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Abstract. This work is intended to form an investigation in concept understanding, along with their representations in various environments, in order to facilitate the Swedish organizations with complex object browsing and navigation in a flexible and efficient fashion. The work involves two main aspects regarding the proposed facilities: internal structures of concepts, and external schemas for concept representations, as well as a variety of relationships both between concepts and between the internal structures and the external schemas.

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Introduction

First of all, let us suggest a possible scenario of observing (navigating) a building.

- Very commonly, people see the building from the front, the side, and the top. We call this view a 3-dimension view. Of course we may have a 6-side view of an object if it is hanged in the air. We percept the building by taking a superficial overview (*panorama*) of the building.

- Possibly, from the viewpoint of designers or house-buyers, they may like to have a *section* view of the building, horizontal or vertical. That is, cut the building, say, horizontally, and have a look top down. This can be considered to be still an overview of the building, but viewing on its internal structure and distribution.

- People may also enter the building and walk into a specific room. The room may be of special interest to the people, who would like to *focus* on the room.

The above three views of a building may be considered to be requirements for observing the building. Different users may have different requirements on observing a building. What is our target group of users should be clearly defined, and what they want or require should be as well clearly defined.

As we have already described, different views of an object can be observed according to people's intention and focus on the object. People's intentioned foci on objects are generated from the concepts and the relationships between the concepts, which are percepted by people. In general, people use a concept model, e.g., an entity relationship model, to describe concepts, the properties of concepts, and the relationships between concepts. An instance of a concept model is usually called a *schema*. Initially, a concept, or schema, may have following characteristics:

- An internal structure. This is an internal representation of a concept. As defined in [Song95, p.100], a concept (named as an object in order to fit to people's frame of a concept) is a triple: <name, attributes, extension>.This representation is not necessarily unique.

- A presentation. This is the external representation of a concept in a schema. In general, the external representation of a concept is its name. Semantic conflicts may arise if the same name is used for different concepts or different names for the same concept.

- A view (or multi-view). Various views may be taken to express one concept. Views are usually associated with how people define the concept. Conflicts may arise between different views for the same concept whereas multiple views of a concept may give a better description and entirety of the concept.

- One or several related symbols. Symbols of a concept are those that appear on computer screen. One symbol may be just as simple as a corner-rounded box, while another symbol may be a moving, physical object of the concept.

The importance of concept modelling has been recognized for long. The importance of concept relationship modelling or description has gradually recognized. And the recognization has been strengthened by modelling complex objects, i.e., relationships between a super-concept and its sub-concepts. For instance, a "part of" relationship can be created between *car* and *engine*.

An essential aspect of managing complex objects lies in how to organize them, i.e., how to structure the objects from different sources so that they can be searched and browsed effectively and efficiently. Among others, a number of structures for objects are suggested: hierarchy - objects can be grouped in terms of the relationships between their super-concepts and sub-concepts, networking - objects are collected by their links with other related (directly or indirectly) objects, and clustering - objects are grouped by their properties and keywords.

In this report, we attempt to establish a sort of relationships between an internal structure and external representation of a concept. We try to define the problem of relationships between entirety and components(relationships between concepts representing the entirety of an object and concepts representing parts of the object).

We will also discuss the technical possibility to implement our method solutions to complex object representation, refinement, browsing, and navigation by analyzing various existing methods and tools facilitating internet and WWW communication and display.

State of the art

Concept model and external schemas

The research work in concept modelling can be seen in these two aspects: The first is to model concepts or objects in the reality. One representative of such concept models is Entity Relationship Model. In a concept model, the basic constructs, among others, include usually entity type or object type, relationship type, and attribute type. One goal of such concept modelling methods is to express real objects and their relationships, as well as their properties of a domain of interest, and to form a systematic description, in either textual or graphical forms, for the domain. The resulting schemas, i.e., descriptions in modelling language, are used for database design in a next step [Song92, Song94].

The second aspect is to associate conceptual modelling in a context of requirements engineering, where it plays a role of support in defining concepts or objects and relating them to each other used in a schema of requirements modelling. A goal of such concept modelling is to clarify the objects which are used in the other modelling schemas, like goal model. An example of this type of concept models is Concept Sub-model in F3 Enterprise Model [Bubenko93, F3-Consortium94]. Due to the diversity and complexity of requirements model, the related concept model should be flexible to fit to a variety of user's needs.

