Agent-oriented modeling for engineering sociotechnical systems

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Who am I?

- Name: Kuldar Taveter
- Position: Professor, Chair in Software Engineering
- Education:
  - Dip.Eng., TUT, 1988
  - M.Sc., TUT, 1995
  - Ph.D., TUT, 2004
- Work experience:
  - 1985-1989: Institute of Cybernetics
  - 1989-1993: Private companies
  - 1993-1998: Department of Informatics of TUT
  - 1997-2005: Technical Research Centre of Finland
  - 2005-2008: The University of Melbourne, Australia
  - 2008- : Department of Informatics of TUT
  - 2011 : Department of Computer Science and Engineering of SCU
- Research areas: requirements elicitation and analysis, agent-oriented modelling, fast prototyping, agent-based simulation, ontologies

Outline

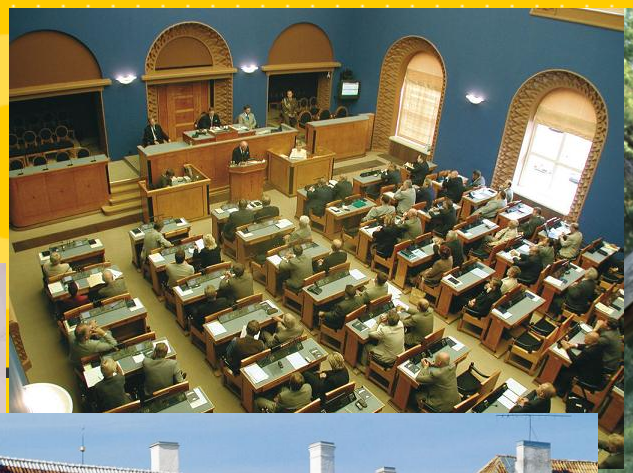
- Overview of Estonia and my university
- Agent-oriented modeling
- The application area of asymmetric threats simulation
- The application area of societal information systems
- Conclusions

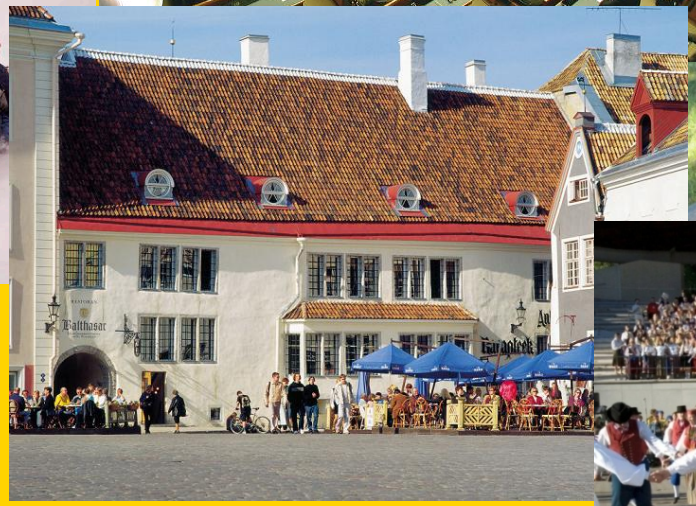
Basic Facts about Estonia

- North-East Europe
- Capital Tallinn
- Population 1,34 mio

- Area 45 000 km2, comparable to the Netherlands and Denmark
- Parliamentary republic, independence Feb 24 1918
- EU, May 1 2004
- Schengen treaty, Dec 21 2007
- Euro zone, Jan 1 2011

People and society





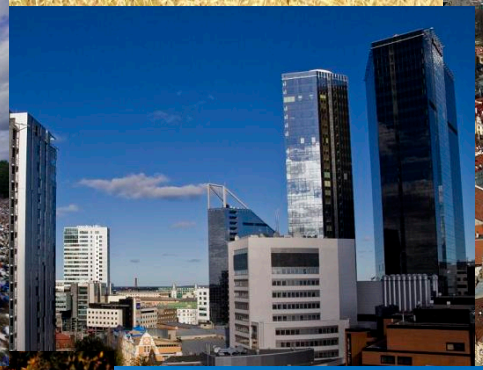
- Nordic mindset
- Peaceful and hard-working people
- Safe and stable society
- 70/30% of population native Estonian/Russian-speakers
- Foreign languages widely spoken: English, Russian, German, Finnish….
- 3 million tourists visit Estonia every year

Nature and country

- 4 seasons
- Well-preserved nature
- 1520 islands
- 1000 lakes…








e-Estonia

- Advanced IT society - free Internet access in 1100 public spots, on coaches, trains, etc.
- ID-card, e-Government, e-Taxation, e-Voting, e-School, e-Signing, e-Parking (no parking meters known!), e-Business Register, e-Land Register, e-Banking (no bank checks known!), etc.
- The headquarters of Skype lie in Tallinn
- The headquarters of the EU IT Agency will be located in Tallinn

e-Estonia

- Some 66% of the population of Estonia (1.3 million people) aged 16-74 use the internet, according to the statistical data from 2008
- 58% of the households have internet capabilities (again according to the 2008 data)
- All Estonian schools are connected to the Internet
- More than 90% of the income tax declarations are filed via the Internet
- The expenditures made by the government can be followed on the internet in REAL TIME!

NATO Cooperative Cyber Defence Centre of Excellence

CCDCOE

Cooperative Cyber Defence
Centre of Excellence
Tallinn, Estonia

Higher Education in Estonia

smartEstonia.ee

- Higher (tertiary) education is offered at **universities** and **professional higher education institutions**
- Ca 2/3 of the age group study in higher education institutions - there are **ca 68 000 students** in Estonia
- There are **8 universities** in Estonia
- All institutions have introduced a **bachelor-master (3+2) structure** for most study programmes
- Growing number of **English taught programmes** are offered, especially at Master level

Tallinn University of Technology

- Founded as an engineering college in 1918
- Acquired university status in 1936
- The second largest universityy in Estonia with about 14,200 students, 2,000 employees and with more than 54,000 graduates
- Courses taught in Estonian, English, and Russian
- International students ~5%
- 134 Bachelor's, Master's, and Doctoral degree programs
- The biggest faculty of economics and business administration in Estonia

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1918
2008

Faculties

- Civil Engineering
- Power Engineering
- Information Technology
- Chemistry and Materials Technology
- Mechanical Engineering
- Mathematics and Natural Sciences
- Social Sciences
- School of Economics and Business Administration

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Department of Informatics

- Department of Computer Mathematics (1967) → Department of Information Processing (1974) → Department of Informatics (1992)
- Faculty
  - 33 members
    - 4 professors
    - 6 associate professors
    - 6 lecturers
    - 7 assistant lecturers
    - 10 researchers
  - Qualifications:
    - PhD: 16 members
    - M.Sc.: 17 members, among them 10 PhD students

Department of Informatics: Composition

- Chair of Information Systems (ass. prof. E. Eessaar):
- Chair of Software Engineering (prof. K. Taveter)
- Chair of the Foundations of Informatics (prof. R. Kuusik)
- Chair of Knowledge-based Systems (prof. J. Tepandi)
- Chair of Information Security (prof. A. Buldas)
- Data Mining Laboratory
- Laboratory of Socio-Technical Systems
  - Evolutionary IS by agents
  - Agent-based simulation
  - Societal information systems
- Laboratory of Web Services

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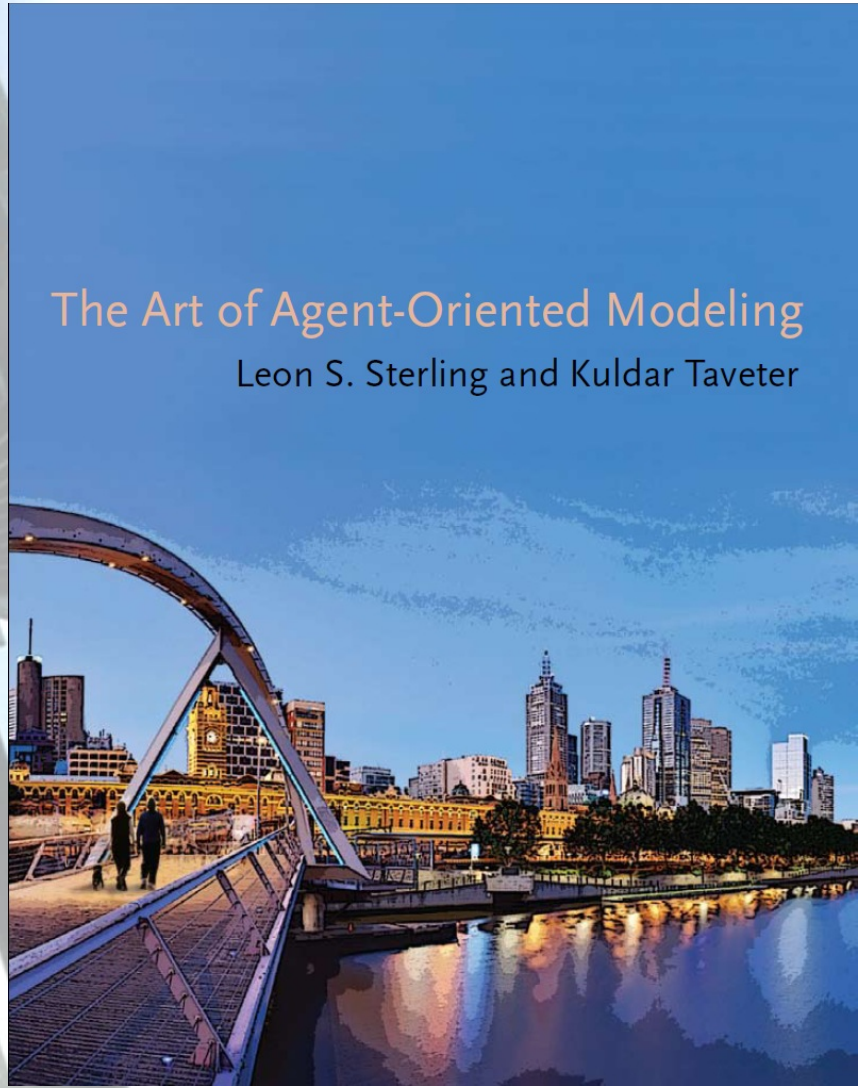
Agent-oriented modelling



The book's mission

- To address how computing can support social organizations in the environment where the computing is:
  - Pervasive;
  - Deployed over a range of devices;
  - With multiplicity of users
- Approach for engineering software systems that are:
  - Open;
  - Intelligent;
  - Adaptive

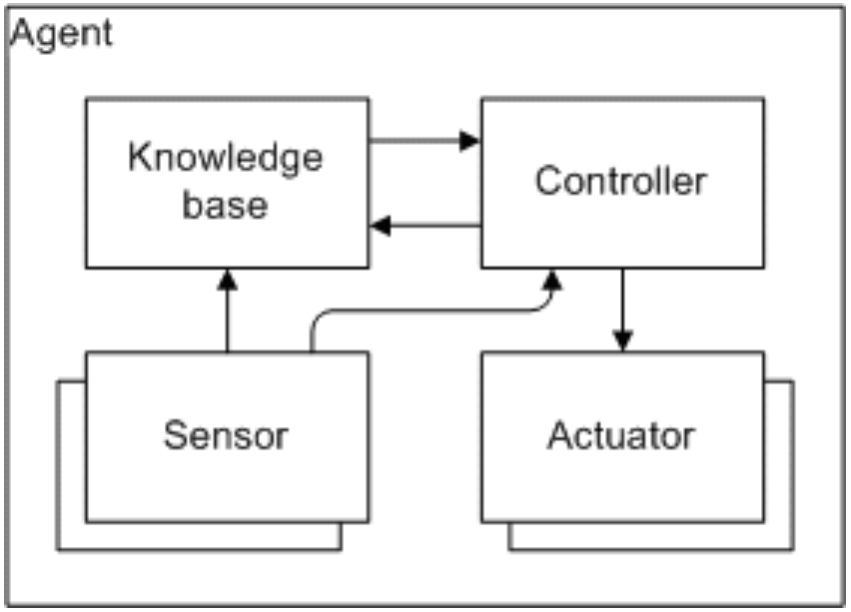
Where has it been applied?

