The Car Repair Assistant

Joost Huizinga (1557017)
Tycho Bismeier (1615440)

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1 Introduction

Cars are probably the most important vehicle of our century. Where most people would use cars only for transport some have turned their car in a hobby. For these hobbyist performing minor upgrades and repairs on there cars is about as important as driving the car.

Unfortunately its is sometimes difficult to find the right information to perform these repairs and upgrades. For this problem we developed the car repair assistant. The car repair assistant is a knowledge system that helps with the identification and repair of various problems a car might have.

Because car repair is a very wide problem area we have narrowed it down to only the electrical system. Most of our models nevertheless assume the complete car repair assistant. It are the domain specific models that only consider the electrical system of the car.

2 Context model

This section contains the tables OM-1, OM-2, OM-5, TM-1, TM-2, AM-1. Since our problem is based on a single person that repairs his car in its own time there is no organization. This makes organizational structures or flows quite

impossible to create. Nevertheless, most parts of the forms that concern the organizational model are still relevant.

2.1 Organizational model

Organization Model	**Problems and Opportunities Worksheet OM-1**
Problems and opportunities	Hobbyists currently experience problems with the availability of documentation, reasoning about complex, partly unknown technical systems and gaps in their own knowledge.
Organizational context	The goal of the hobbyist is to repair his or her car. He wants to have fun and learn about cars. He might also save money because he does not have to go to a garage or he might be better than a garage in repairing his car because he has more specific knowledge about his car. The car needs to be in a good enough shape to pass the APK. Other users of the car require the car to be available. External factors like work and family restrict the time and resources available to repair in ways that are uncontrollable or unexpected.
Solutions	Possible solutions are: • An information retrieval system to find documentation about car repair and specific cars on the Internet. • A knowledge system holding knowledge about car repair, reasoning about that knowledge and using it to assist the hobbyist in repairing his car. • Educating the car hobbyist about car repair.
Organization Model	**Variant Aspects Worksheet OM-2**
Structure	The organizational structure is simple. The car hobbyist is working alone.
Process	There is the process of repairing a car.
People	The car hobbyist might occasionally have an assistant if he perform a task that requires it. Like checking whether the headlights are working.
Resources	Repair manuals, technical description of a specific car, general technical description of car. Tools.
Knowledge	The car hobbyist uses knowledge about how to repair a car, knowledge about how cars work in general and knowledge about how a specific car works.
Culture & power	Car repair happens in the social environment of his or her family.

Organization Model	**Checklist for Feasibility Decision Document: Worksheet OM-5**
BUSINESS FEASIBILITY	We expect that: car repairs are performed more quickly, car repairs with a higher difficulty can be performed and the hobbyist learns more while repairing his car. The car hobbyist spends less time on thinking about repairs and performing repairs that don't result in a repaired car. Depending on the hobbyist this might increase or decrease his fun in repairing the car. We don't know how much time might be saved, or how much more a hobbyist might learn. The hobbyist does need to have computer to run the knowledge system on. That computer also needs an interface that is usable with greasy hands. This compare favourably with the other solutions. The hobbyist would be prepared to spend money on a knowledge system, while the time needed for further eduction is not available, and a knowledge retrieval system would not have the same benefits. There is no need for organizational changes. The hobbyist still works on his own while repairing the car.
TECHNICAL FEASIBILITY	The system needs to perform diagnosis with causal reasoning. That can be done with a knowledge system. There is no need to reason with the knowledge about how to repair a car, this can be represented in text form to the user. The system needs to run on a PC sized computer. It should respond in seconds to response of the user. The system has minutes of reasoning time when the hobbyist is performing repairs. The system is successful if it can guide a car repair hobbyist in common repairs to the electrical system of one specific car. It also needs to be modular and modifiable enough, so that it's clear it can be extended to more special repairs, repairing more kinds of car and repairing non-electrical faults.
Project feasibility	The project is feasible. We have access to an expert on car repair and a car hobbyist.

2.2 Task and agent models

Task Model	**Task Analysis Worksheet TM-1**
Task	Car diagnoses task
Organization	This task is not part of an organization and is executed by a hobbyist.
Goal and value	To find the cause of an observed problem. Once the cause is know it might be possible to repair the problem or bring the car tho a garage so they can fix the problem.
Dependency and flow	*Input tasks*: None *Output tasks*: Car repair task
Objects handled	*Input objects*: An observed problem, type of car. *Output objects*: Cause(s) of the observed problem. *Internal objects*: General car knowledge, specific car knowledge
Timing and control	The task is performed only when a problem is observed, which is expected to be very infrequent. The task might take from about 15 min to a few hours. *preconditions* There must be an observed problem. *postconditions* One or more causes for the observed problem are reported or the system reports it could not find the problem. *constraints* The system needs access to the car knowledge of the specified car.
Agents	The hobbyist, the car diagnoses system
Knowledge and competence	The hobbyist needs to be able to preform certain tests, interpret the results correctly and give them to the car diagnoses system.
Resources	The task will consume the time of the person performing it. In addition, depending on the problem being diagnosed, some measuring equipment and/or spare parts might be needed.
Quality and performance	The quality measure will be that the identified cause is the real cause of the problem. The performance will be measured by the time it takes to diagnose the problem.

