTECHNIK GMBH	FEV	DE	1	48
CR	23	FACHHOCHSCHULE NORDOSTNIEDERSACHSEN	FHNON	DE	1	48
CR	24	HELLA AUTOTECHNIK S.R.O	HAT	CZ	1	48
CR	26	PONTIFICA UNIVERSIDADE CATOLICA DO RIO DE JANEIRO	PUC	BR	1	48
CR	30	FREEGLAS	FREEGLAS	DE	1	48
CR	31	EBP CONSULT GMBH	EBP	DE	1	48
CR	32	FERROSTAAL INDUSTRIE- UND SYSTEM-LOGIK GMBH	FIS	DE	1	48
CR	33	SIEMENS AG	SIEMENS	DE	1	48
CR	34	CERAMICX IRLAND LTD	CX.I.L	IR	1	48
CR	36	BMW MOTOREN GMBH	BMW	AT	1	48
CR	37	DEBONDING LIMITED	DEBONDING	GB	1	48
CR	38	EFTEC AG	EFTEC	CH	1	48

FP6 Project ILIPT: CAIS' Task and Technological Framework

- One of the tasks: development of a common knowledge management platform to support interoperability within the "5-day car" supply chain
  - to accumulate, share, reuse and process knowledge across the "5-day car" supply chain that in turn can significantly help in increasing the supply chain effectiveness and in decreasing the lead time



Introduction: Dynamic Logistics

- Logistics management often involves such problems as creation of routing plans for a given set of vehicles available and goods to be transported
- This is quite a common problem that has a number of solving techniques
- In real life situations it is often necessary to take into account continuously changing situation
  - traffic jams
  - closed roads
  - etc.
- Dynamic logistics problems have to be solved
- Operational decision making support is required

Proposed Schema: Operational Decision Support

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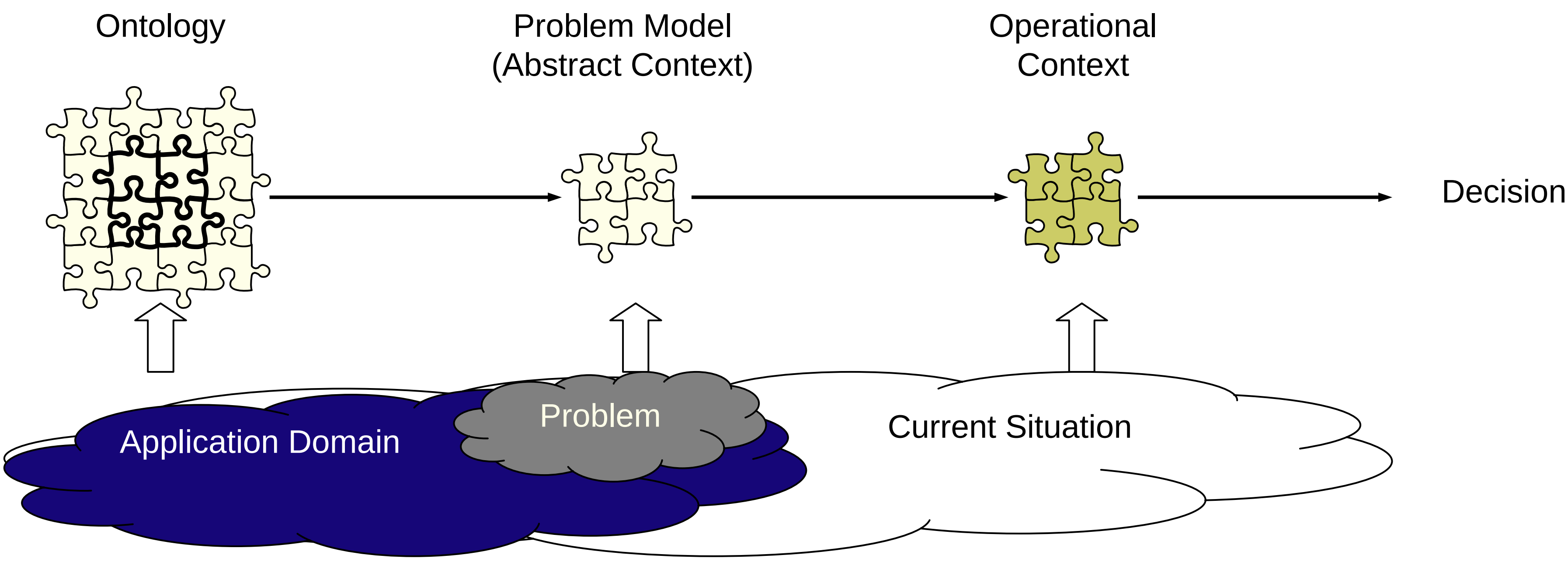
- Domain level
  - Integration of heterogeneous knowledge describing the domain knowledge
- Task level
  - Integration and formalization of tasks and problem-solving methods
- Context level
  - Integration of information and knowledge relevant to the problem or situation



Proposed Schema: Ontology and Context

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- Ontology
  - an explicit specification of a structure of a certain domain
  - provides a vocabulary for representing and communicating knowledge about some topic, and a set of relationships and properties that hold for the entities denoted by that vocabulary
    - Foundation for Intelligent Physical Agents (FIPA), www.fipa.org
- Context
  - any information that can be used to characterize the situation of a component, where a component can be a person, place, physical or computational object
  - For problem solving “context is what constraints a problem solving without intervening in it explicitly”
    - Brézillon P., “Context in problem solving: A survey”, The Knowledge Engineering Review, vol. 14, no. 1, 1999, p. 1-34.

Proposed Schema: Central Ontology Example (a Fragment)