- Designing intelligent lifestyle applications (Australia)
  - Greeting
  - Intruder detection
  - Flirting
  - Smart Music Player
  - Intergenerational play
- Designing educational applications (Australia)
- Designing prototypical multiagent system for B2B e-commerce (Finland)
- Designing simulation systems for:
  - Manufacturing (Estonia)
  - Aircraft turnaround (Australia)
  - Asymmetric warfare in Afghanistan (European Defense Agency)
- Designing societal information systems (USA)
  - Grocery shopping
  - U.S. Healthcare

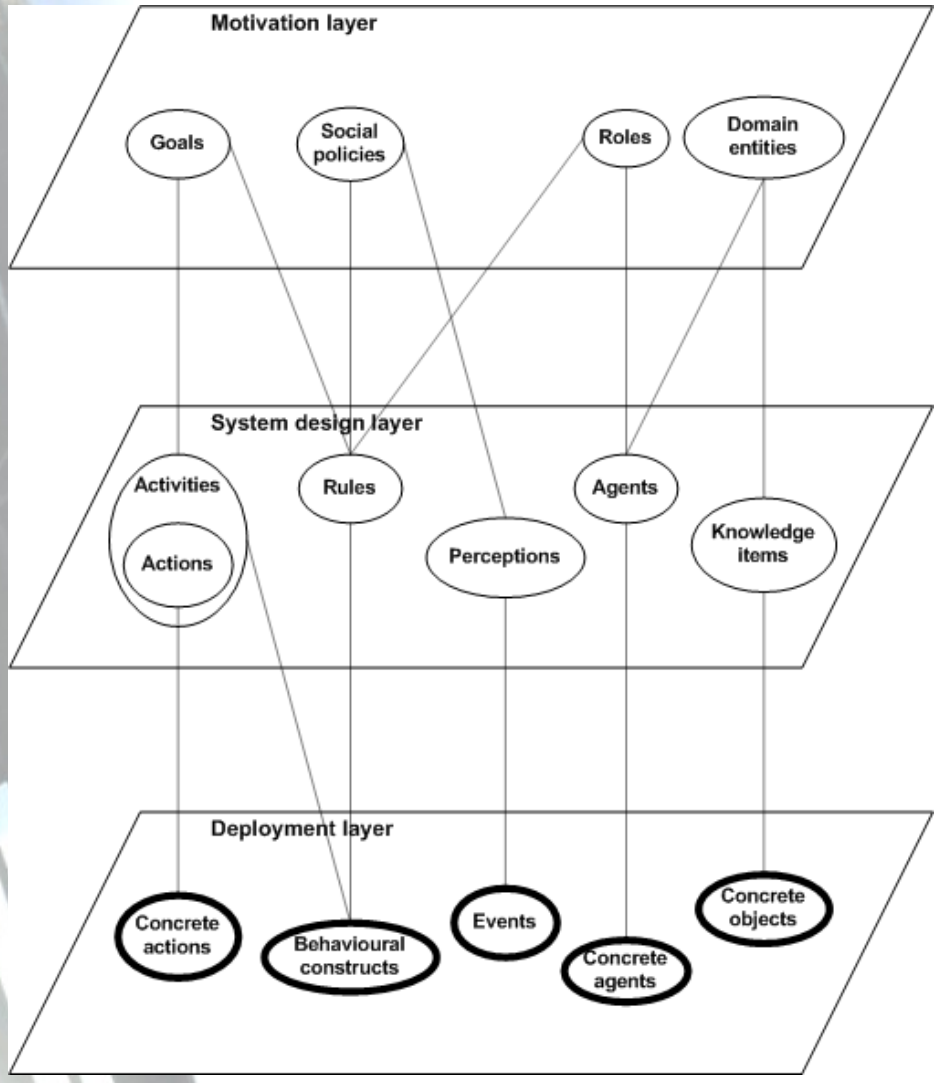
The “agent” metaphor

- An active entity as opposed to a passive entity
- An entity that can act in the environment, perceive events, and reason
- An entity that acts on behalf of someone or somebody

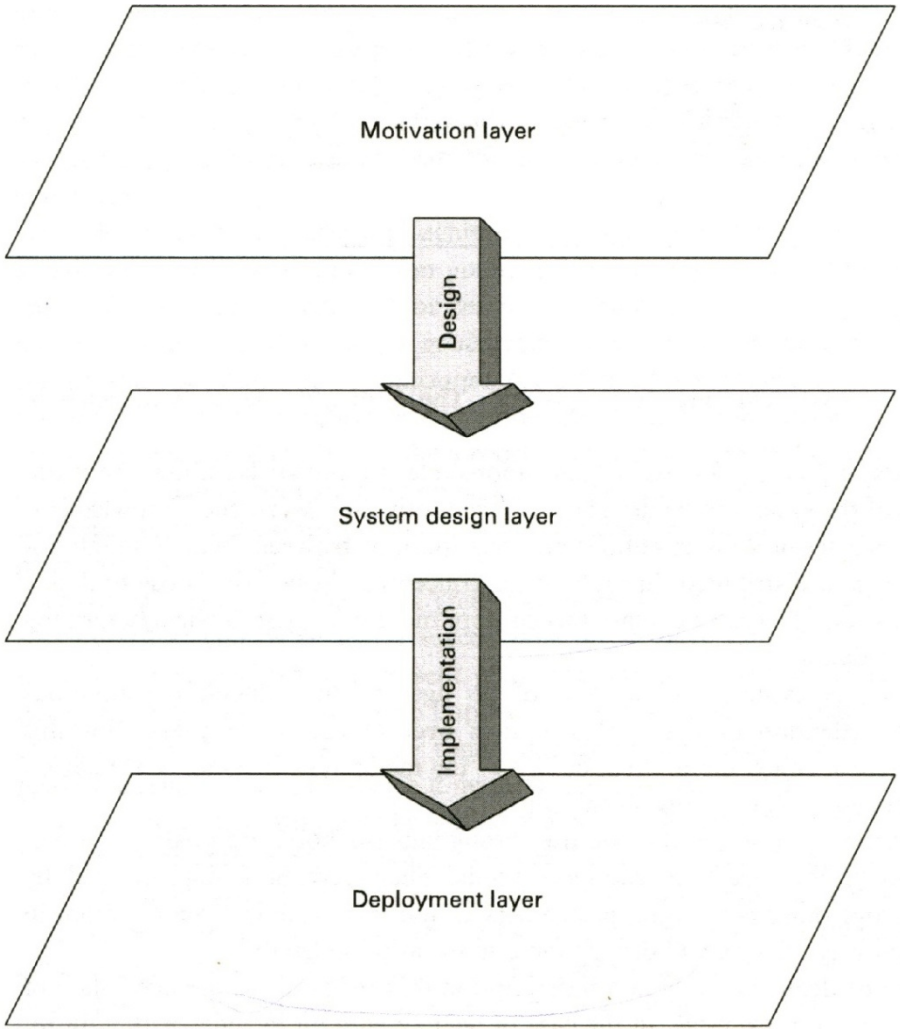
The abstract agent architecture



Concepts of AOM



From models to implementations



Model types of AOM

Viewpoint models	***Viewpoint aspect***		
Abstraction layer	*Interaction*	*Information*	*Behavior*
Conceptual domain modeling	Role models and organisation models	Domain models	Goal models and motivational scenarios
Platform-independent computational design	Agent models and acquaintance models, interaction models	Knowledge models	Scenarios and behavior models
Platform-specific design and implementation	Agent interface and interaction specifications	Data models and service models	Agent behavior specifications

Mapping Prometheus to viewpoint framework

Viewpoint models	***Viewpoint aspect***		
Abstraction layer	*Interaction*	*Information*	*Behavior*
Conceptual domain modeling	Analysis Overview Diagram, System Roles Diagram		Goal Overview Diagram, Initial Role Descriptors, Scenarios
Platform-independent computational design	Agent Acquaintance Diagram, Interaction Diagrams, Protocol Diagrams, System Overview Diagram	Knowledge Coupling Diagrams	Agent Descriptors
Platform-specific design and implementation	Event Descriptors	Data Descriptors	Agent Overview Diagrams, Process Specifications, Capability Overview Diagrams

Mapping Tropos to viewpoint framework

Viewpoint models	***Viewpoint aspect***		
Abstraction layer	*Interaction*	*Information*	*Behavior*
Conceptual domain modeling	Actor Diagram	Actor Diagram	Goal Diagrams
Platform-independent computational design			Refined Goal Diagrams
Platform-specific design and implementation	Agent Interaction Diagrams	UML Class Diagrams	Capability Diagrams, Plan Diagrams

Mapping MaSE to viewpoint framework

Viewpoint models	***Viewpoint aspect***		
Abstraction layer	*Interaction*	*Information*	*Behavior*
Conceptual domain modeling	Sequence Diagrams, Role Model		Goal Diagram, Use Cases, Role Model
Platform-independent computational design	Protocol Diagrams, Agent Class Diagram		Concurrent Tasks, Agent Class Diagram
Platform-specific design and implementation			Plan Diagrams, Deployment Diagrams

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Modeling and simulation of asymmetric threats in urban environment

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Two lines of work

- Modeling and simulation of asymmetric threats in military operations
- Modeling and simulating how “hearts and minds” of people can be won by conflict resolution

Motivation

- How to create practical training scenarios for crisis management and military operations?
  - A trainee is acting in a simulated environment that consists of agents and objects
  - The environment has asymmetric threats
- How to design such environments?

Solution

- Modelling
- Simulation
  - Standalone or human-in-the-loop;
  - Varying with latencies of simulated exogeneous events

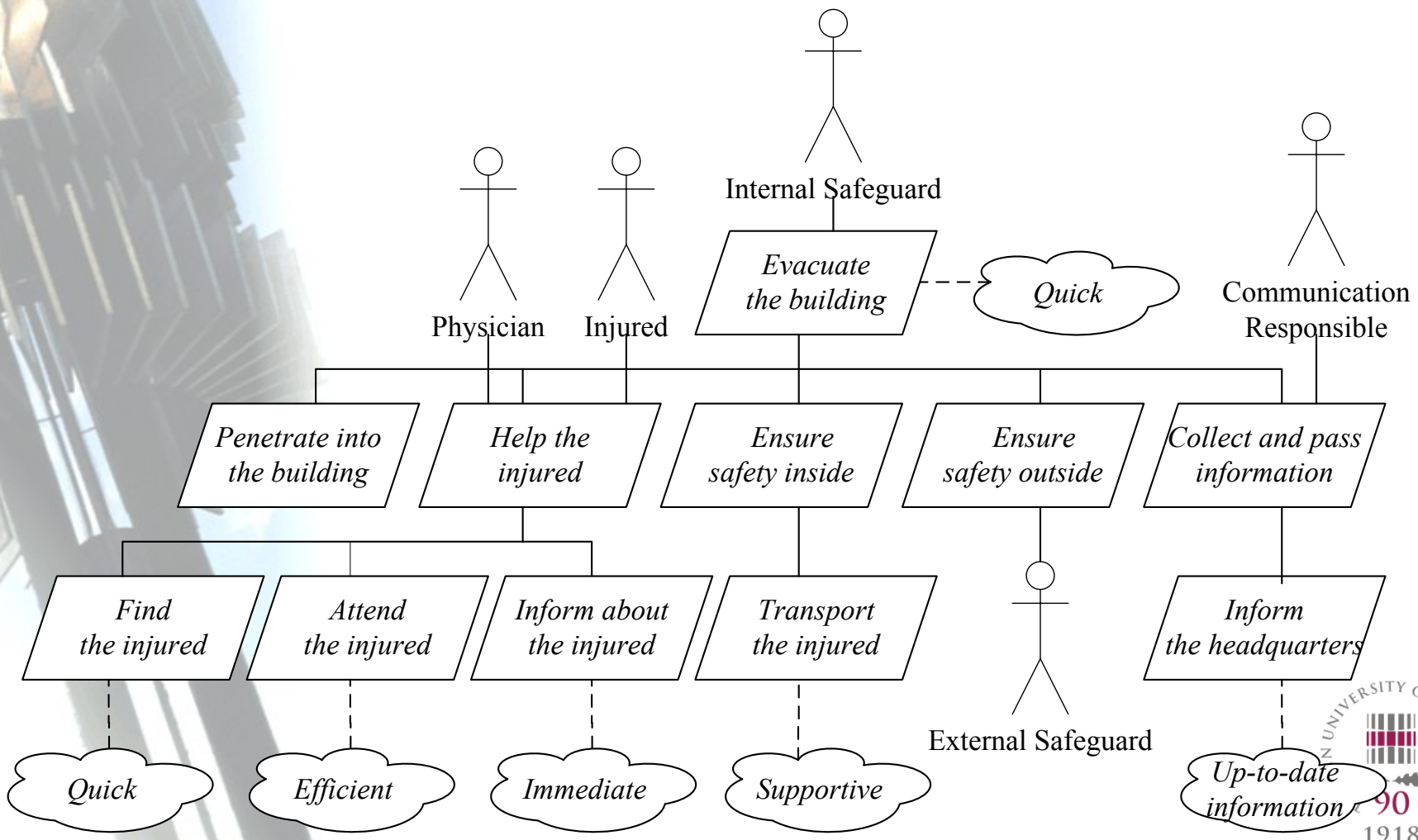
Viewpoint Framework

	Viewpoint aspect		
Abstraction layer	Interaction	Information	Behaviour
Analysis	Role models and organization model	Domain model	**Goal models and motivational scenarios**
Design	Agent models and acquaintance model, interaction models	Knowledge models	Scenarios and behaviour models
Platform-specific design	Platform-specific design models		

Motivational scenario

Scenario name	An urban rescue operation
Scenario description	The building that is located in the enemy`s territory and shielded our warriors was hit by a bomb. The rescue team has to perform the following tasks: • Penetrate into the building; • Find the warriors killed; • Find and evacuate the warriors injured; • Find and detonate possible explosives. During evacuation, the following events occur: • Civilians appear outside of the building; • Small cave-in occurs in the building.
Quality description	The building is in ruins, low, and dark. There are bodies and many obstacles in the building. Because of the danger of cave-in, the tasks have to be accomplished as soon as possible. All the members of the rescue team are equipped with radio transmitters. The members of the rescue team have to provide other team members and the headquarters constantly with up-to-date information.