Task Model	**Task Analysis Worksheet TM-1**
Task	Car repair task
Organization	This task is not part of an organization and is executed by a hobbyist.
Goal and value	To repair the observed cause. If successful then the car functions properly again, saving repair costs
Dependency and flow	*Input tasks*: Car diagnoses task *Output tasks*: None
Objects handled	*Input objects*: A cause for a problem, type of car. *Output objects*: Confirmation if the task was successful *Internal objects*: General car knowledge, specific car knowledge, repair knowledge
Timing and control	The task is performed only when a problem is observed, which is expected to be very infrequent. The task might take from about 15 min to a few hours. *preconditions* A cause for a problem must be identified *postconditions* The problem is either fixed or it is known that the repair failed *constraints* The system needs access to the car knowledge of the specified car.
Agents	The hobbyist
Knowledge and competence	The hobbyist needs to be able to preform the necessary repairs
Resources	The task will consume the time of the person performing it. In addition, depending on the repair, some tools and/or parts might be needed.
Quality and performance	The quality measure will be that the problem is fixed by taking away the cause. The performance will be measured by the time it takes to perform the repair.

Task Model	**Knowledge Item Worksheet TM-2**
NAME	Component knowledge
EXPLANATION	Knowledge about what the individual components do. Knowing that the battery provides power and that if the battery is connected to lights then the lights will work is component knowledge. This knowledge does not include how the components are wired in a car.
POSSESSED BY	Car mechanics, some hobbyists, manufacturers
USED IN	Car diagnoses, car repair
DOMAIN	Cars

Nature of the knowledge		**Bottleneck / to be improved?**
Formal, rigorous	X	
Empirical, quantitative	X	
Heuristic, rules of thumb		
Highly specialized, domain-specific		
Experience-based		
Action-based		
Incomplete		
Uncertain, may be incorrect		
Quickly changing		
Hard to verify		
Tacit, hard to transfer		

Form of the knowledge		
Mind	X	
Paper	X	
Electronic	X	
Action skill		
Other		

Availability of knowledge		
Limitations in time		
Limitations in space		
Limitations in access		
Limitations in quality		
Limitations in form		

Task Model	**Knowledge Item Worksheet TM-2**
Name	General car knowledge
Explanation	Knowledge about the overall layout of cars in general. This knowledge will include the fact that car usually have a battery and that this battery is usually connected to the lights in one way or an other.
Possessed by	Car mechanics, most hobbyists
Used in	Car diagnoses
Domain	Cars

Nature of the knowledge		**Bottleneck / to be improved?**
Formal, rigorous		
Empirical, quantitative		
Heuristic, rules of thumb	X	
Highly specialized, domain-specific		
Experience-based	X	
Action-based		
Incomplete	X	X
Uncertain, may be incorrect	X	X
Quickly changing		
Hard to verify		
Tacit, hard to transfer		

Form of the knowledge		
Mind	X	
Paper	X	
Electronic	X	
Action skill		
Other		

Availability of knowledge		
Limitations in time		
Limitations in space		
Limitations in access		
Limitations in quality	X	X
Limitations in form		

Task Model	**Knowledge Item Worksheet TM-2**
NAME	Specific car knowledge
EXPLANATION	Knowledge about the exact layout of a specific car. This knowledge includes exactly what components are connected to what but it does not include what to components actually do.
POSSESSED BY	Some car mechanics, some hobbyists, manufacturers
USED IN	Car diagnoses
DOMAIN	Cars

Nature of the knowledge		**Bottleneck / to be improved?**
Formal, rigorous	X	
Empirical, quantitative	X	
Heuristic, rules of thumb		
Highly specialized, domain-specific	X	
Experience-based		
Action-based		
Incomplete		
Uncertain, may be incorrect		
Quickly changing		
Hard to verify		
Tacit, hard to transfer		

Form of the knowledge		
Mind	X	
Paper	X	
Electronic	X	
Action skill		
Other		

Availability of knowledge		
Limitations in time		
Limitations in space		
Limitations in access	X	X
Limitations in quality		
Limitations in form		

Task Model	**Knowledge Item Worksheet TM-2**
NAME	Car Repair Knowledge
EXPLANATION	Knowledge about the best way to perform tasks that include finding, reaching and replacing parts. This knowledge also includes the way to handle tools like a wrench in the car repair domain.
POSSESSED BY	Car mechanics, some hobbyists
USED IN	Car diagnoses, car repair
DOMAIN	Cars