Semantic capture for a concept

A number of methods have been proposed to describe a concept and relationships between concepts being described. There are three approaches discussed in [Sowa84] to capture or define the semantics (concept) of a word: 1) using type definition, 2) using a prototype and 3) using schemata. *Type definition* of a word (concept), in general, is to give its genus and differentia. In a simpler way, we may explain it as that to define a word is to find out its super-concept (of course symbolized by a word) and one or several properties which differ the word to be defined from the words which represent the rest concepts within the super-concept. However, it is rather difficult to find a suitable super-concept and the properties which exactly identify the word to be defined[1]. *Prototype* approach is to recognize a word (concept) against an existing set of properties. When the word resemble all the properties, it is considered to be identified.

However, the problem here is how to obtain the needed properties and according to what criteria to group the properties. *Concept schemata* are considered as a kind of means to acquire the properties of a word (or a concept). For each concept symbolized by a word, schemata describe the conventional, normally occurring, or default roles that it plays with respect to other concepts. Comparing to the type definition method, where for example, the definition of Employee will present the primary (identically, uniquely) defining characteristic, a schema would include the neighbouring information about Employee such as having an employee number, earning salary, reporting to a manager, working in a department, and so forth, all of which together form the properties of Employee and may uniquely identify it.

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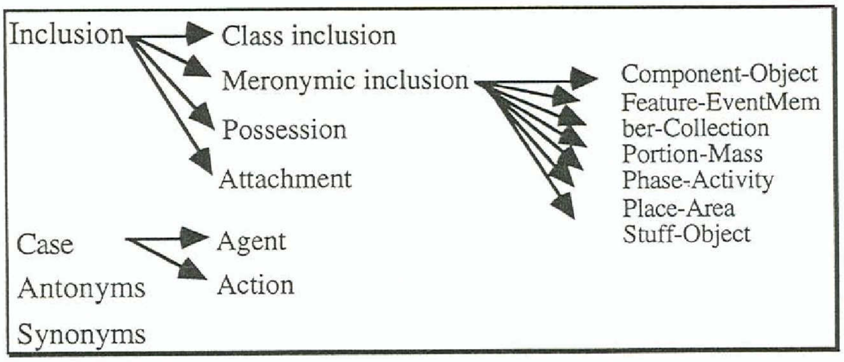
[1]In addition, normally the definitions are in natural languages,therefore difficult to deal with by computer.

Concept relationships



A number of methods have been proposed to describe the relationships between concepts being described. The inquiry to a deep analysis of semantic relationships in semantic data models [Storey93], discusses various characteristics and representations of semantic relationships, used in different modelling schemas. Here we give a short summary of the relationship categories Storey proposed in the figure above.

Groupware - cooperative

"Collaboration" over the World Wide Web is a very broad area of research, involving wide-reaching issues such as knowledge representation, annotation of objects by objects, notification, and any other issues which arise in the creation of shared information systems and collaborative development.

Computer-Supported Cooperative Work (CSCW) has been an issue of active research for more than a decade. The World-Wide Web offers unique possibilities as an underlying infrastructure to support collaborative work across the internet. On the other hand, the architecture of the Web imposes some barriers to CSCW applications that are hard to overcome. Over the last year, Web-based collaborative applications have started to emerge.

Multimedia and internet communications

A variety of methods and tools, which will be described in the following sections, have been presented to support a wide range of searching and browsing in plain texts, images, and even voice and movies. In general , they support in design of

- Mediator, which connects various applications providing manipulations on data through internet or the web.
- Interface, which offers paths and operations on various data sources in local sites or intranet.
- Access, which supports gateways to different remote applications and databases via internet.

Object browsing and queries

In [Kim, etc. 88], operations and implementation of complex objects are defined, where complex objects are considered to be the units of sharing among configurations of higher level entities. The complex objects discussed there appear in the context of

CAD/CAM AI and OIS. An approach to complex object description is based on a set of attributes which give characteristics of the object. A group of manipulations and queries are suggested for processing complex objects.

Schemas in the industry

A lot of domains in the industry require large, complex schemas in various forms to convey information. For example, schemas are used for describing electricity systems, hydraulic systems, and mechanic systems.