Goal model


Internal Safeguard
Physician
Injured
Evacuate the building
Quick
Communication Responsible
Penetrate into the building
Help the injured
Ensure safety inside
Ensure safety outside
Collect and pass information
Find the injured
Attend the injured
Inform about the injured
Transport the injured
External Safeguard
Inform the headquarters
Quick
Efficient
Immediate
Supportive
Up-to-date information

Viewpoint Framework

	Viewpoint aspect		
Abstraction layer	Interaction	Information	Behaviour
Analysis	**Role models and organization model**	Domain model	Goal models and motivational scenarios
Design	Agent models and acquaintance model, interaction models	Knowledge models	Scenarios and behaviour models
Platform-specific design	Platform-specific design models		

The role of External Safeguard

Role name	**External Safeguard**
Description	The role of the external safeguard of the building during the operation
Responsibilities	Ensure safety outside the building Inform the Communication Responsible about any potential threats Receive the injured from the Internal Safeguard along with the instructions Inform the Communication Responsible about the injured received and the instructions
Constraints	Quick, efficient, informed, and helpful behaviour

The role of Physician

Role name	**Physician**
Description	The role of the physician during the operation
Responsibilities	Penetrate into the building Find the bodies in the building Tell the injured apart from the dead Inform the Communication Responsible about the injured and dead found Attend the injured Pass the injured to the Internal Safeguard along with the instructions
Constraints	Quick, efficient, informed, and helpful behaviour

The role of Internal Safeguard

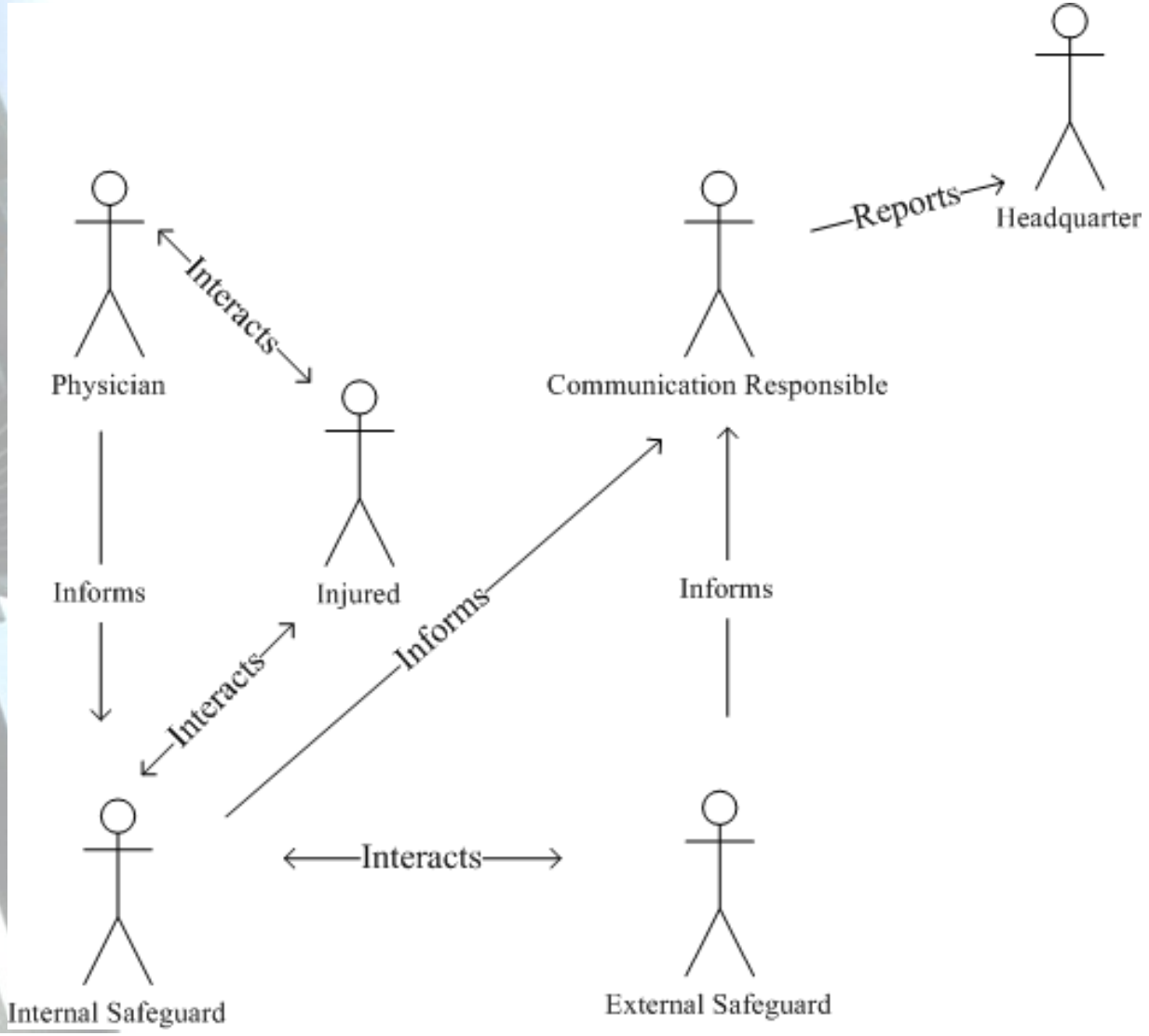
Role name	**Internal Safeguard**
Description	The role of the internal safeguard of the building during the operation
Responsibilities	Penetrate into the building Ensure safety inside the building Find and detonate possible explosives Inform the Communication Responsible about any potential threats Support the Physician in attending the injured Pass the injured to the External Safeguard along with the instructions by the Physician
Constraints	Quick, efficient, informed, and helpful behaviour

The Roles of Communication Responsible and Injured

Role name	**Communication Responsible**
Description	The role of the communication responsible in the operation
Responsibilities	Collect and pass information to the headquarters
Constraints	Quick, efficient, informed, and helpful behaviour

Role name	**Injured**
Description	The role of the injured in the operation
Responsibilities	Tell the physician about the injuries
Constraints	Precise information

Organization model



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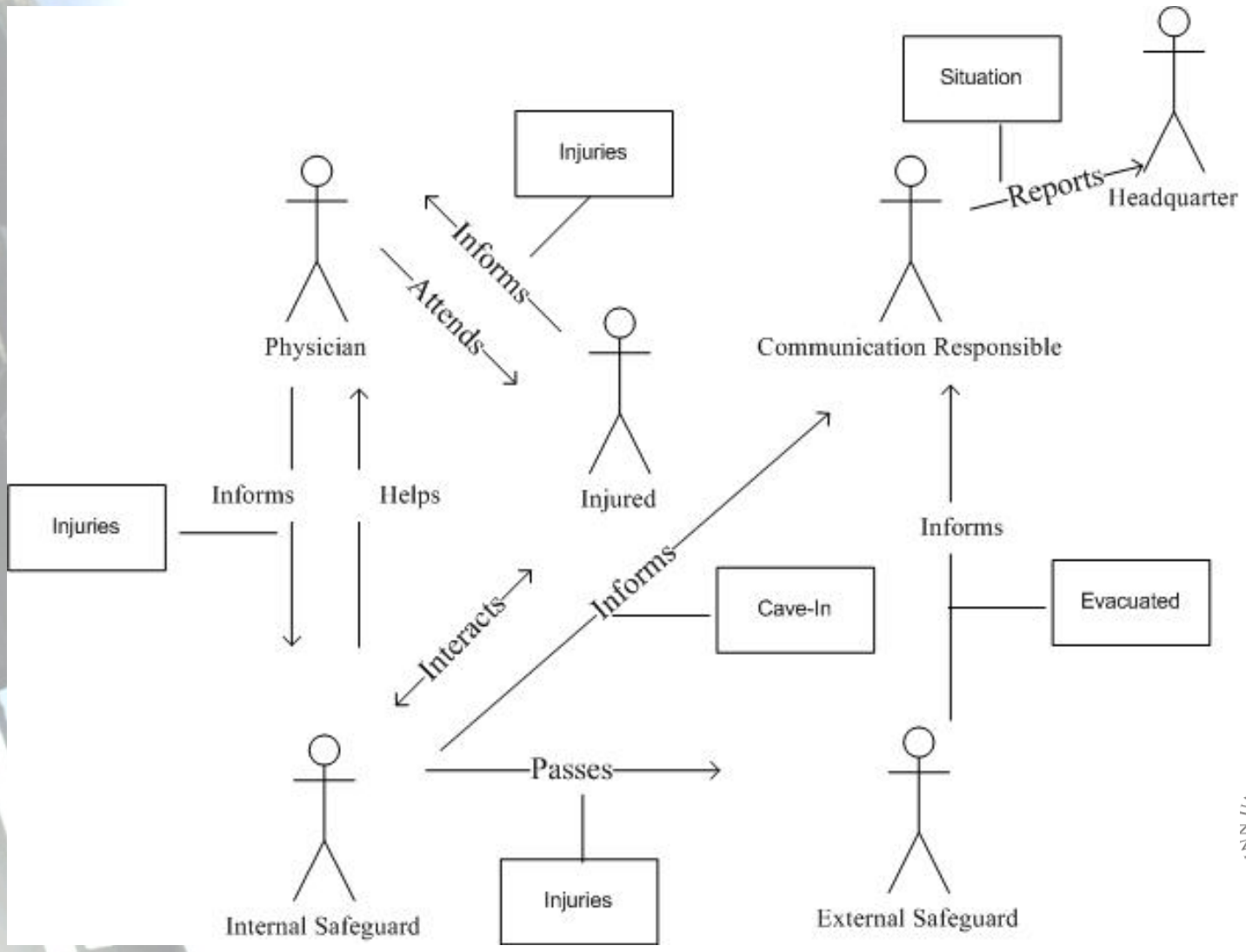
Resources

Resource	Roles	Description
Injuries	Injured, Physician, Internal Safeguard, External Safeguard	Information about the injuries
Cave-in	Internal Safeguard, Communication Responsible	Information about the cave-in
Evacuated	External Safeguard, Communication Responsible	Information about the injured evacuated
Situation	Communication Responsible, Headquarter	Information collected from agents performing the roles Internal Safeguard and External Safeguard

Domain model



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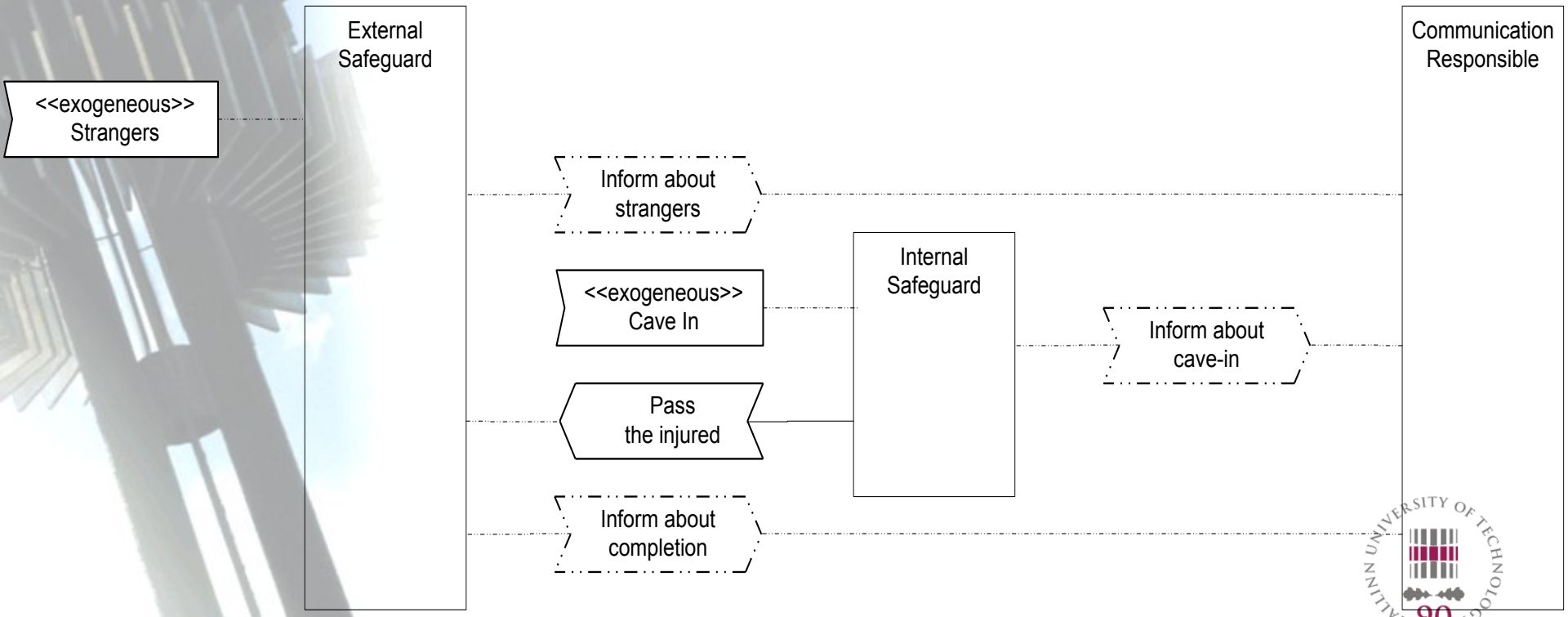
Platform-specific design	Platform-specific design models		