Nature of the knowledge		**Bottleneck / to be improved?**
Formal, rigorous	X	
Empirical, quantitative		
Heuristic, rules of thumb	X	X
Highly specialized, domain-specific		
Experience-based	X	X
Action-based	X	X
Incomplete		
Uncertain, may be incorrect		
Quickly changing		
Hard to verify		
Tacit, hard to transfer	X	X

Form of the knowledge		
Mind	X	
Paper	X	
Electronic	X	
Action skill	X	
Other		

Availability of knowledge		
Limitations in time		
Limitations in space		
Limitations in access		
Limitations in quality		
Limitations in form	X	X

Agent Model	Agent Worksheet AM-1
Name	*Hobbyist*
Organization	The agent is the human person physically executing the diagnoses. Usually the owner of the car.
Involved in	Car diagnoses, car repair
Communicates with	The car diagnoses system
Knowledge	Some very basic car knowledge
Other competences	Able to perform simple tests and repairs
Responsibilities and constraints	The agent has the responsibility to make sure its car works correctly, without the risk of suddenly failing The agent might have the responsibility to make sure its car works at a certain time point because someone else wants to use it. The agent might be constrained by warranty voids when handling certain parts himself

3 Knowledge model

3.1 Domain knowledge

This section contains an initial knowledge model. The domain model is shown in figures 1 and 2. Since we will only consider the electrical system this model only concerns electrical components. It is also modeled to support a specific car and, if this knowledge is not available, general car templates.

Thus far we have not modified the diagnoses task template. Our inference structure, shown in figure 3 is thus far exactly the same as that of the standard diagnoses task. It has been annotated to show how it can be used in our domain.