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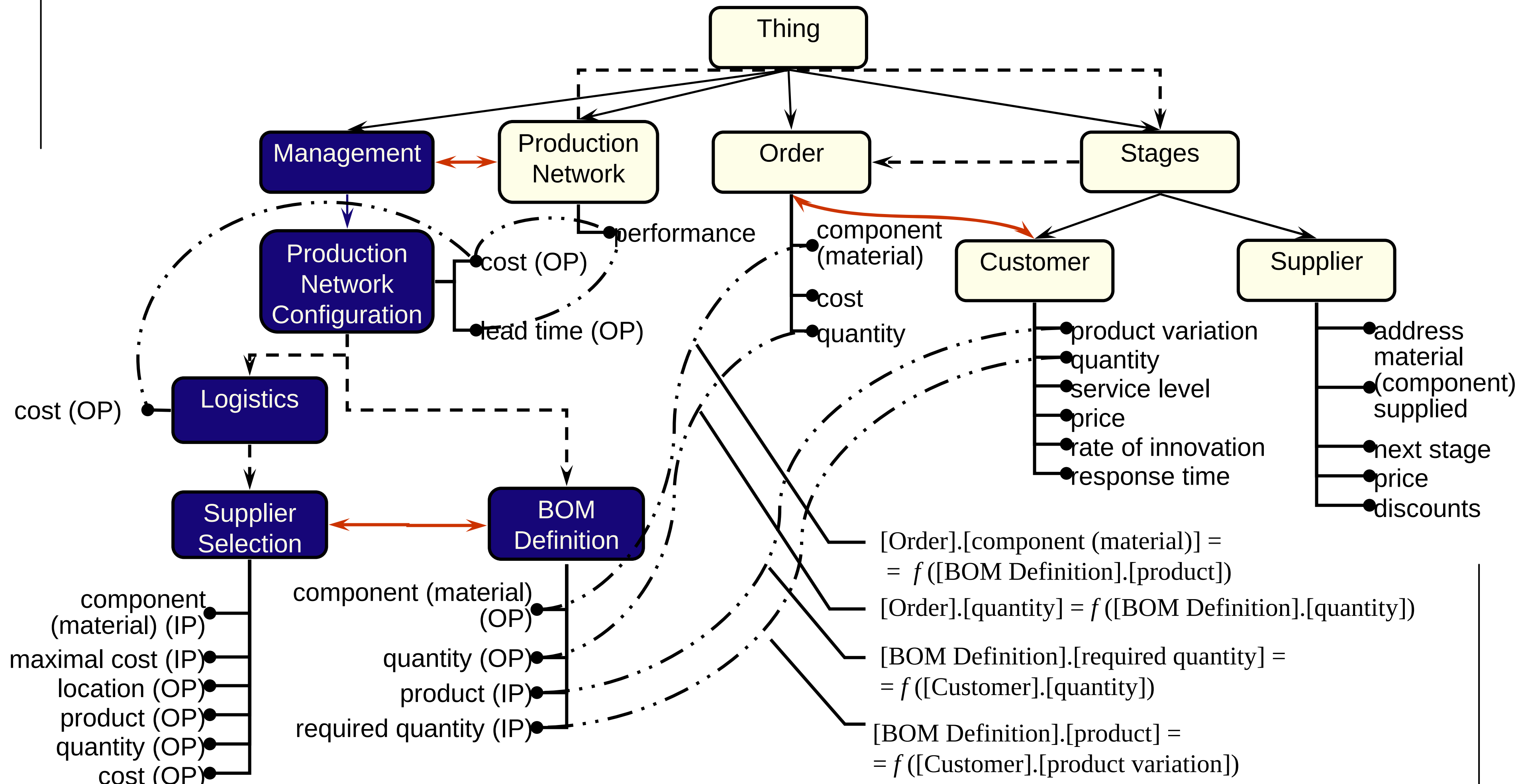

Proposed Schema: Object-Oriented Constraint Network

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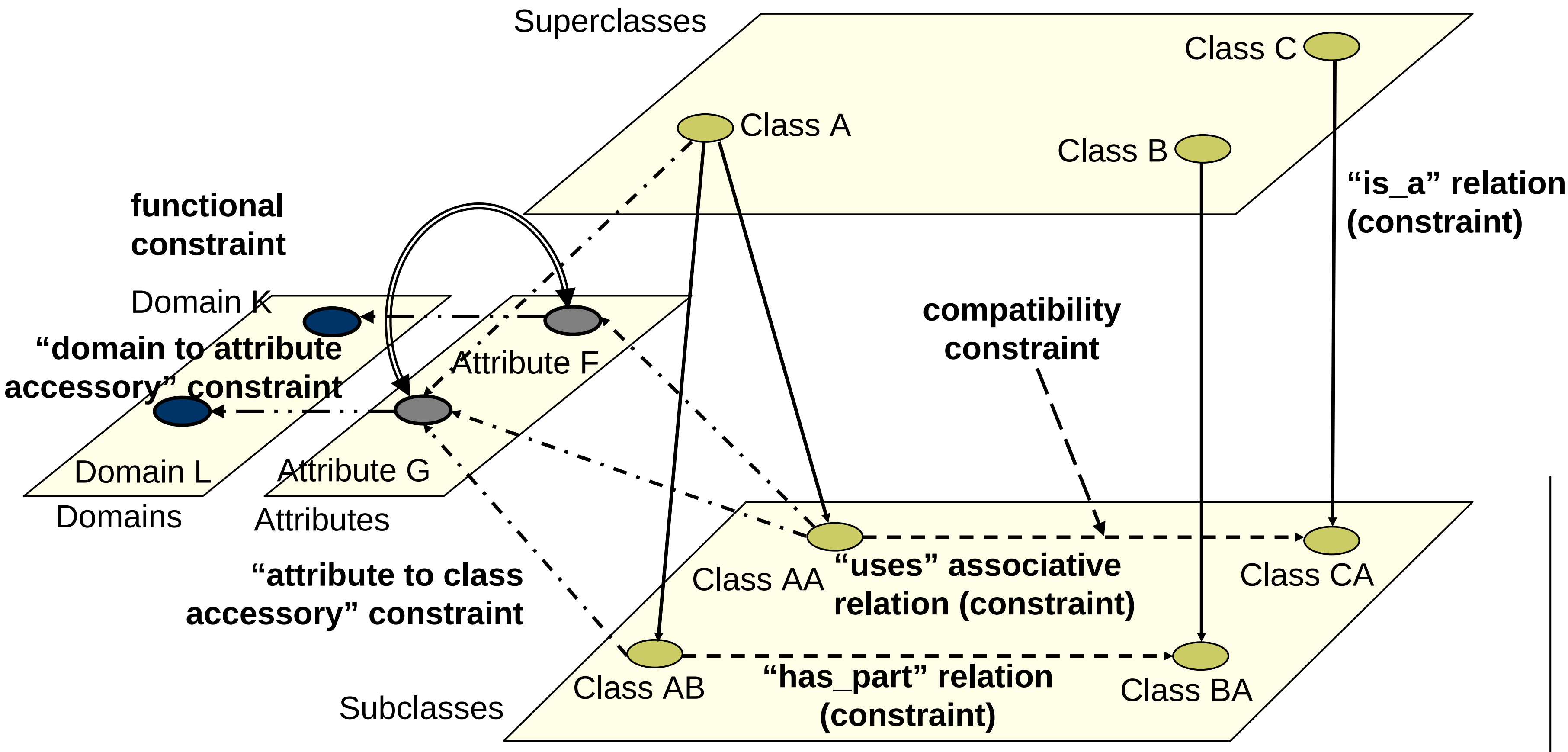
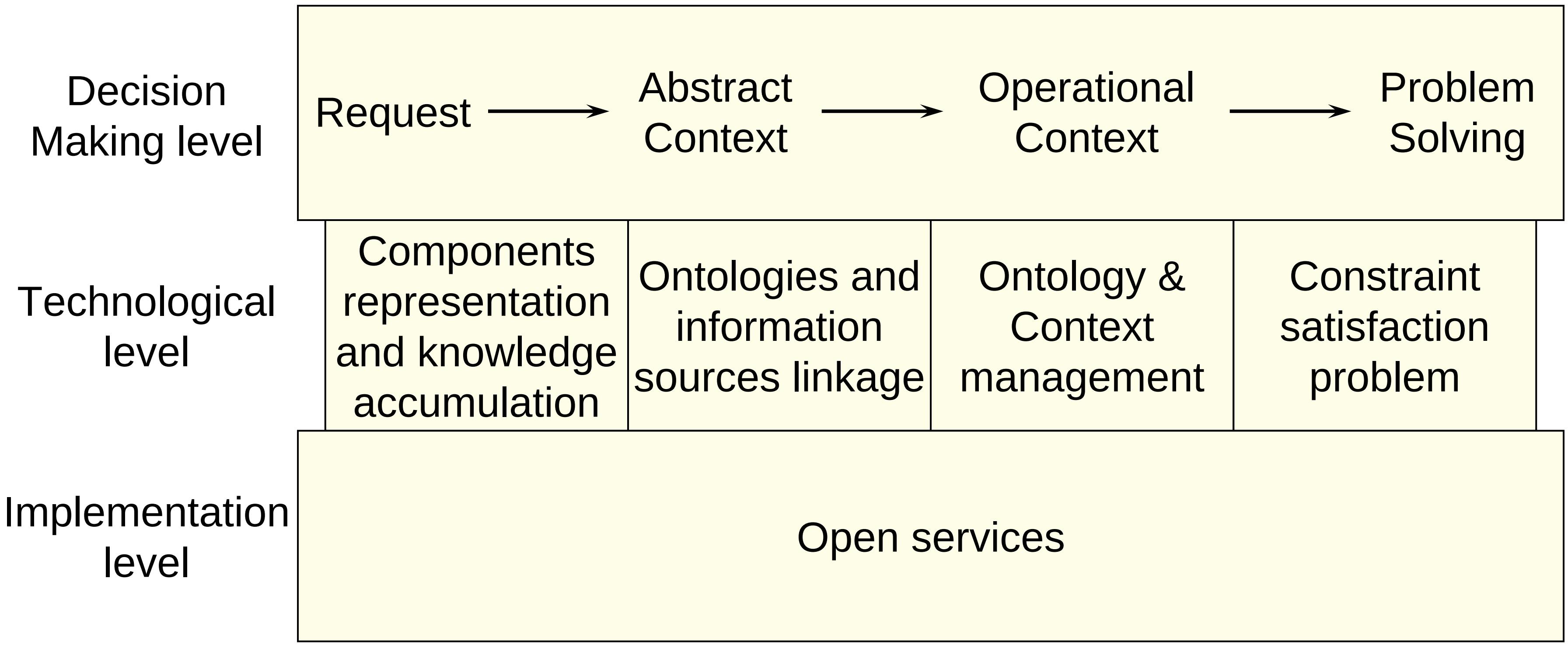