Interaction model



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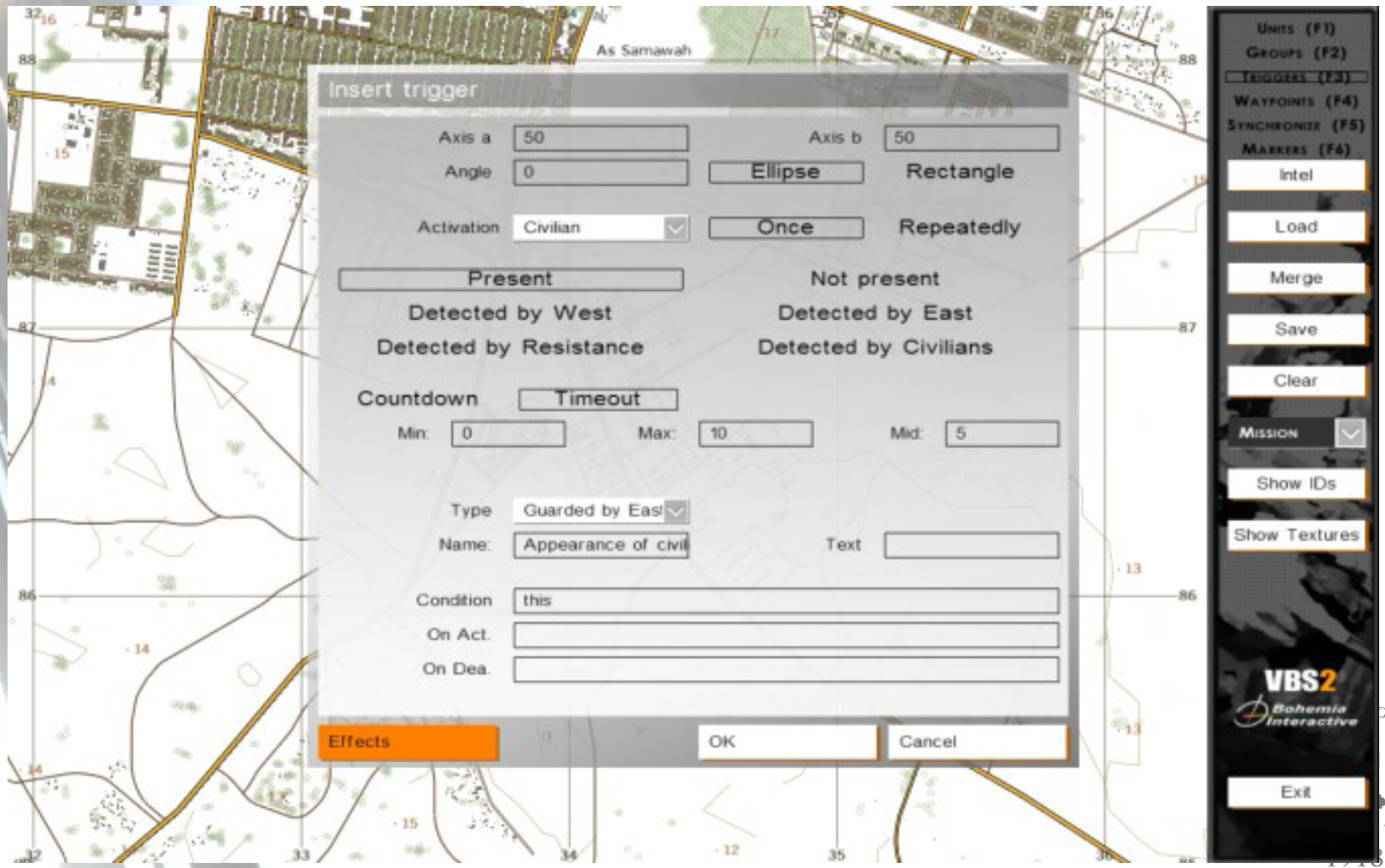
Platform-specific design	**Platform-specific design models**		

Simulation platform VBS2



Two lines of work

- Modeling and simulating asymmetric threats in military operations
- Modeling and simulating how “hearts and minds” of people can be won by conflict resolution

Viewpoint Framework

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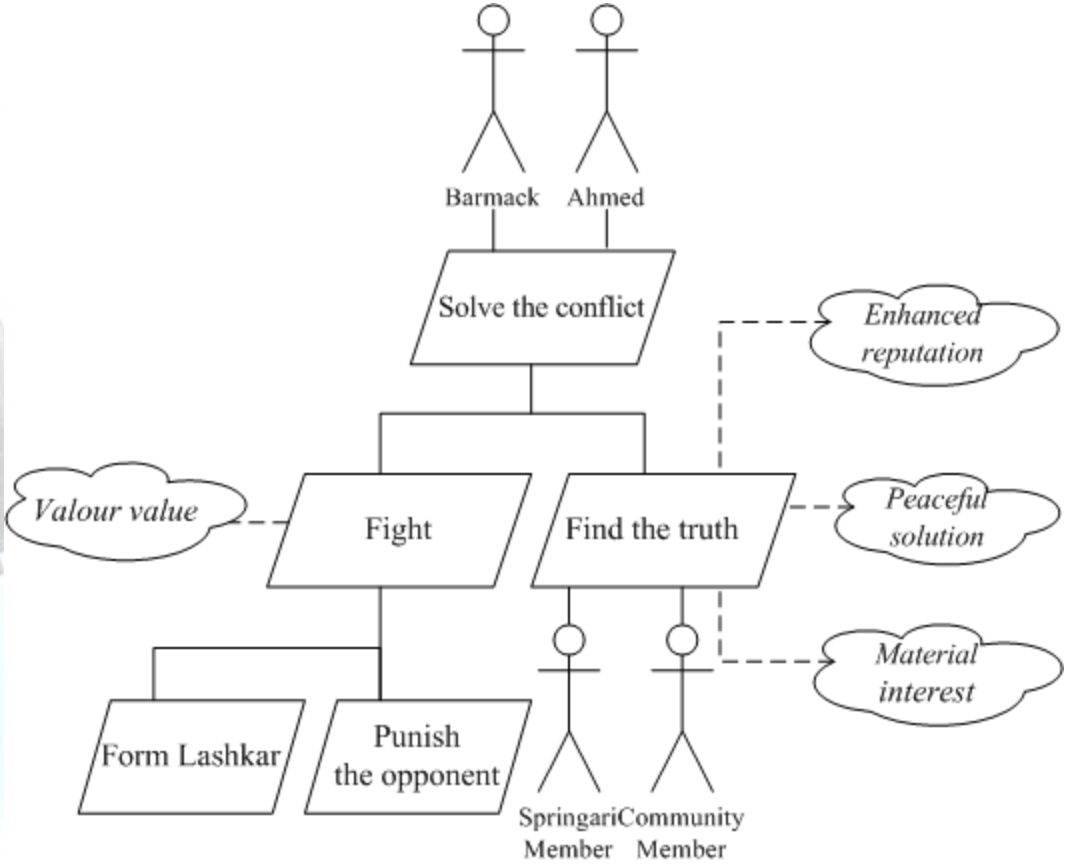
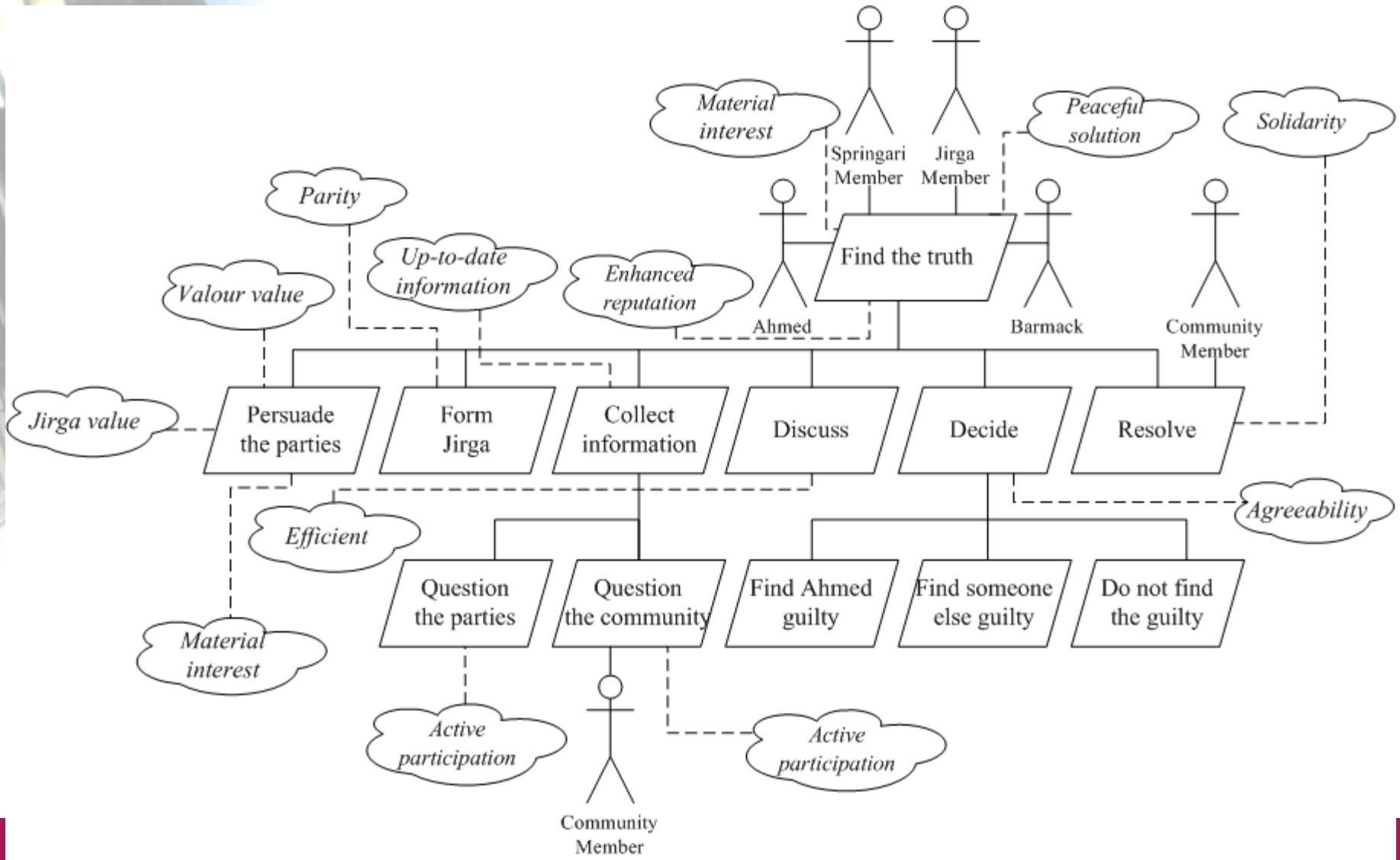
The overall goal model



The goal model for Jirga



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Societal information systems

- Software agents represent members of the society
- The tasks:
  - Regulation (e.g., banking)
  - Allocation of scarce resources (e.g., energy, parking spaces, emergency care)
  - Distributed situation assessment (e.g., traffic jams, snowstorms)
  - Decentralized decision-making (e.g., grocery shopping, choosing healthcare providers)
- Open distributed systems

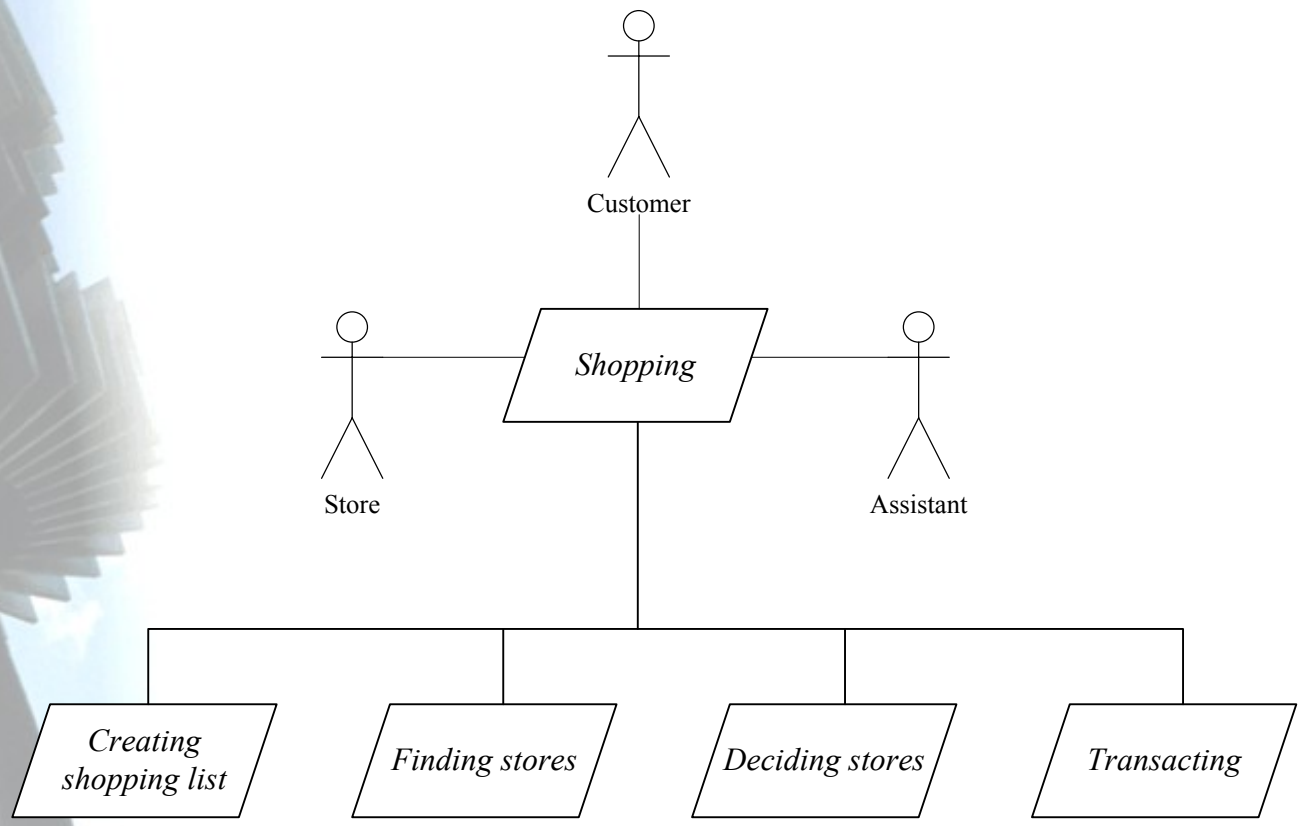
The case study of social grocery shopping

- Customers post the prices they paid for their groceries (this could be automated by querying the RFID tags of the items) and QoS information
- A prospective shopper enters a grocery list and obtains a pointer to the store(s) with the lowest total price (and best service)
- Each customer has an agent representing his/her interests and interacting with the agents of the other customers.