Traditionally these schemas are represented as drawings, pictures, and even texts. As companies are moving into the era of computer-based information technology, to make use of a variety of computer supported media in not only indispensable, but displays a promising opportunity in the future.

The portable personal computer is used by many organizations as a tool for service technicians. CD-ROM and mobile communication make it possible for technicians to have instant access to up to date information when doing field work. Examples of such applications are MULTI (Scania Trucks and Buses) and PROSIS (Volvo Construction Equipment), developed by ENEA. These applications handle service information such as spare parts, reparation manuals, working schemas, et cetera.

Object structures and their maintenance

Industrial products are usually represented by using a hierarchical structure. A product typically consists of a number of major functional blocks or groups, which, in turn, can be split into several smaller functional blocks or sub-groups. Such structure is usually related to modules, where each functional block may correspond to one or several modules which together construct a product. Using a truck as an example, one major group can be engine. The engine can be decomposed into components, like engine block, cooling system, camshaft, cylinders, spark plugs, and so on. These components can be further detailed by their sub-components.

There exist a number of different structures or constructs used in industrial products. For instance, Volvo uses a product structure system based on function blocks or groups consisting in several levels. Each level has ten groups, numbered from 0 to 9. The maximum number of levels is currently five. The function group number 234, for instance, is interpreted as subgroup 4 of subgroup 3 of main group 2. It can be contrasted to the chapters and subsections in a report or a manual. In this case the section number will be 2.3.4. Scania has a similar product structure called BTI.

Information objects, such as truck components and reparation manuals, are usually stored in a variety of formats and in different database systems. Data used by the PROSIS and MULTI applications mentioned above, for example, are managed in the following different ways:

- The data for spare parts are stored and maintained in a database under a mainframe.
- Reparation manuals are stored in SGML-files. Service editors are responsible for maintaining this information.
- Working schemas and other images are also stored as files. These files are either of digitized hand-drawn images, or of 2-dimensional vector images.

In addition, efforts are being put in standardization of organizing products and their structures. One such initiative within the trucking industry is VMRS (Vehicle Maintenance Reporting Standards), a standard established and maintained by ATA (American Trucking Associations). VMRS is a set of codes developed to facilitate computerized tracking of parts and labour used in equipment repair.

Tool and method support

In the following, we introduce a number of new information technologies for support in information system development and information service improvement. Most of them have been world widely accepted as standard means for application and interface mediator development.

CALS (Continuous Acquisition and Life-Cycle support). CALS began as a US defence industry and government strategy to integrate systems development, production and support. The CALS standard is a collection of various standards and formats. Formats of interest with respect to concept modelling and schemas are:

- CGM (Computer Graphics Metafile, MIL-D-28003) is a format for description of vector and raster objects. Simple support for application structures are included.

- IGES (Initial Graphics Exchange Specification, MIL-D-28000 and ANSI Y14.26M) is a format for description of graphics data for CAD applications. It is designed for exchange of mechanical product drawings between dissimilar Computer Aided Design (CAD) systems. Support for application data is better than with CGM. Efforts are being made to extend IGES to cover a broader range of product data.

- Raster (CCITT Group 4, MIL-R-28002) is a format for description of raster data. This format does not include any form or meta-information, such as information about objects in the image.

- SGML (Standard Generalized Mark-up Language, MIL-M-28001 and ISO 8879) is a format for description of document structure information via tags embedded in the document text.

- STEP (Standard for the Exchange of Product Model Data, ISO 10303) is a format to describe product data for processing throughout all stages of the product's life cycle. The goal is to enable a product representation to be exchanged without any loss of completeness or integrity. STEP includes the information modelling language EXPRESS.

The development of the World Wide Web has introduced new standards of potential interest:

- HTML (Hyper Text Mark-up Language) is a fixed subset of SGML used to describe document structure via tags embedded in the document text.

- VRML (Virtual Reality Modelling Language) is used to describe 3-dimensional models.

Another initiative is OLE for Design & Modelling, a set of OLE extensions that enables 3 dimensional objects from different vendors to be integrated in Microsoft Windows applications using OLE technology. The specification was originally developed by Intergraph Corp., and is an published standard.