Case Study & Prototype: Integrated Framework



Case Study & Prototype: Dynamic Transportation Problem (1)

- Several vehicles in different known locations that change in time
- Central depot with a number of products (containers) to be transported
- Several warehouses with given capacities where the containers are to be transported to
- It is necessary to take into account the current situation in the area (traffic jams, closed roads, etc.) to find a feasible solution with possibly minimal time of transportation

- Though the problem seems to be simple it appears to be more complicated than it looks. For example, it can be more reasonable for one vehicle to make two or more rides instead of using two or more vehicles.

Case Study & Prototype: Dynamic Transportation Problem (2)

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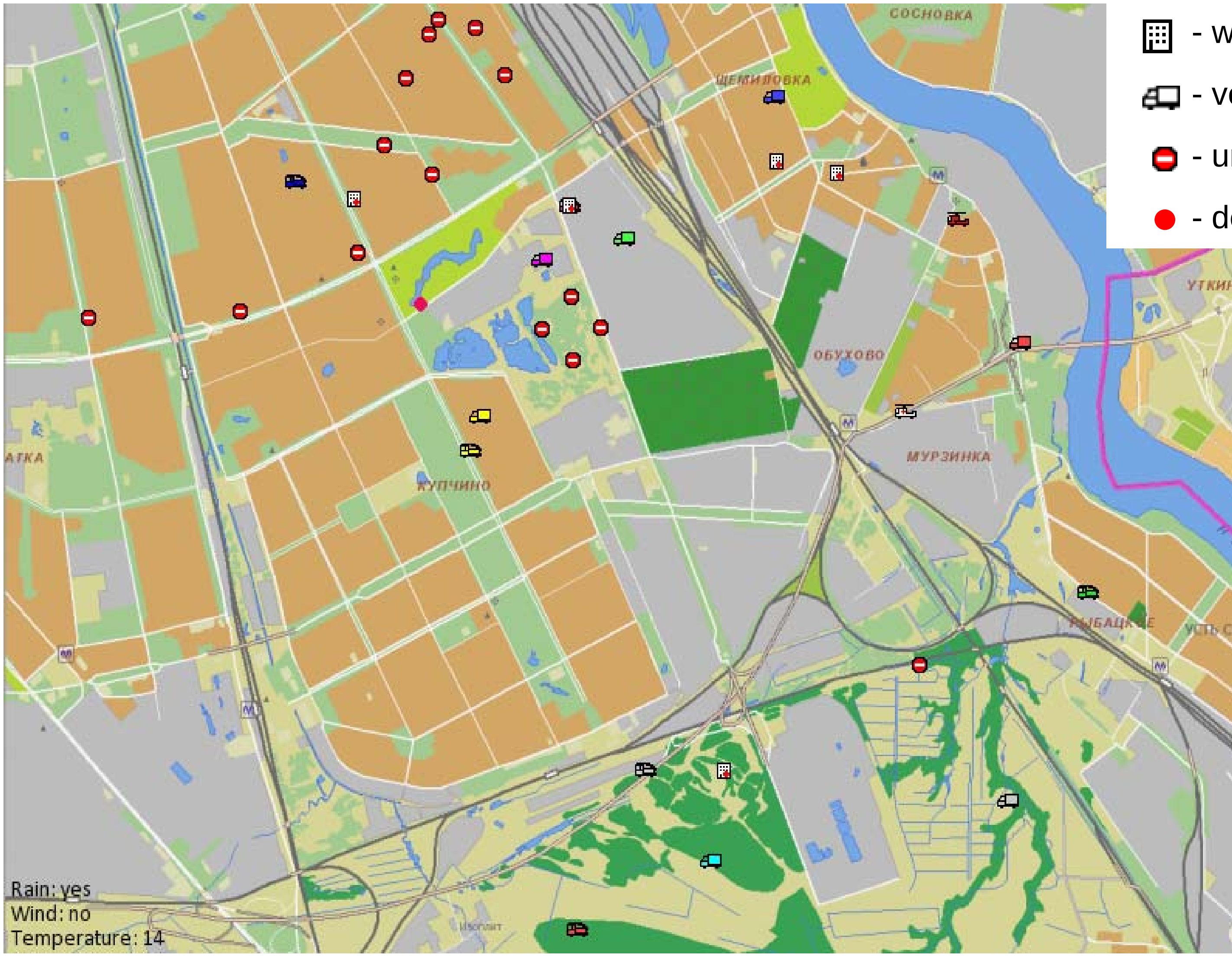