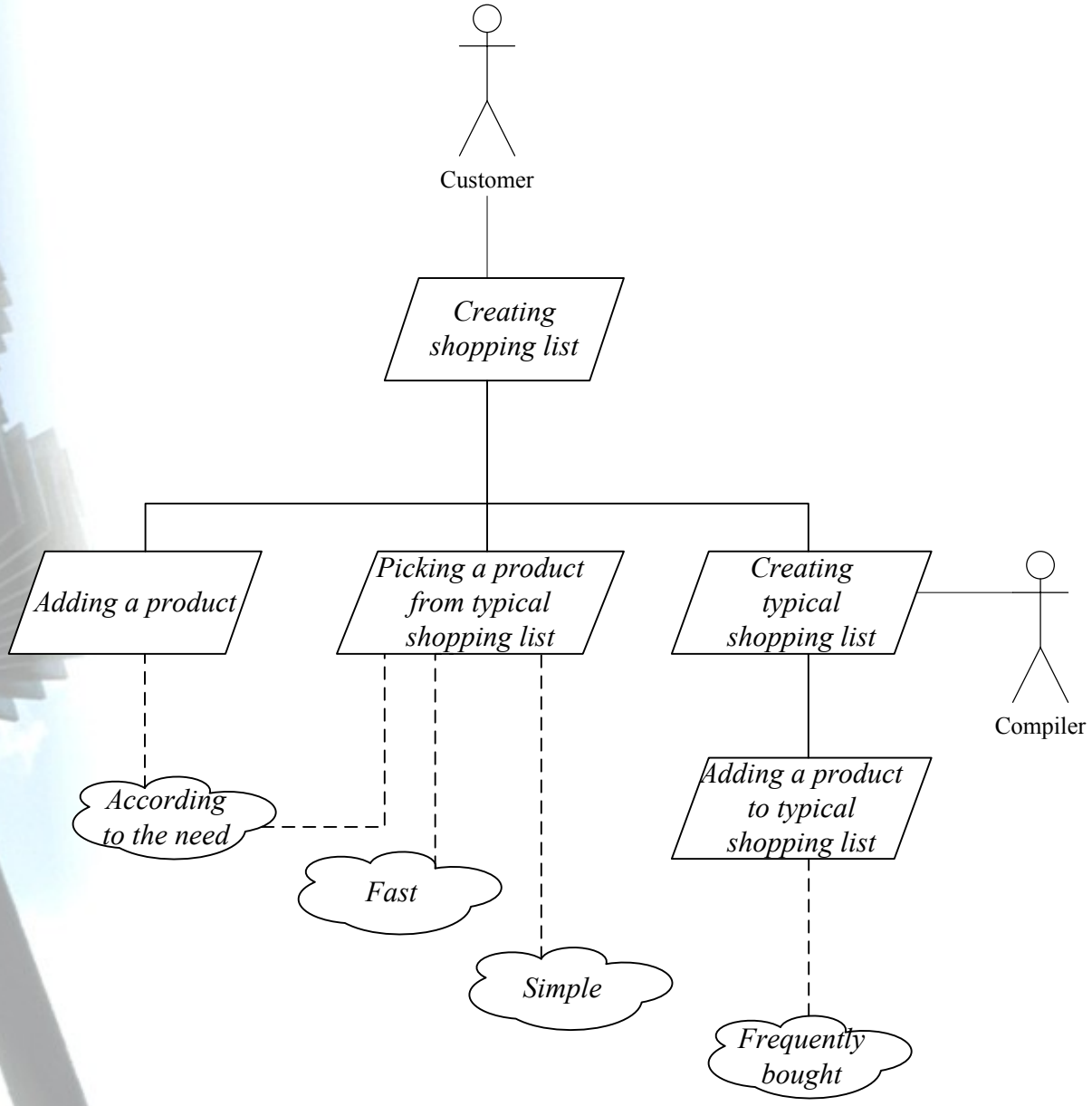
Extending the case study to healthy eating

- Agent:
  - Manages the profile of its principal;
  - Retrieves nutrition and price information of products;
  - Processes price information posted by other customers;
  - Processes feedback posted by other customers;
  - Suggests healthy and affordable alternatives;
  - Accordingly creates the list of stores to be visited.

Overall goal model



Creating shopping list



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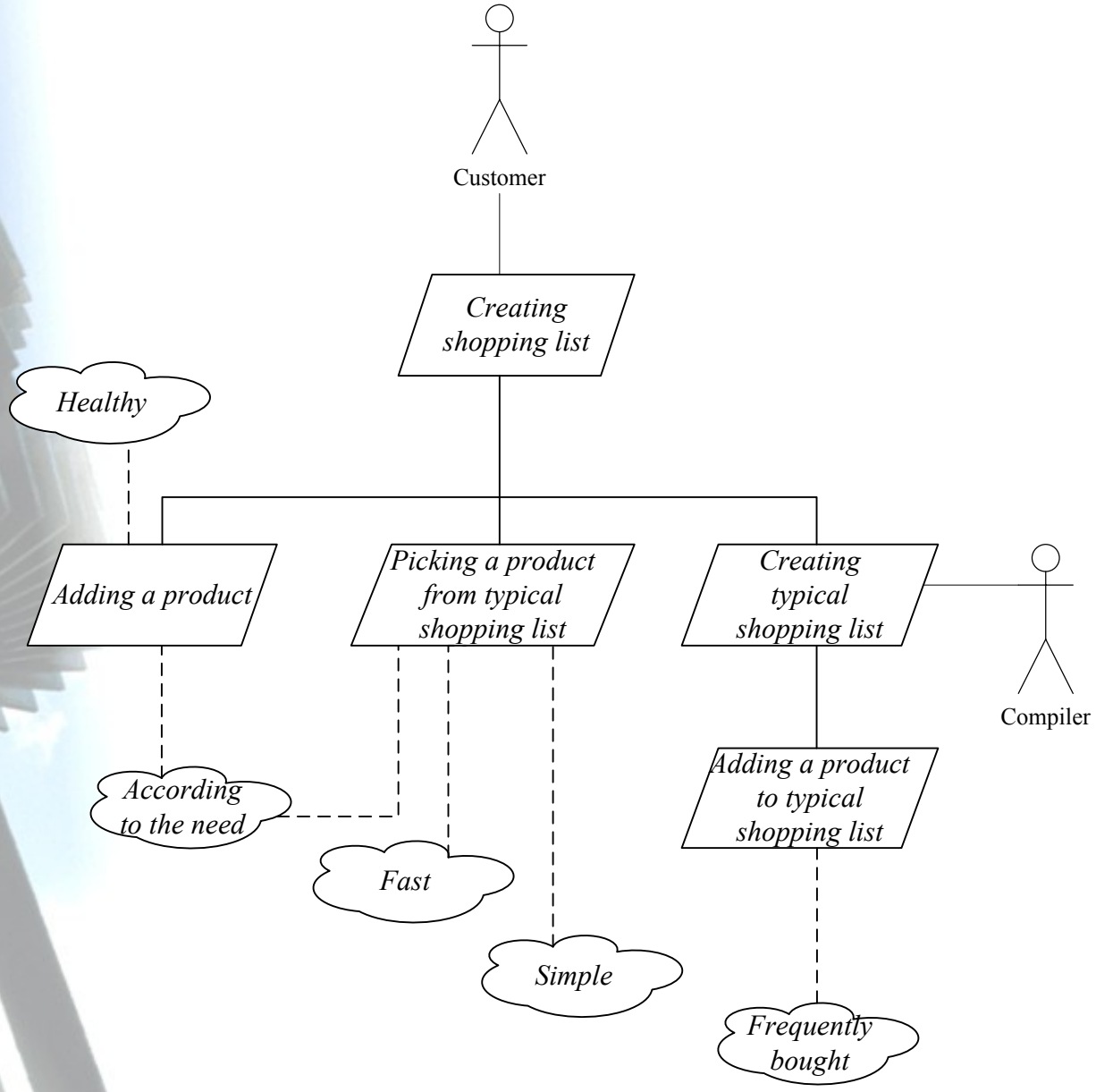
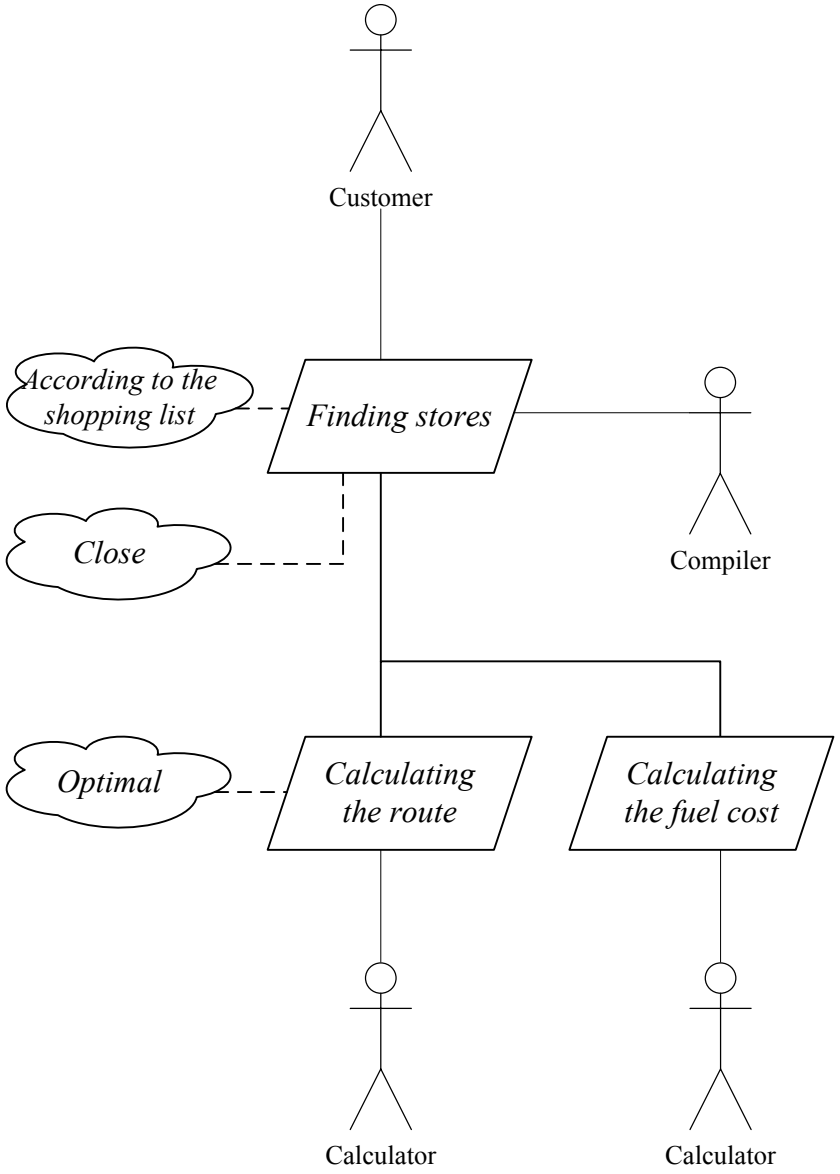
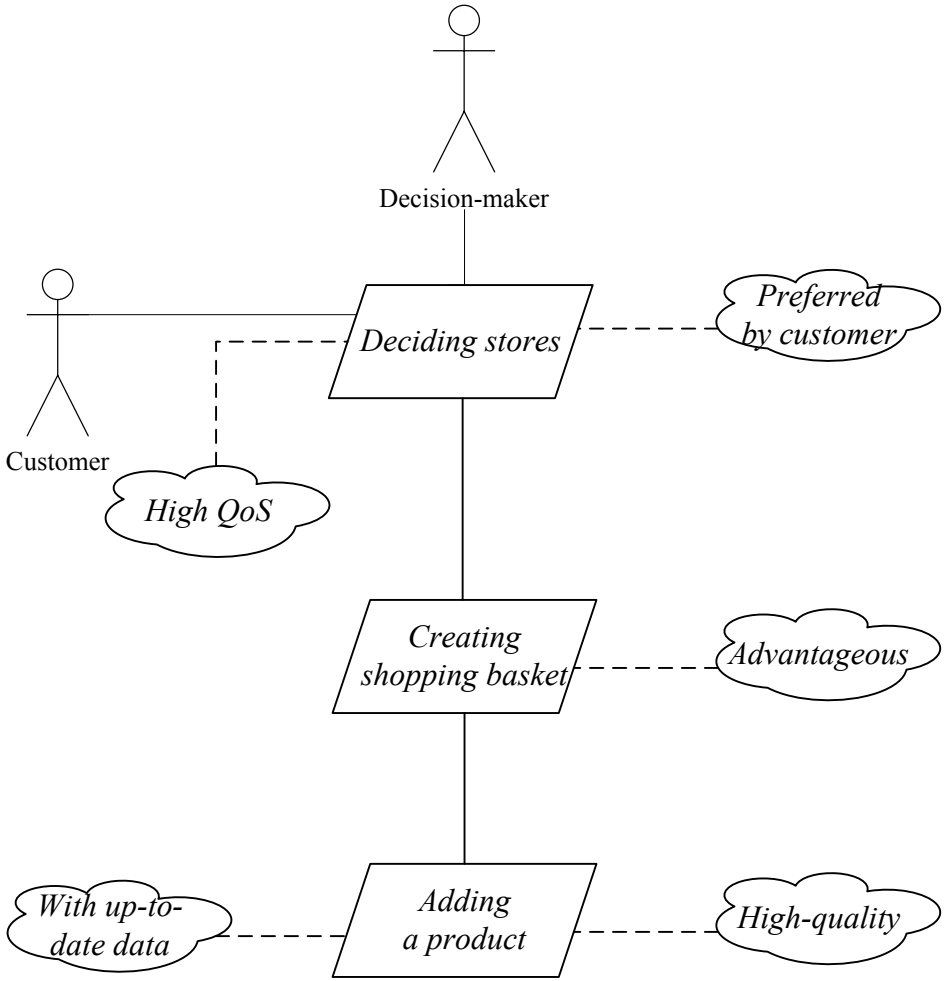