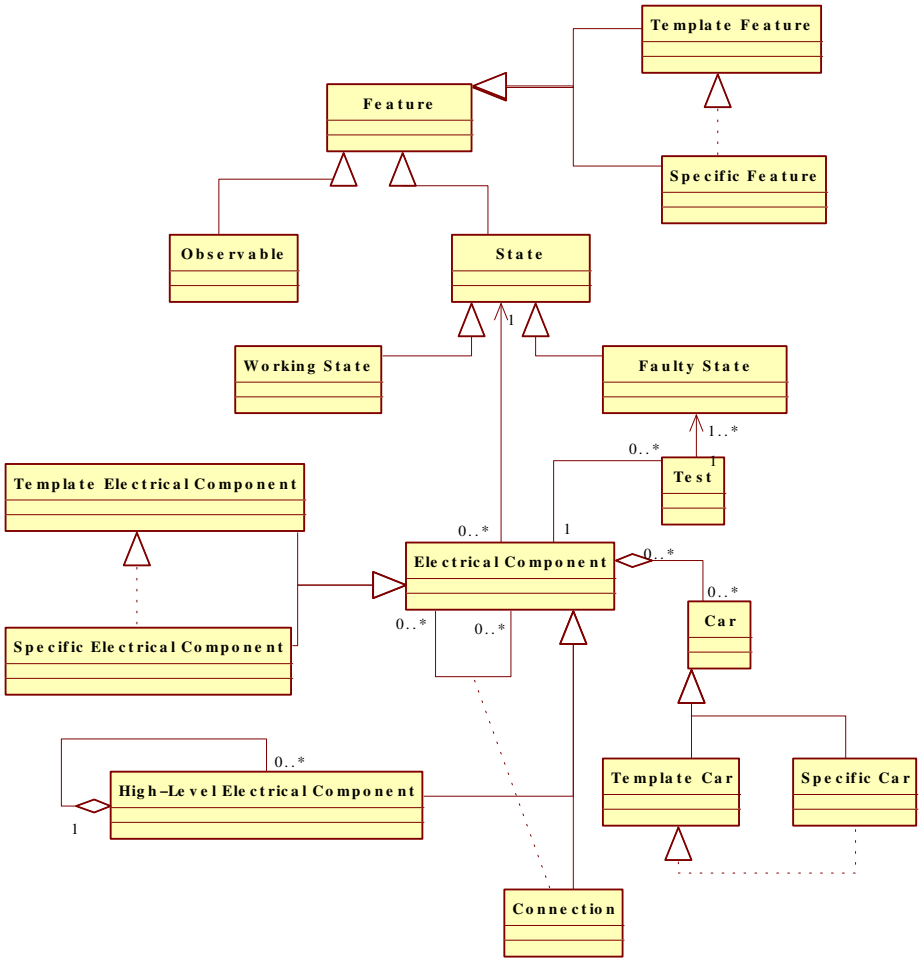

Figure 1: Domain schema for the car diagnoses task

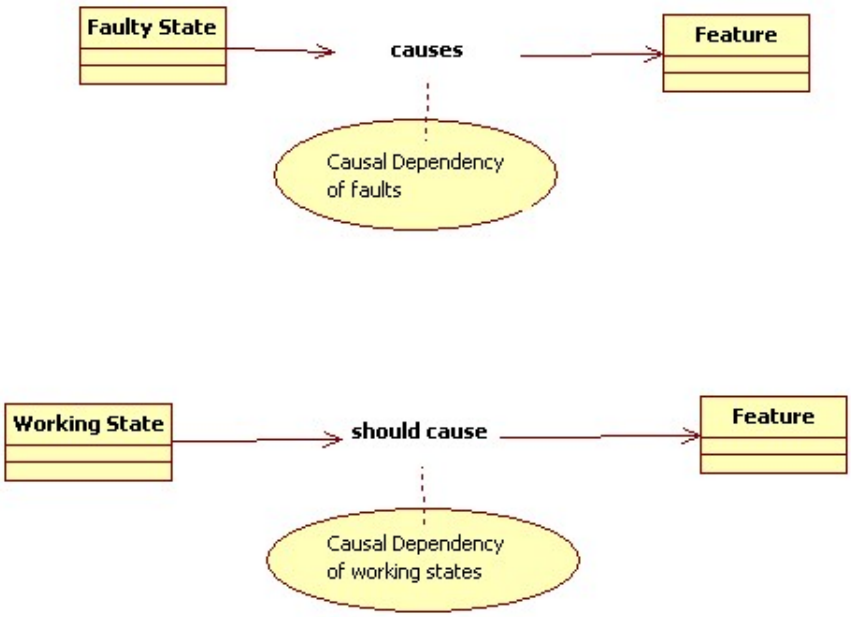

Figure 2: More domain schema

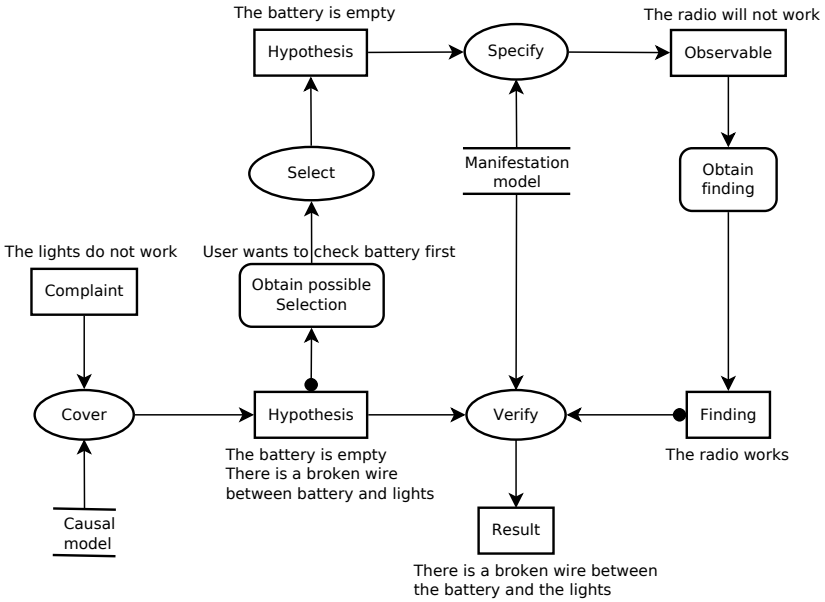

Figure 3: Annotated inference model

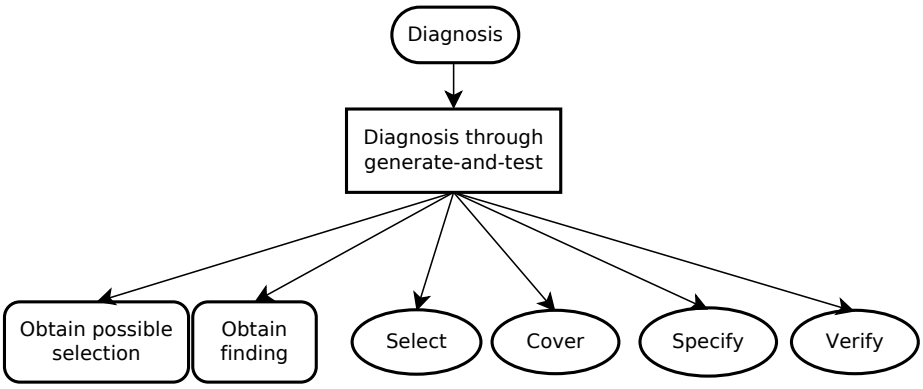

Figure 4: Task-decomposistion diagram for the diagnoses task

3.2 Inference knowledge

3.3 Task knowledge

4 Communication model

4.1 CRA communication plan

4.2 CRA transactions

Communication model	**Transaction Description Worksheet CM-1**
Transaction identifier/name	*Transaction 1: Report complaint*
Information object	Transferring a complaint between the *find complaint* and *cover complaint* task.
Agents involved	*Car repair assistant*: receiving the complaint; *Hobbyist*: sending the complaint
Communication plan	CRA communication plan
Constraints	Before the transaction the car repair assistant must be ready to reiceve complaints
Information exchange specification	See worksheet CM-2 below.