- warehouses
- vehicles
- unavailable roads
- depot location

Case Study & Prototype: Information Sources

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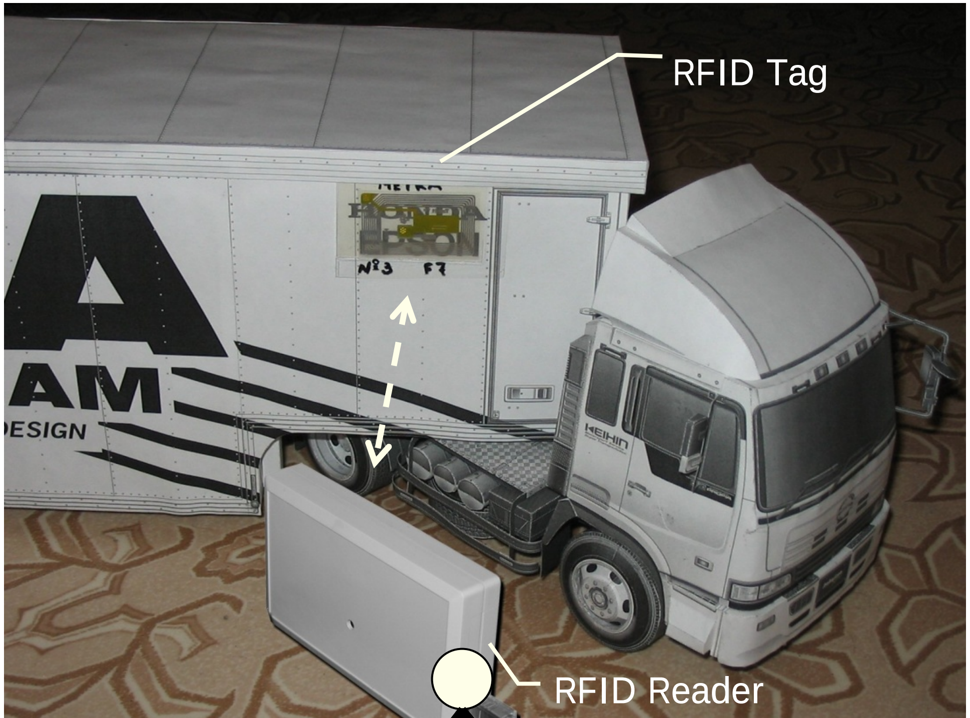
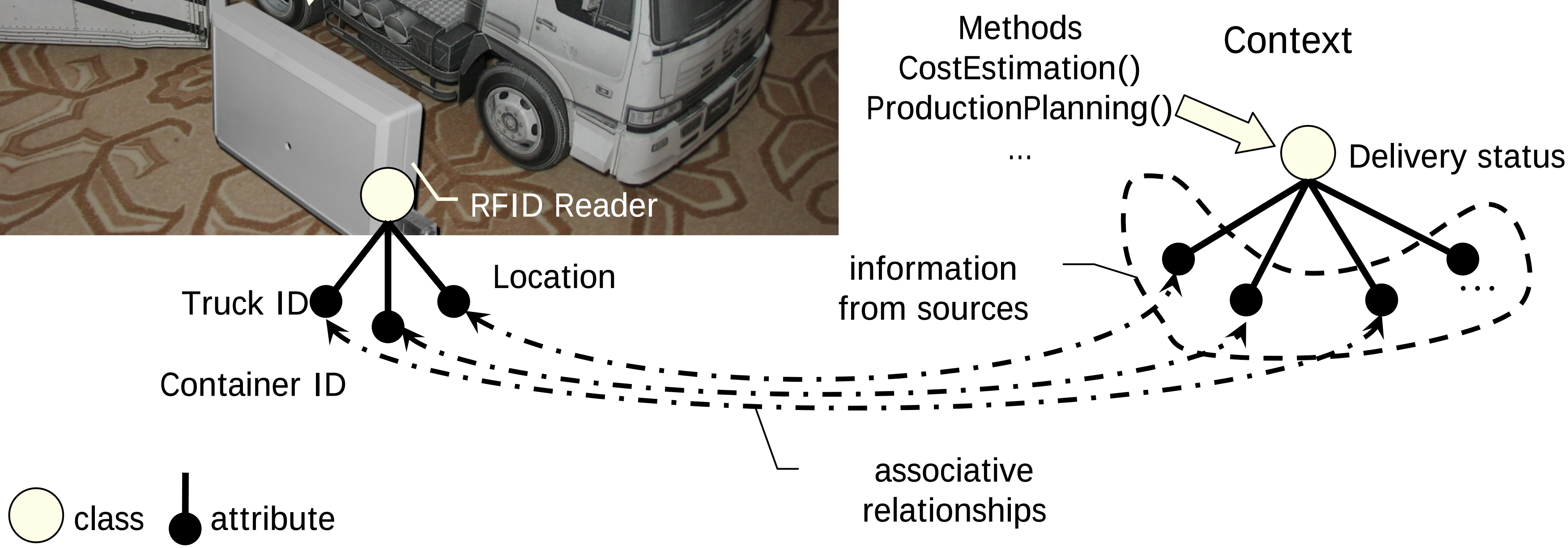
- Road network of the region provided by a geographical information system (GIS)
- Traffic situation is acquired form an Intelligent Transportation System
- Current weather conditions are provided by a weather service
- Available warehouses and their current capacities are acquired from a special directory

Case Study & Prototype: RFID Table Imitator



RFID Table Imitator: Simulated Movement of trucks

Equipped with two RFID readers ID ISC.M02 and ID ISC.PR101, and RFID tags RI-I11-112A-03.