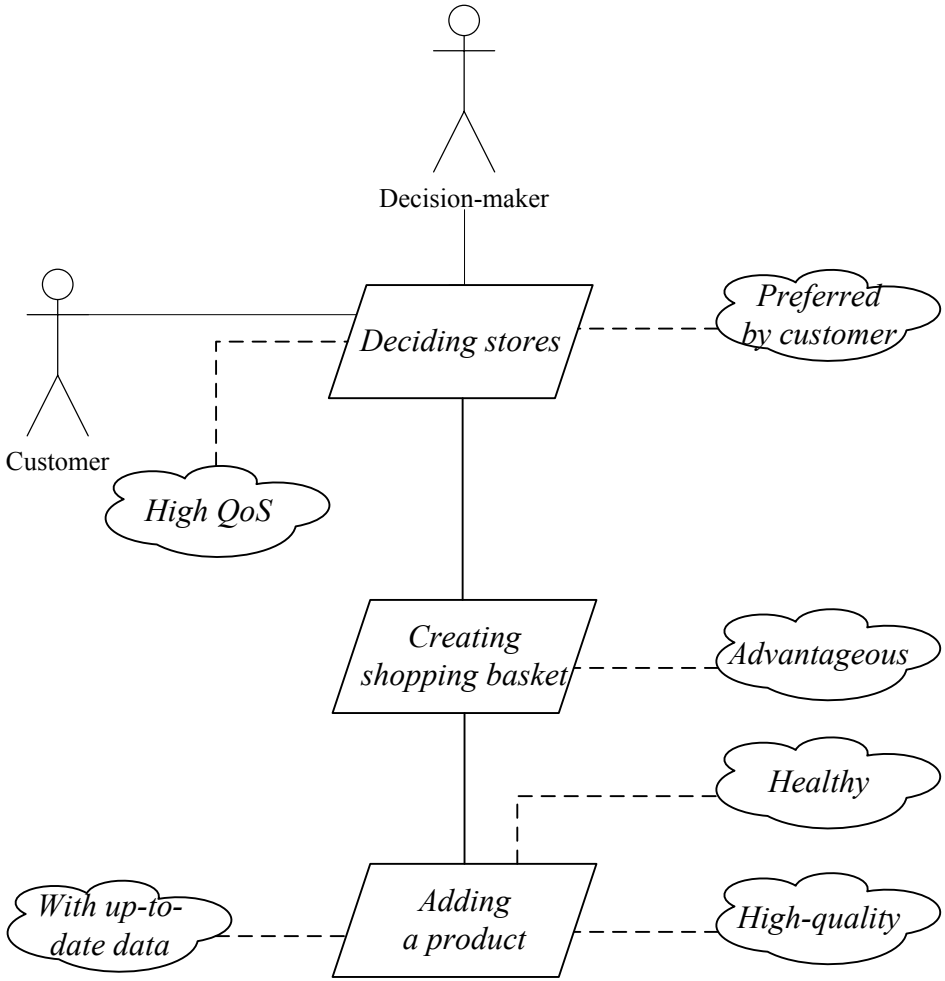
Finding stores



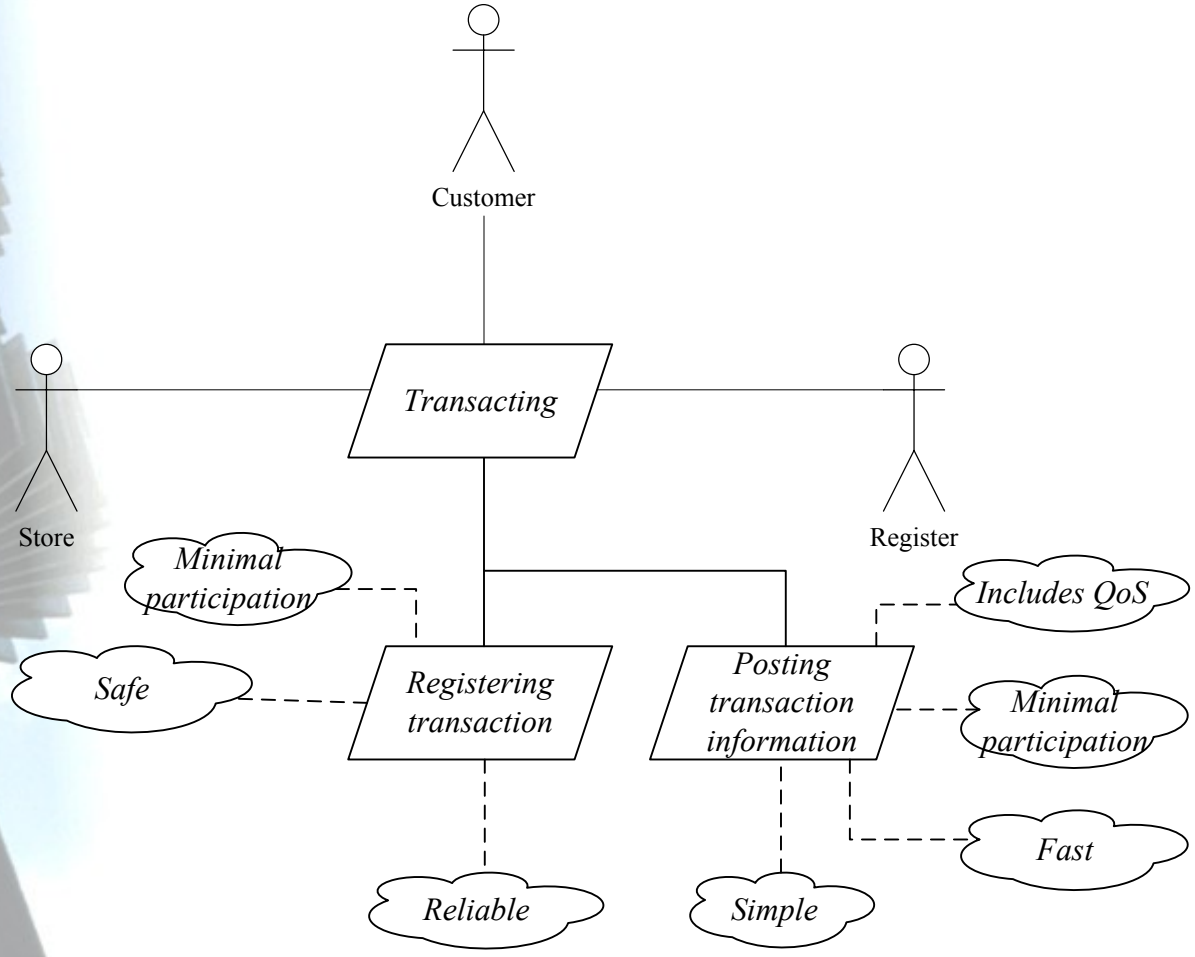
Deciding stores



Deciding stores



Transacting



Role model for Customer

Role	Customer
Description	The role of a customer buying groceries
Responsi-bilities	Creating the shopping list - Adding a product to the shopping list - Picking a product from the typical shopping list Determining preferences Confirming the stores found by the Compiler Confirming the decisions made by the Decision-maker Driving to the stores Making transactions
Constraints	For picking products from the typical shopping list, the typical shopping list must have been created for the Customer To find the most advantageous shopping baskets, the Customer should consider the stores found by the Compiler and the decisions made by the Decision-maker To benefit from the transaction information posted by other customers, the Customer must authorize posting of his/her transaction information

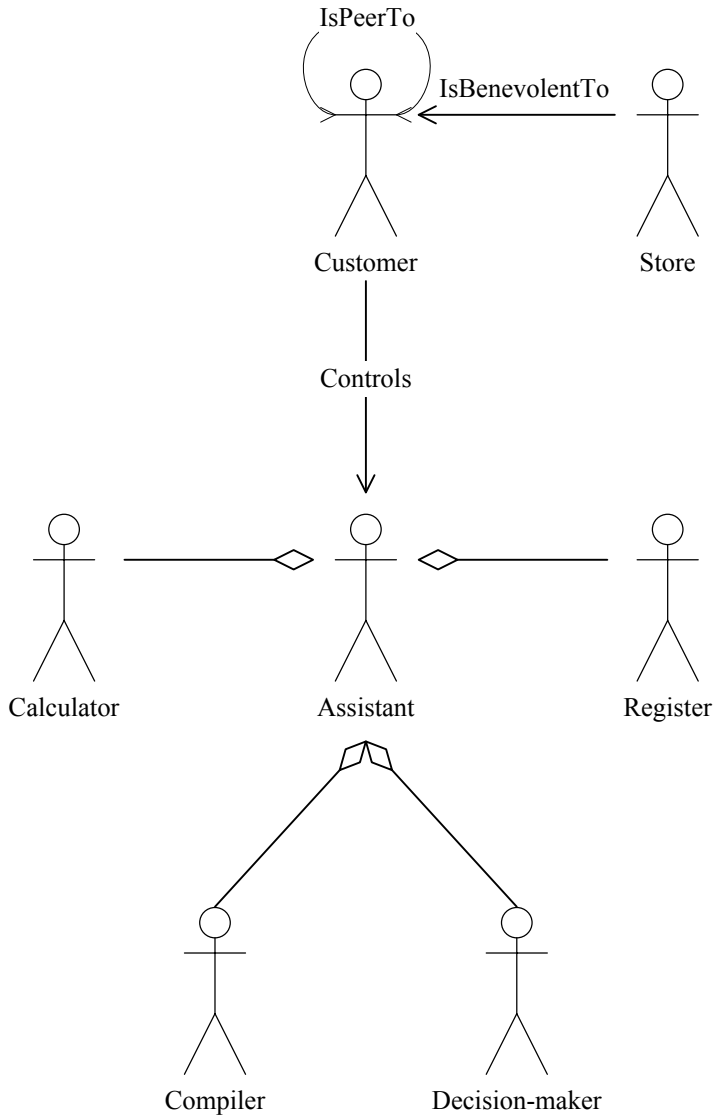
Role model for Compiler

Role	Compiler
Description	The role of shopping list and store list compiler
Responsi-bilities	Creating and managing the typical shopping list by the buyer - Add a product to the typical shopping list Storing shopping lists for statistics and data mining Finding potential stores with the help of the Calculator
Constraints	The shopping list by the Customer must be considered when finding potential stores The typical shopping list must be considered when finding potential stores The proximity of stores must be considered when finding potential stores For creating the typical shopping list, the Customer must have created shopping list(s) before.