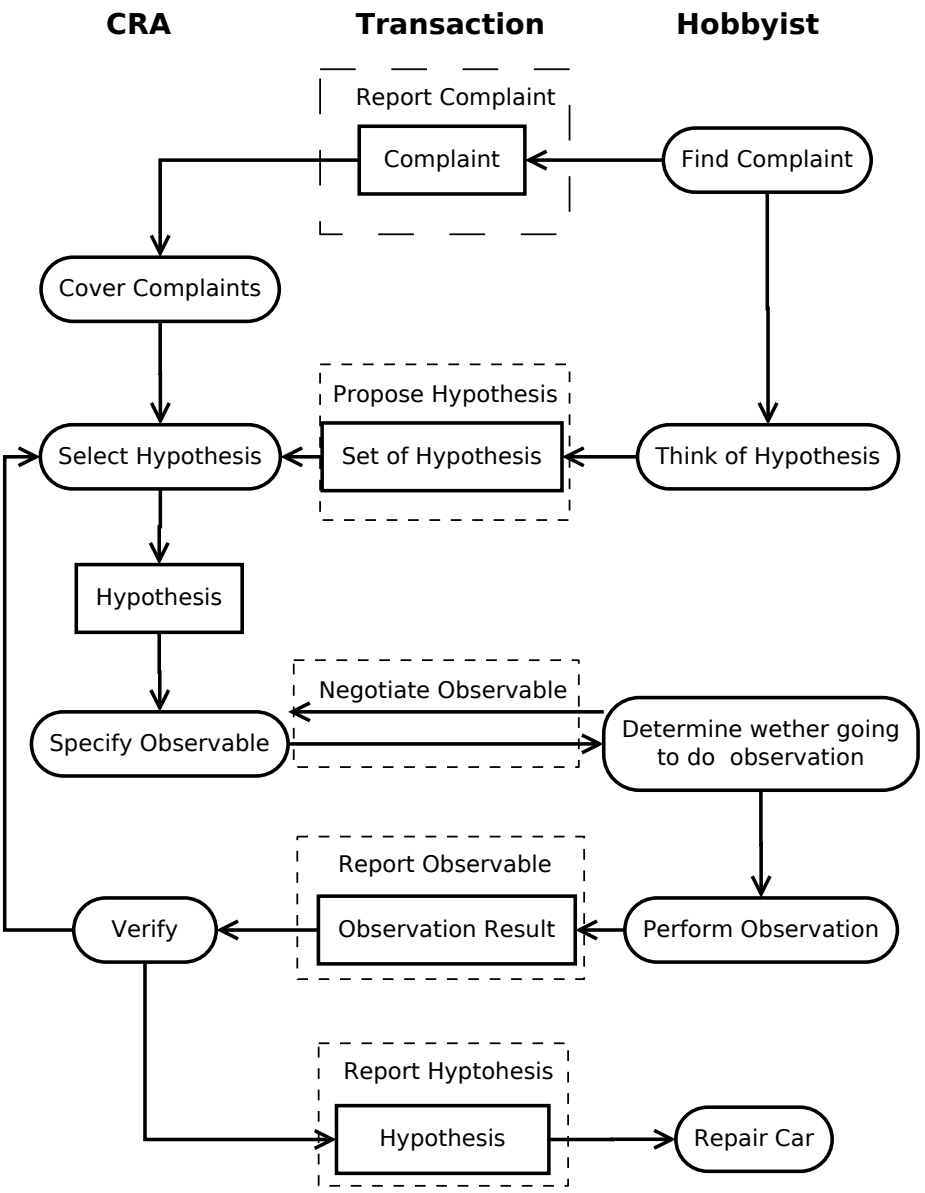

Figure 5: Dialogue diagram of the diagnoses task

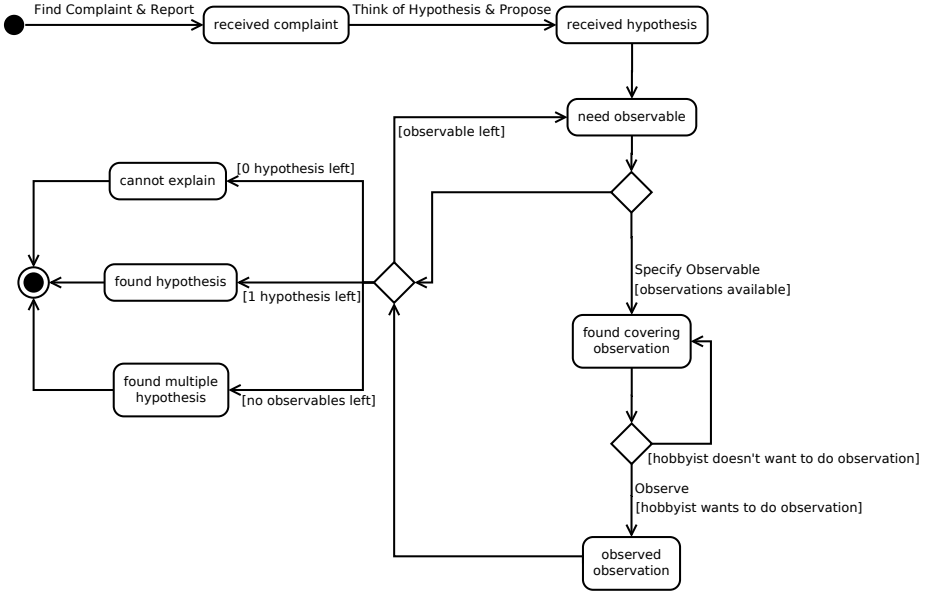

Figure 6: The communication plan of the diagnoses task.

Communication model	**Transaction Description Worksheet CM-1**
TRANSACTION IDENTIFIER/NAME	*Transaction 2: Propose hypothesis*
INFORMATION OBJECT	Transfering sets of hypothesis between the *propose hypothesis* and *select hypothesis* task.
AGENTS INVOLVED	*Hobbyist*: receiving the set of proposed hypothesis, sending a set of hypothesis (might be an empty set); *Car repair assistant*: sending a set of proposed hypothesis; receiving a set of hypothesis
COMMUNICATION PLAN	CRA communication plan
CONSTRAINTS	Before the transaction the car repair assistant must have a set of hypothesis ready. As a post condition one hypothesis has to be selected.
INFORMATION EXCHANGE SPECIFICATION	See worksheet CM-2 below.

Communication model	**Transaction Description Worksheet CM-1**
Transaction identifier/name	*Transaction 3: Negotiate observable*
Information object	Transferring observation instructions between the *specify observable* and *determine whether going to do observation* task.
Agents involved	*Car repair assistant*: sending observation instructions; *Hobbyist*: receiving observation instructions
Communication plan	CRA communication plan
Constraints	Before the transaction the car repair assistant must have a set of observables ready. As a post condition one observable must be excepted.
Information exchange specification	See worksheet CM-2 below.

Communication model	**Transaction Description Worksheet CM-1**
Transaction identifier/name	*Transaction 4: Report observable*
Information object	Transferring observation result between the *perform observation* and *verify* task.
Agents involved	*Hobbyist*: sending observation result; *Car repair assistant*: receiving observation result
Communication plan	CRA communication plan
Constraints	Before the transaction the hobbyist must have carried out the observation instructions and remembered there results.
Information exchange specification	See worksheet CM-2 below.

Communication model	**Transaction Description Worksheet CM-1**
TRANSACTION IDENTIFIER/NAME	*Transaction 5: Report hypothesis*
INFORMATION OBJECT	Transferring hypothesis result between the *verify* and *repair car* task.
AGENTS INVOLVED	*Car repair assistant*: sending hypothesis; *Hobbyist*: receiving hypothesis
COMMUNICATION PLAN	CRA communication plan
CONSTRAINTS	Before the transaction the car repair assistant must have either no observations left or he has one or less hypothesis left.
INFORMATION EXCHANGE SPECIFICATION	See worksheet CM-2 below.