Dynamic Transportation Problem: Formalization

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- Main variables of the problem:
  - b – vehicles ($1\ldots B$).
  - i – iterations ($1\ldots PQ$), where PQ is a number of containers to be transported
  - h – warehouses ($1\ldots H$).
- Auxiliary variables:
  - Set of Boolean variables P_{bih} (whether vehicle b transports a container at iteration i into warehouse h).
  - Auxiliary Boolean variables $i > 1$: R_{bih} defining if vehicle *b* has to return to the depot after iteration $i - 1$.
  - Auxiliary variable TE_{max} (maximal time of transportation)
- Constraints:
  - $\forall h$: $\Sigma_{bi} P_{bih} \le HC_h$ (warehouse capacity)
  - $PQ \le \Sigma_{bih} P_{bih}$ (number of transported containers should not be less than the given number of containers)
  - $\forall(b, i)$: $\Sigma_h P_{bih} \le 1$ (not more than 1 container can be transported at once)
  - $\forall(b, i_1, i_2), i_1 < i_2$: $\Sigma_h P_{bi1h} - \Sigma_h P_{bi2h} \le 0$ (iteration for a vehicle cannot take place if no containers were transported by this vehicle at the previous iteration)
  - $\forall(b, i, h), i > 1$: $\Sigma_h P_{bih} + P_{b,i\text{-}1,h} - R_{bih} \le 1$ (constraint between R and P)
  - $\forall(b, i), i = 1$: $\Sigma_h P_{bih} (AT_b + HT_{bh}) - TE_{max} \le 0$, where AT_b – time required for getting to the depot at the first time, HT_{bh} – time required for getting from the depot to warehouse *h*.
  - $\forall(b, i), i > 1$: $\Sigma_h P_{b1h} (AT_b + HT_{bh}) + \Sigma^{i}_{k=2} \Sigma_h HT_{bh} \ (P_{bih} + R_{bih}) - TE_{max} \le 0$
- Goal: minimize TE_{max} by changing P_{bih} and R_{bih}.

Dynamic Transportation Problem: Solving by Constraint Solver

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- Constraint solver: Choco (vision 2) (http://choco.sourceforge.net/)
  - free source software
  - Supports constraint solver explanation (e-CSP)
  - widely used
- Disadvantages:
  - Solving the considered problem is complex and requires special efforts for its implementation
  - Increasing problem dimensions caused significant increase of the computational time
  - Special commercial products like ILOG Dispatcher probably would allow solving it easier
- Advantages:
  - Finds optimal solutions
  - Possibility of integration with modern technologies for distributed applications development
- Conclusion: not reasonable to use for the current project

Dynamic Transportation Problem: Linearization

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- Disadvantages
  - Linearization increased the dimension of the problem
  - Increasing problem dimensions caused significant increase of the computational time
- Advantages
  - Linear programming problems can be solved analytically by specialized solvers (e.g. Excel solver, or other solvers implementing SIMPLEX method)
  - Small-sized problems are solved very quickly
- Conclusion: not reasonable to use for the current project

Dynamic Transportation Problem: Algorithm for Finding Feasible Solutions (1)

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- **Inputs**: AT_b, HT_{bh}, HC_h, PQ
  - AT_b – time required for getting to the depot at the first time,
  - HT_{bh} – time required for getting from the depot to warehouse h,
  - HC_h - warehouse capacity,
  - PQ is a number of containers to be transported

- **Result**: Transportation plan
- Initialize times required for vehicles to get to the depot from their current locations: $TimeToDepot_b = AT_b$
- For each container find the closest vehicle. This vehicle goes to the depot, picks up the container and transports it to the closest available warehouse:
  - **For each** container
    - Find the closest vehicle b_{min}
    - Find the closest available warehouse h_{min} for vehicle b_{min}
    - Update transportation plan (add to the transportation plan information that vehicle b_{min} transports container to warehouse h_{min})
    - Update times required for the chosen vehicle to get to the depot considering that the return time is the same
    - Update capacity of warehouse h_{min}
  - **End For**

Dynamic Transportation Problem: Algorithm for Finding Feasible Solutions (2)

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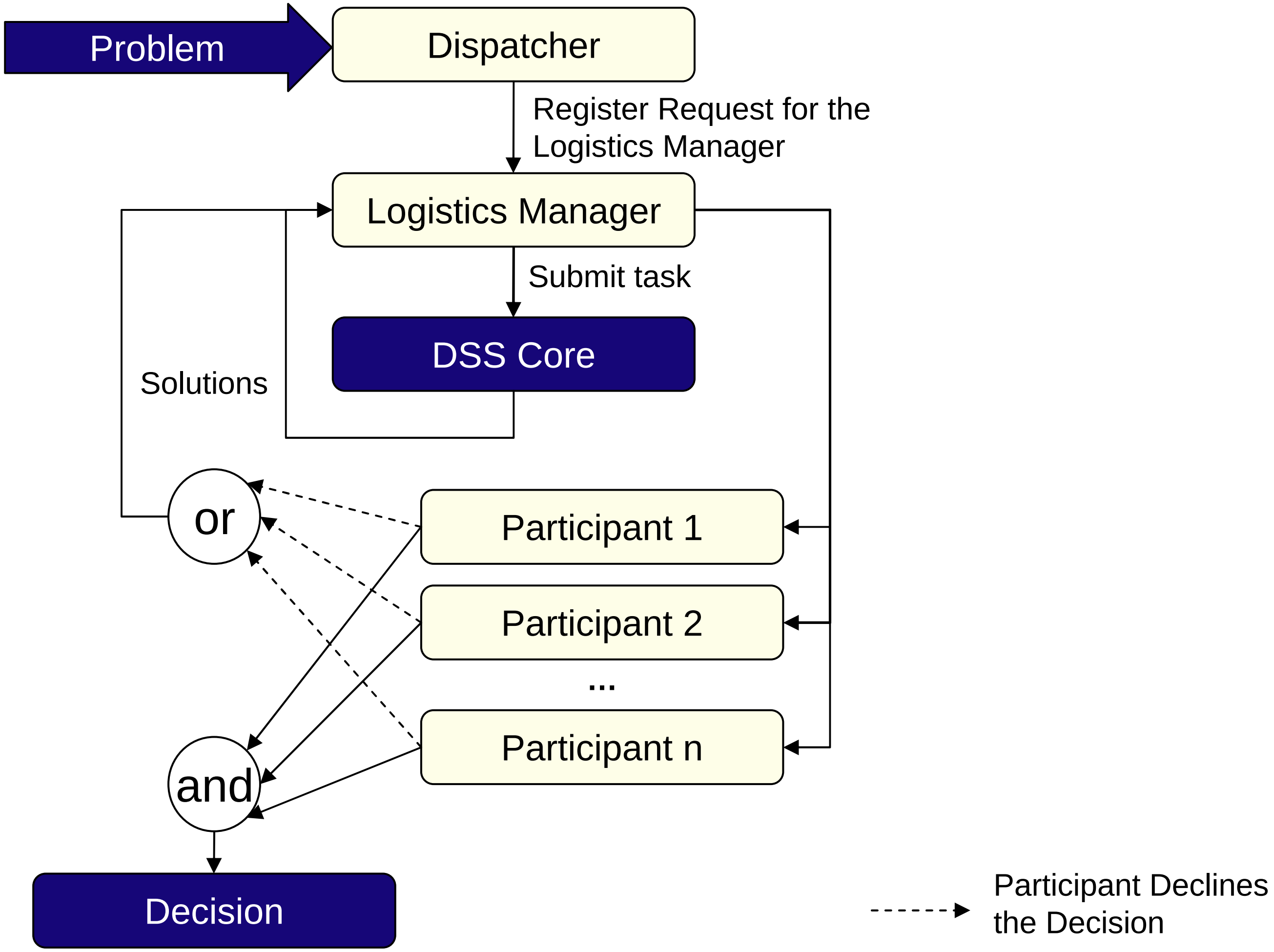
- An algorithm to solve the problem in a direct way was proposed
- Disadvantages
  - Solutions are not always optimal
  - Algorithm has narrow specialization
- Advantages
  - The algorithm is very straightforward and simple
  - Solutions are feasible, often optimal
  - Solutions are generated in a very short time
  - Time does not change significantly when the size of the problem increases (the algorithm is scalable)
- Application of the developed algorithm has been chosen in the project