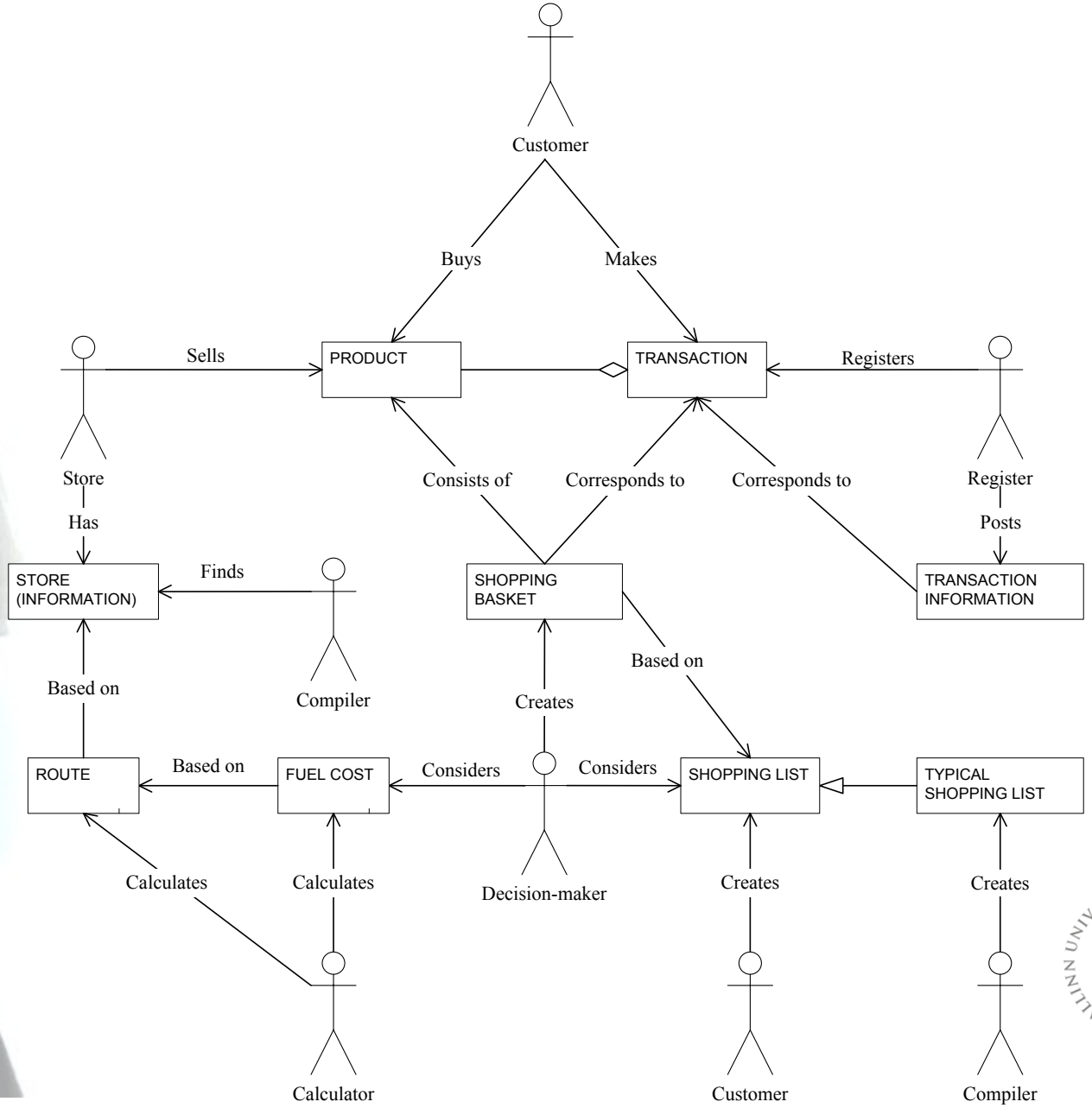
Role model for Decision-maker

Role	Decision-maker
Description	The role of decision-maker about the stores and their shopping baskets
Responsi-bilities	Comparing potential shopping baskets for the stores found by the Compiler Deciding the stores Deciding the shopping basket for each store selected
Constraints	The preferences by the Customer must be honored when deciding about the stores and their shopping baskets The transaction information posted by other customers, including QoS, must be considered when deciding about the stores and their shopping baskets The transaction information should be considered in the order of its age The fuel costs computed by the Calculator must be considered when deciding about the stores and their shopping baskets The shopping baskets created should be maximally advantageous for the Customer The shopping baskets should include high-quality and healthy products with up-to-date data

Organization model



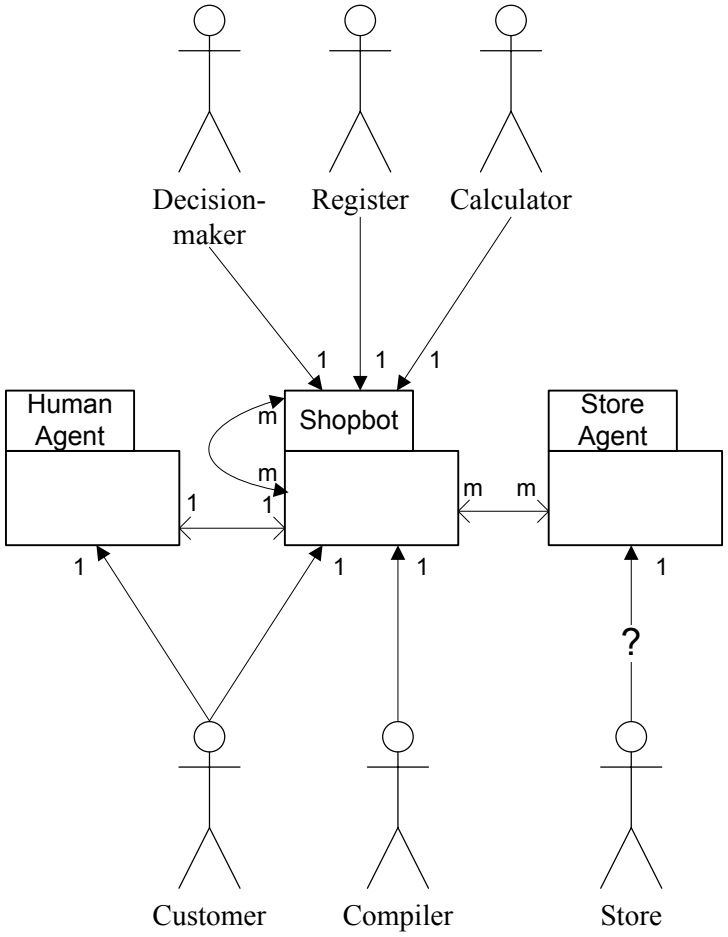
Domain model

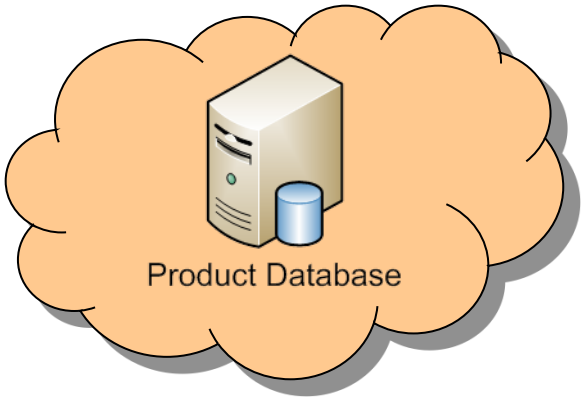


Design models

- Agent and acquaintance models
- Interaction models
- Knowledge models
- Scenarios and behavior models

Agent and acquaintance model

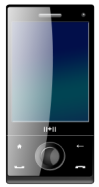


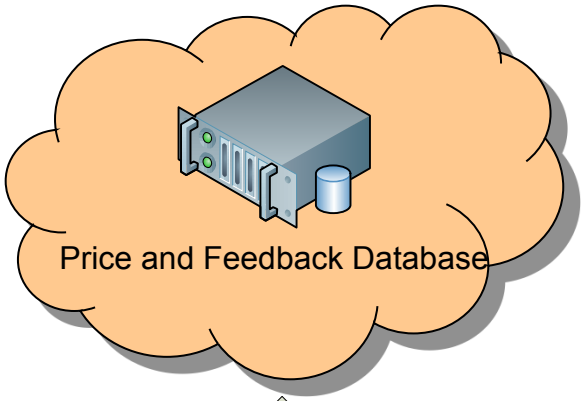


Product information

Product information

Product information

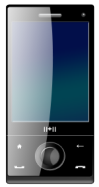


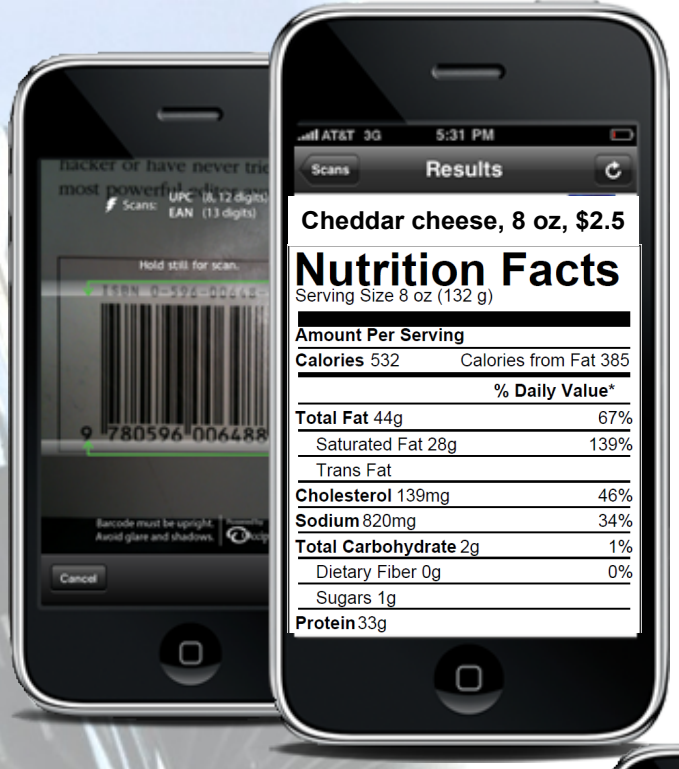


Price information

Price information

Price information





Healthy alternatives

Customer ratings

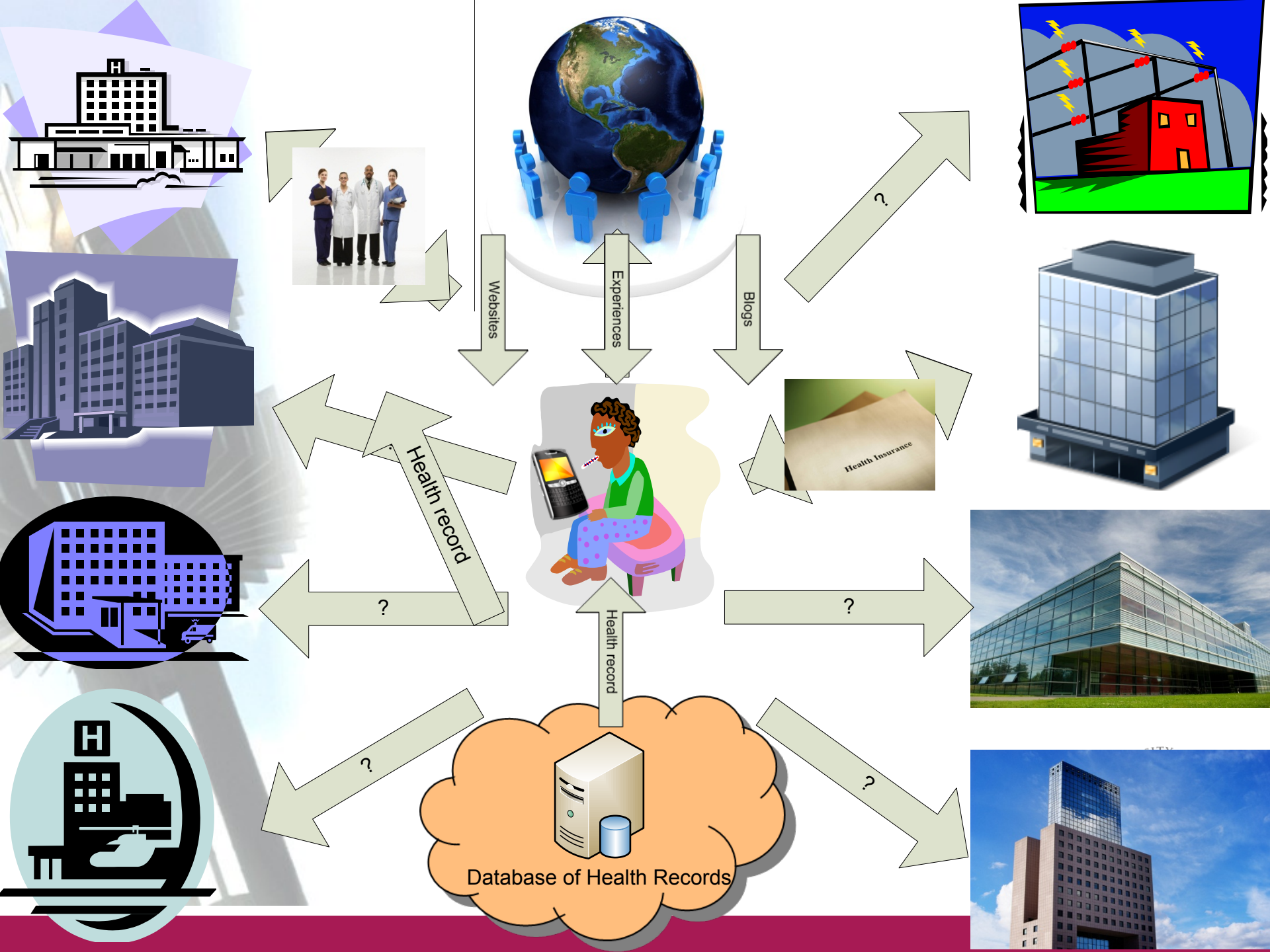
TALLINN UNIVERSITY OF TECHNOLOGY
90
1918
2008

Results from initial experiments by Prof Huhns and Hongying Du

- Savings up to 21% can be obtained by social grocery shopping!