Communication model	**Information Exchange Specification Worksheet CM-2**
TRANSACTION	*Transaction 1: Report complaint*
AGENTS INVOLVED	1. **Sender**(Hobbyist): Initiate repair 2. **Receiver**(Car repair assistant): Initiate repair 3. **Sender**(Car repair assistant): List of components 4. **Receiver**(Hobbyist): List of components 5. **Sender**(Hobbyist): Component 6. **Receiver**(Car repair assistant): Component 7. **Sender**(Car repair assistant): List of malfunctions 8. **Receiver**(Hobbyist): List of malfunctions 9. **Sender**(Hobbyist): Malfunction 10. **Receiver**(Car repair assistant): Malfunction
INFORMATION ITEMS	
INITIATE REPAIR	1. **Role**: A core information object. 2. **Form**: A boolean indicating the start of a repair process 3. **Medium**: By starting the program using an icon or command
LIST OF COMPONENTS	1. **Role**: A support information object. 2. **Form**: A list of strings 3. **Medium**: As menu items
COMPONENT	1. **Role**: A core information object. 2. **Form**: An identifier 3. **Medium**: As a selection within a menu
LIST OF MALFUNCTIONS	1. **Role**: A support information object. 2. **Form**: A list of strings 3. **Medium**: As menu items
MALFUCNTION	1. **Role**: A core information object. 2. **Form**: An identifier 3. **Medium**: As a selection within a menu
MESSAGE SPECIFICATIONS	
INITIATION-MESSAGE	**Communication type**: ORDER **Content**: Initiate repair **From**: Hobbyist **To**: Car repair assistant
COMPONENT-LIST-MESSAGE	**Communication type**: ASK **Content**: List of components and the request to chose one **From**: Car repair assistant **To**: Hobbyist
COMPONENT-MESSAGE	**Communication type**: REPLY **Content**: Component **From**: Hobbyist **To**: Car repair assistant
MALFUNCTION-LIST-MESSAGE	**Communication type**: ASK **Content**: List of malfunctions and the request to chose one **From**: Car repair assistant **To**: Hobbyist
MALFUNCTION-MESSAGE	**Communication type**: REPLY **Content**: Component **From**: Hobbyist **To**: Car repair assistant

Communication model	**Information Exchange Specification Worksheet CM-2**
TRANSACTION	*Transaction 2: Report complaint*
AGENTS INVOLVED	1. **Sender**(Car repair assistant): List of components 2. **Receiver**(Hobbyist): List of components 3. **Sender**(Hobbyist): Component 4. **Receiver**(Car repair assistant): Component 5. **Sender**(Car repair assistant): List of malfunctions 6. **Receiver**(Hobbyist): List of malfunctions 7. **Sender**(Hobbyist): Malfunction 8. **Receiver**(Car repair assistant): Malfunction
INFORMATION ITEMS	
LIST OF COMPONENTS	1. **Role**: A support information object. 2. **Form**: A list of strings 3. **Medium**: As menu items
COMPONENT	1. **Role**: A core information object. 2. **Form**: An identifier 3. **Medium**: As a selection within a menu
LIST OF MALFUNCTIONS	1. **Role**: A support information object. 2. **Form**: A list of strings 3. **Medium**: As menu items
MALFUNCTION	1. **Role**: A core information object. 2. **Form**: An identifier 3. **Medium**: As a selection within a menu
MESSAGE SPECIFICATIONS	
COMPONENT-LIST-MESSAGE	**Communication type**: REQUEST **Content**: List of components and the request to chose one **From**: Car repair assistant **To**: Hobbyist
COMPONENT-MESSAGE	**Communication type**: PROPOSE **Content**: Component **From**: Hobbyist **To**: Car repair assistant
MALFUNCTION-LIST-MESSAGE	**Communication type**: REQUEST **Content**: List of malfunctions and the request to chose one **From**: Car repair assistant **To**: Hobbyist
MALFUNCTION-MESSAGE	**Communication type**: PROPOSE **Content**: Component **From**: Hobbyist **To**: Car repair assistant
NO-HYPOTHESIS-MESSAGE	**Communication type**: REJECT-ta **Content**: Component **From**: Hobbyist **To**: Car repair assistant
CONTROL OVER MESSAGES	See code below.

```
SEND(COMPONENT-LIST-MESSAGE)
REPEAT WHILE <no NO-HYPOTHESIS-MESSAGE received>
  IF <user wants to suggest a hypothesis>
  THEN
    IF <COMPONENT-LIST-MESSAGE received>
    THEN
      SEND(COMPONENT-MESSAGE)
    END-IF
    IF <MALFUNCTION-LIST-MESSAGE received>
    THEN
      SEND(MALFUNCTION-MESSAGE)
    END-IF
  ELSE
    SEND NO-HYPOTHESIS-MESSAGE
  END-IF
  IF <COMPONENT-MESSAGE received>
  THEN
    SEND(MALFUNCTION-LIST-MESSAGE)
  END-IF
  IF <MALFUNCTION-MESSAGE received>
  THEN
    PROCESS(store-hypothesis)
  END-IF
END-REPEAT
```