Implementation Details: Types of Users and Their Interaction



Implementation Details: Prototype Architecture

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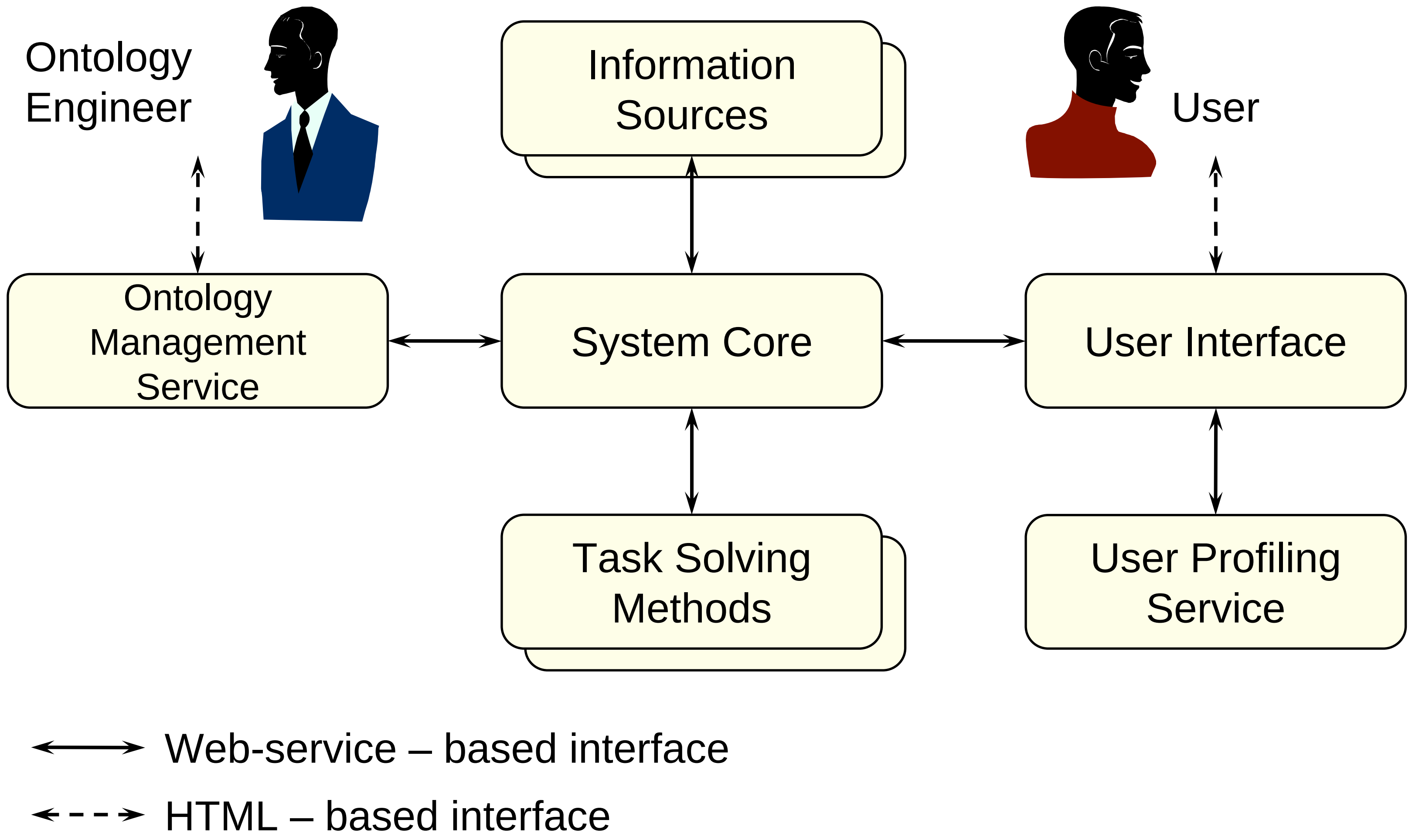