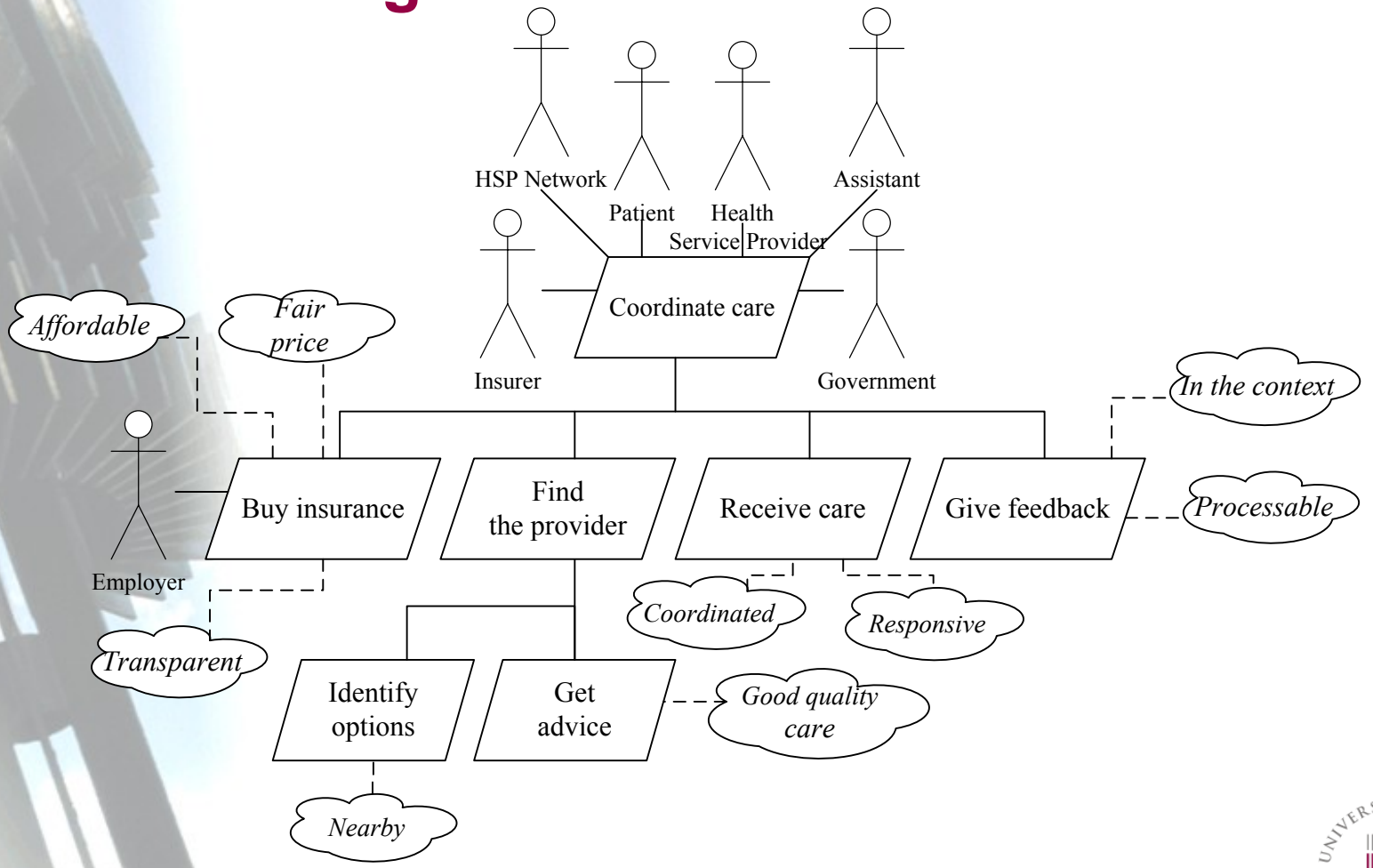
The case study in U.S. healthcare

- A complex system
- No information systems available to support individual patients
- Patients are distributed -> distributed multiagent systems
- Assisting patients with
  - Finding good healthcare providers
  - Understanding and interpreting insurance rules
  - Providing advice
  - Monitoring the spread of cold and flu symptoms

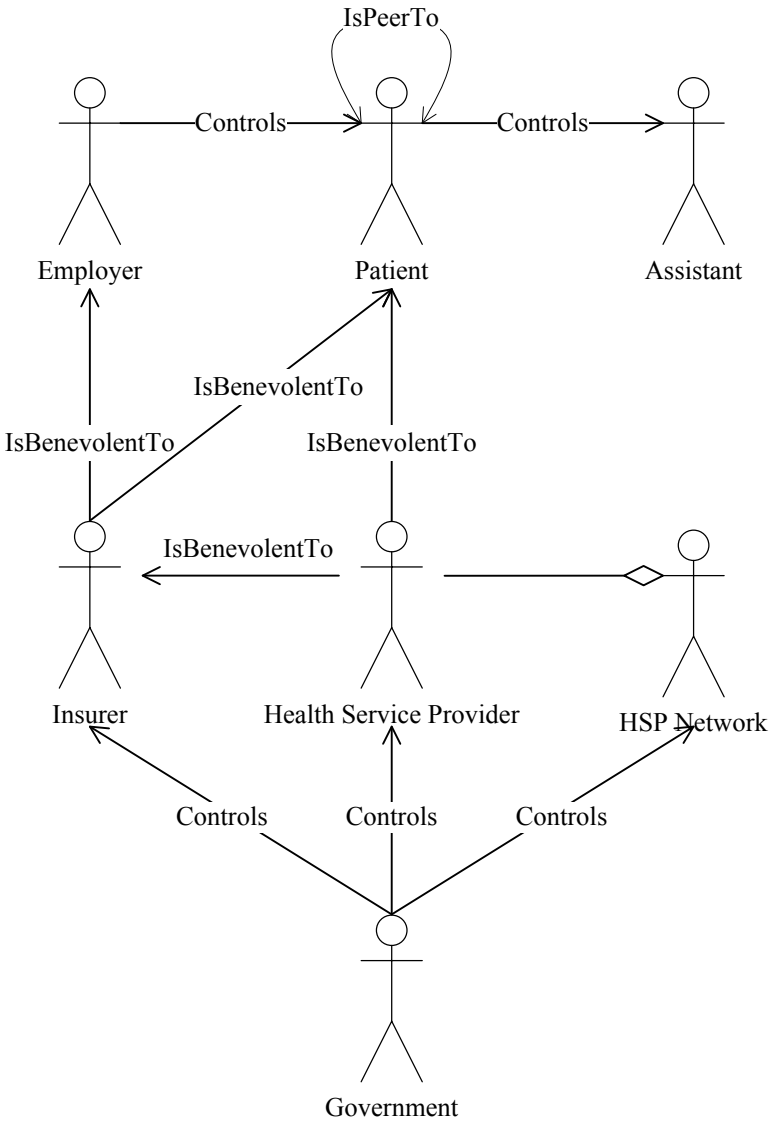

Websites
Experiences
Blogs
?
Health record
Health Insurance
?
?
Health record
?
?
Database of Health Records

Sharing experience within the context

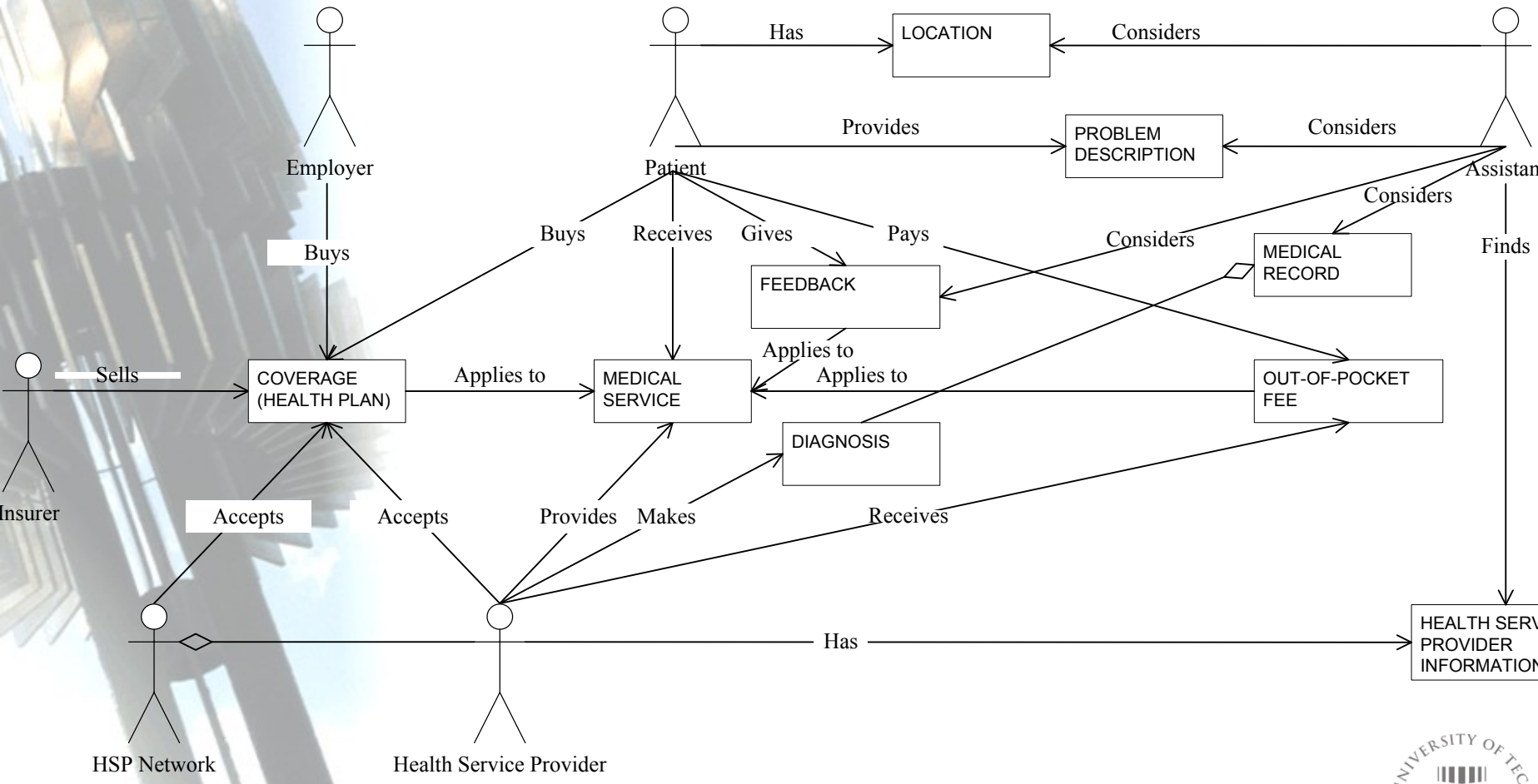
Overall goal model



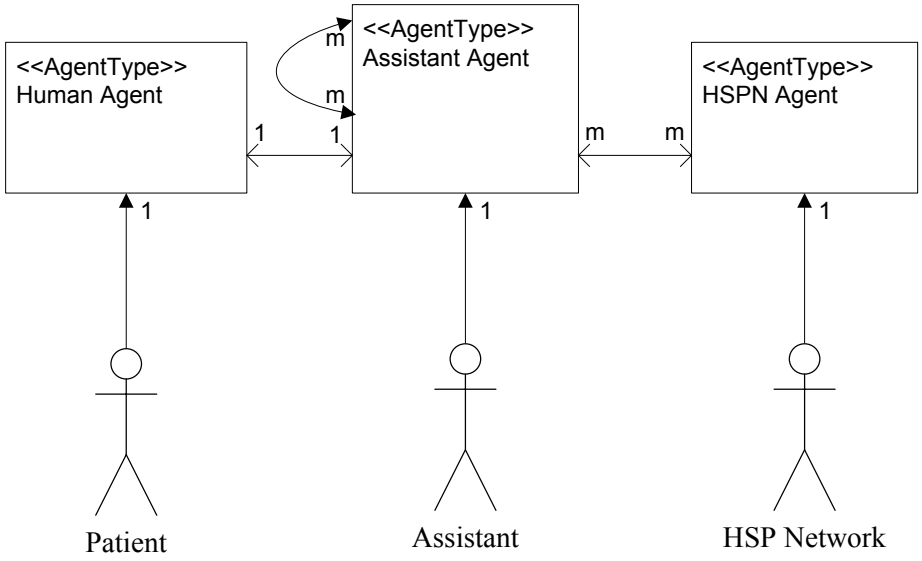
Organization model



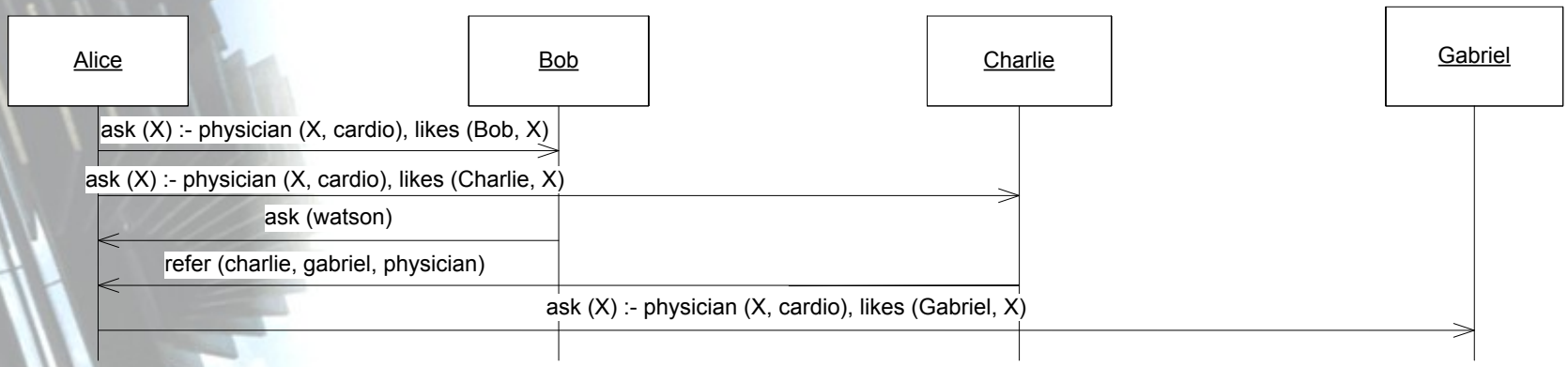
Domain model



Agent and acquaintance model



Preliminary interaction model



Conclusions

- To reduce complexity, a problem domain should be structured
- Agent-oriented modeling is a good way of structuring problem domains
- Simulation is relevant for both
  - Training;
  - Signing of requirements
- Sociotechnical aspect is important in both simulation systems and deployed information systems