Communication model	**Information Exchange Specification Worksheet CM-2**
Transaction	Transaction 3: Negotiate Observable
Agents involved	1. **Sender** CRA send a request for an obervation, and an explanation of that observation 2. **Receiver**: The hobbyist receives the request for an observation, and an explanation.
Information items	
	There is two information objects, the name of the observation to be done, and an explanation of that obervation. 1. **Role**: The name of the observation is core, while the explanation is support. 2. **Form**: The name of the observation is a string. The explanation is canned rich text. 3. **Medium**: The name of the observation can be selected in a menu. The explanation can be shown in a text box.
Message specifications	
1. REQUEST-OBSERVATION	**Communication type**: REQUEST **Content**: Request for some observation **From**: CRA **To**: The hobbyist
2. OFFER-OBSERVATION	**Communication type**: OFFER **Content**: The Hobbyist wants to do a certain observation **From**: The hobbyist **To**: CRA
3. DO-OBSERVATION	**Communication type**: ORDER **Content**: explanation and observation the hobbyist needs to make **From**: CRA **To**: The hobbyist
4. REJECT-OBSERVATION-REQUEST	**Communication type**: REJECT-ta **Content**: Don't want to do this observation **From**: The hobbyist **To**: CRA
5. REJECT-OBSERVATION-OFFER	**Communication type**: REJECT-td **Content**: Explanation why that observation is not needed **From**: CRA **To**: The hobbyist
Control over messages	See figure 7.

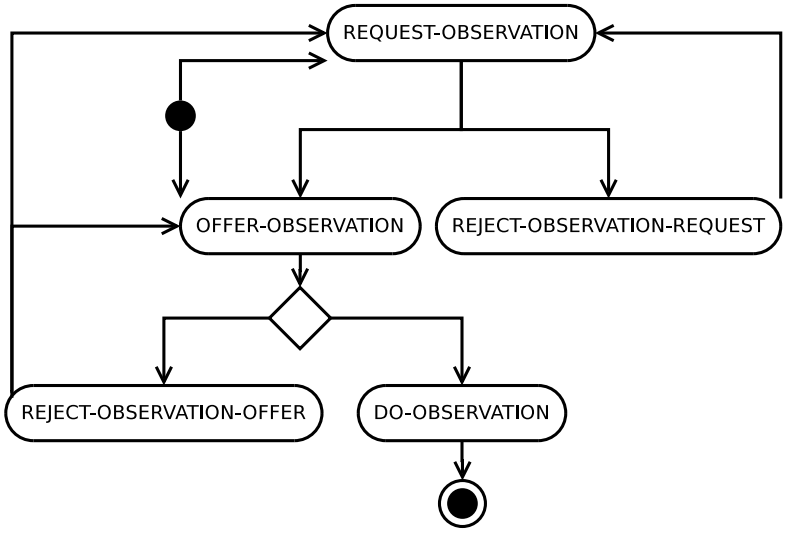

Figure 7: Control flow of the negotiate observable transaction

Communication model	**Information Exchange Specification Worksheet CM-2**
TRANSACTION	*Transaction 4: Report observable*
AGENTS INVOLVED	1. **Sender**(Car repair assistant): Observation result options 2. **Receiver**(Hobbyist): Observation result options 3. **Sender**(Hobbyist): Observation result 4. **Receiver**(Car repair assistant): Observation result
INFORMATION ITEMS	
OBSERVATION RESULT OPTIONS	1. **Role**: A support information object. 2. **Form**: List of strings 3. **Medium**: Varies, it might be a menu or it might be a free form with suggestions noted separately
OBSERVATION RESULT	1. **Role**: A core information object. 2. **Form**: Varies, it might be a identifier, a number or a string. 3. **Medium**: Varies, it might be selection in a menu or it might be typed in a field.
MESSAGE SPECIFICATIONS	
OPTION-MESSAGE	**Communication type**: ASK **Content**: Observation result options and the request to provide the actual observation result **From**: Car repair assistant **To**: Hobbyist
OBSERVATION-MESSAGE	**Communication type**: REPLY **Content**: The observation result **From**: Hobbyist **To**: Car repair assistant

Communication model	**Information Exchange Specification Worksheet CM-2**
TRANSACTION	*Transaction 5: Report hypothesis*
AGENTS INVOLVED	1. **Sender**(Car repair assistant): Hypothesis 2. **Sender**(Car repair assistant): Hypothesis argumentation 3. **Sender**(Car repair assistant): Repair plan 4. **Receiver**(Hobbyist): Hypothesis 5. **Receiver**(Hobbyist): Hypothesis argumentation 6. **Receiver**(Hobbyist): Repair plan
INFORMATION ITEMS	
HYPOTHESIS	1. **Role**: A core information object. 2. **Form**: A string stating the hypothesis 3. **Medium**: Displayed in the main window
HYPOTHESIS ARGUMENTATION	1. **Role**: A support information object. 2. **Form**: A list of strings each stating one reasoning step 3. **Medium**: Displayed in the main window
REPAIR PLAN	1. **Role**: A support information object. 2. **Form**: A text, possibly with images 3. **Medium**: Displayed in the main window
MESSAGE SPECIFICATIONS	
HYPOTHESIS-MESSAGE	**Communication type**: REPORT **Content**: The hypothesis, the hypotheses argumentation and the repair plan (plan depending on car repair information) **Reference**: car repair information **From**: Hobbyist **To**: Car repair assistant