Implementation Details: Example of the Situation Presented to Dispatcher

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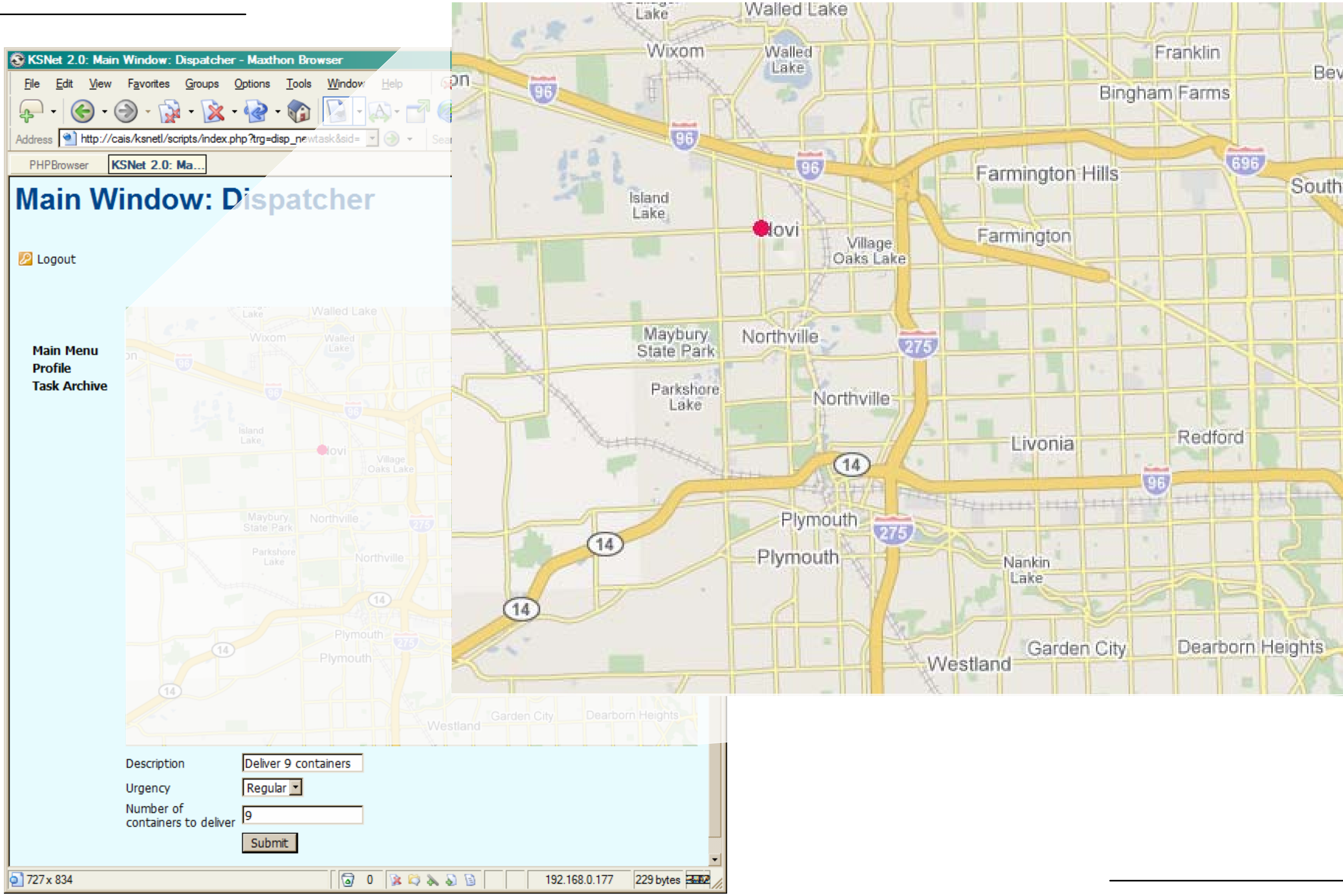

Implementation Details: Example of the Solution Presented to Logistics Manager

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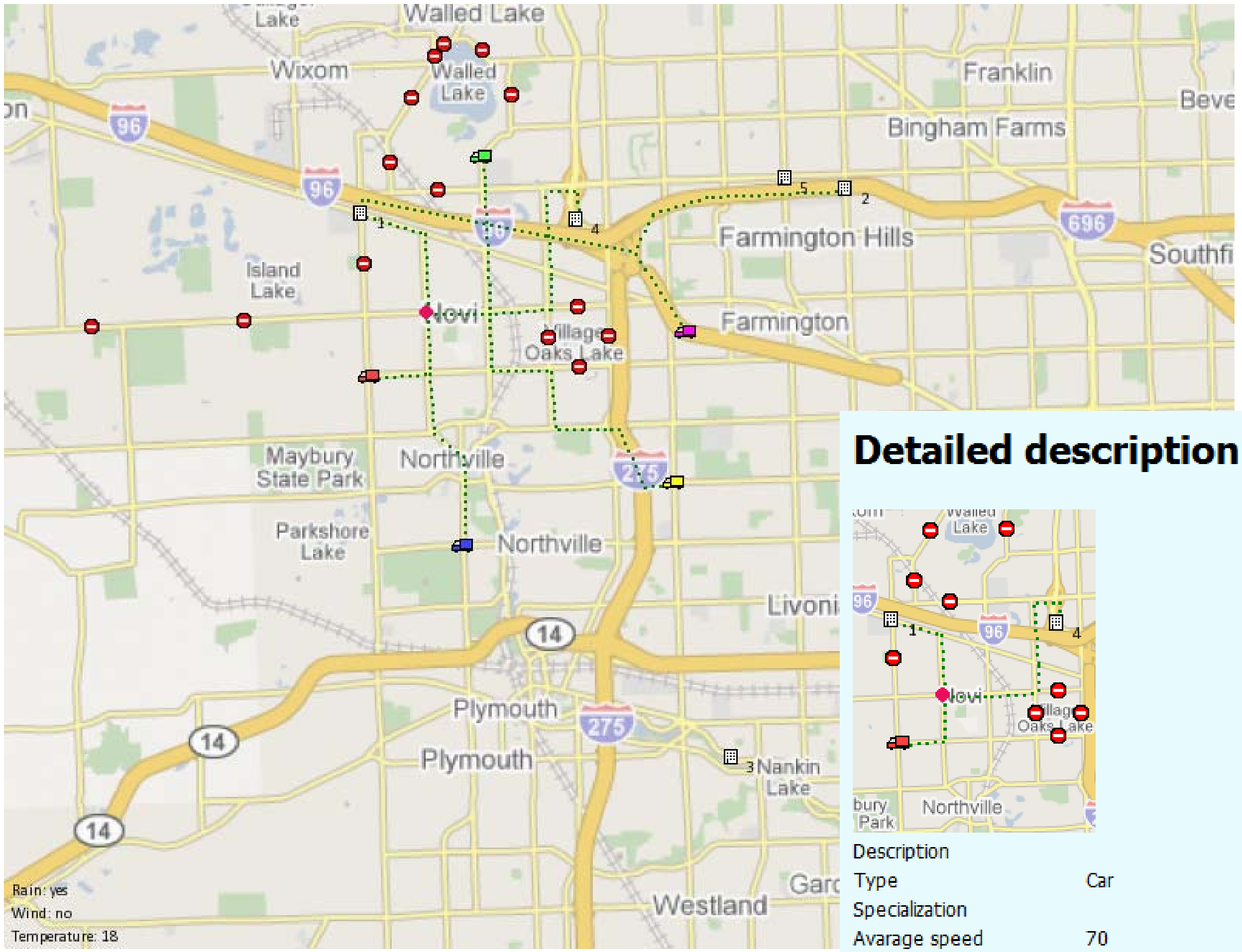
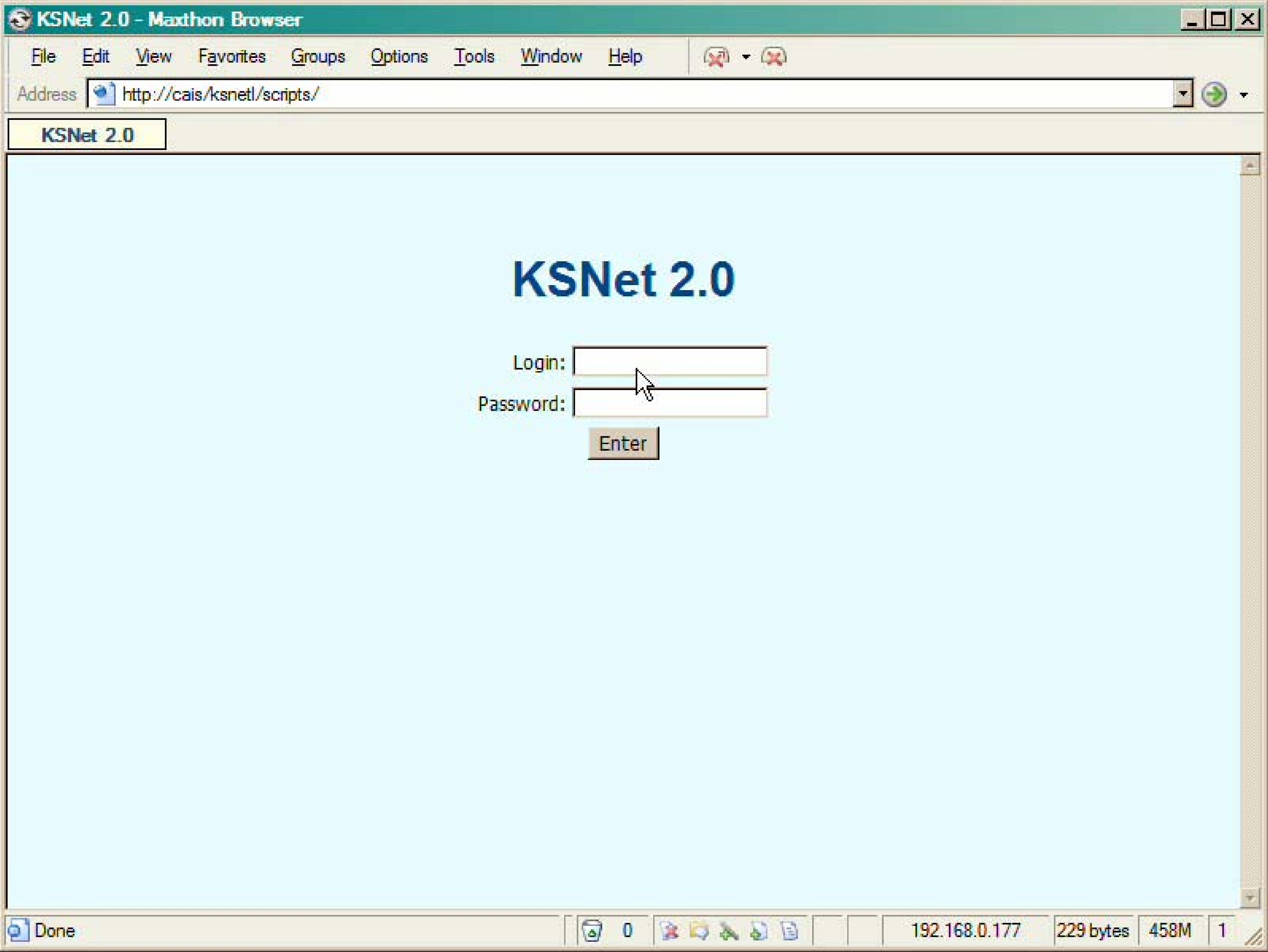


Detailed description of truck

Description	
Type	Car
Specialization	
Avarage speed	70
Cost	1500
Staff	2
Capacity	1
Path	location -> central depot -> warehouse 1 -> central depot -> warehouse 4

Implementation Details: Solution Presented to Driver

- The interface of the prototype is Web-based
- Regular Web browsers can be used for working with the system
- The drivers of the vehicles (participants) receive their assignments via Internet: they can see their routes using PDA or mobile phones


KSNet 2.0 - Maxthon Browser
File
Edit
View
Favorites
Groups
Options
Tools
Window
Help
Address
http://cais/ksnetl/scripts/
KSNet 2.0
KSNet 2.0
Login:
Password:
Enter
Done
0
192.168.0.177
229 bytes
458M
1

Conclusions

- The approach proposed assumes acquisition of information from distributed heterogeneous sources via Web services
- Web-based prototype implementation enables using existing infrastructure (e.g. mobile phones)
- RFID is a promising technology for providing actualized information into the decision support system
- The problem considered takes into account continuously changing environment and requires nearly real-time solving
- In the considered case time pressure on problem solving made it reasonable to use algorithms for finding feasible solutions instead of trying to find the optimal solution

Future Work:
Self-Organizing Networks

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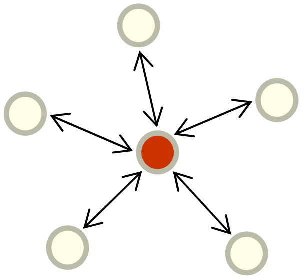
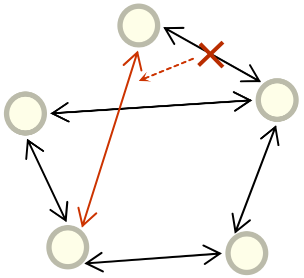
- Centralized control is not always acceptable:
  - probable damages in local infrastructure
  - different subordination of participating teams
  - etc.
- Possible failure in the core of a centralized system would cause stopping of the entire operation



- Proposed solution: organization of a decentralized self-organizing coalitions consisting of the operation members.



Future Work: Lifecycle Phases of Self-Organizing Networks

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Life cycle phase	Needs	Services
Community building (once, new members are added on a continuous basis)	Common infrastructure Common communication standards and protocols	Modelling goals and objectives Identification, qualification, registration of members Common knowledge representation Common modeling for community members
Formation (continuous, initiated by the situation, or a task as a part of the situation)	Task definition model (context) Partner selection	Task modelling Rules of partner selection
Operation (continuous)	Coordination and synchronization	Rules of re-negotiation and solution modification if necessary
Discontinuation (continuous, initiated by members)	Termination of the established agreements	Update of the current solution

Thank you!

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