Two tools can be seen as representatives in mediating various Web methods and applications and integrating them together [Song96]. They are *ActiveX* by Microsoft and *ObjectStore* by Object Design.

ActiveX suggests a new method, based on the Web browser, to access to different applications, such as database system management, existing architecture of client/server, and various programs. It also merits of access to different working environments. ActiveX provides us with a work bench, based on the Web browsing, of using various resources offered for object acquisition, representation, and navigation.

ObjectStore provides a natural solution for all the data type requirements of the Web, now and in the future. ObjectStore was architected from the ground up to be extensible and store data types of any type. So, storing a Web object and meta data which describes the object is a natural ObjectStore function. What others call extended, ObjectStore provides standard.

The second major requirement for a Web database, and perhaps even more important, is managing extended relationships. It is not sufficient just to store these new extended data types. Web objects themselves have a "web" relationship, that is, multiple, complex interrelationships (1 to 1, 1 to many, or many to many). New Web applications require the ability to define relationships between objects and retrieve objects by traversing these relationships. Modeling these extended relationships is difficult and performance suffers with relational databases. Unlike a logical "join" operation of the relational model, ObjectStore's direct reference architecture provides superior modeling capability, improved usability and great flexibility.

One of the ramifications of this object model is fast traversal of these extended relationships at computer memory speeds. No searching, no joining, no indices. Just real-time response! An additional benefit of ObjectStore's direct-pointer architecture is scalability. ObjectStore support of extended relationships provides predictable near linear performance as database size increases.

Problems

Some problems should be identified in order to display our intention and ways to solve them. Initially, we try to break down the problems in the following three aspects: The first one is concerning conceptual schemas, where problems are directed toward various representations of concepts or objects. Importance here maybe the identification of objects - physical or visible existence, and concepts - invisible percepts. We also focus on the relationships between general concepts and their sub-concepts.

Browsing and searching is the second aspect we will look at, where problems may be the relationships between various representations, both between internal ones and external ones, as well as between the representations of various forms, for instance, 3D objects with respect to moving objects, overview with respect to detailed components, et cetera.

Tool selection or design can be an important aspect, since we have to group together various viewing facilities to support object illustrations, their browsing and searching, and possible associations between these facilitating functions. We believe that a survey of browsing and navigation tools is vitally critical to the success of the work we intend to pursue.

Conceptual schemas

- Complexity problems. Causes for difficulties with interpreting schemas can arise as a result of too many concepts, too many relations between concepts, and too many types of concepts in one schema.

- Conflicts in multi-view representations. Due to the distinction in people's understanding and representation of concepts, conflicts arise in semantics and structures now and then. These conflicts have to be resolved in order to gain a correct and exact view of concepts. Many approaches have been proposed toward the resolutions of the problems of semantic and structural conflicts [Song, thesis, 95].

- Hierarchical representation vs. networking representations of concepts. Atypical hierarchical representation of concepts is to connect concepts through "is a" relationship type. Such relationship type provides a navigation of concepts in term of their specialization. Another typical one is "part of" relationship type, which supports a navigation of concepts according to a concept's entirety with respect to its components. There are more relationships, which have been described in [Stoery93].

- Specific foci vs. general overviews. By entering a general concept, people like to focus on some special parts or components of the concept. These parts are also concepts, termed generally as "sub-concepts". The importance here lies in a reasonable path to be established for the navigation or searching from the general view of the concept to its specialized, particular, and focused views of the sub-concepts.

- External schemas vs. internal structures. In concept modelling, external schemas, ones that we can contemplate on computer screen, should be correctly associated to their internal structural representations. In general, an internal structure of a concept or a group of concepts is uniquely defined and expressed, whereas corresponding to it there may be a number of external schemas, each representing either one part or one view of the internal structure. In either case, representational conflicts should betaken into account, like overlapping parts.

- Various representation forms vs. unique external schemas. We may define that an external schema is a representation of an internal structure of a concept in terms of a conceptual modelling method, say, F3 enterprise model or entity relationship model. Various media can be used for displaying the external schema. We assume that an external schema is a workbench, on which various user views can be represented while their physical illustrations will be displayed, for instance, on pictures, voice, etc.

Browsing schemas

- Overviews vs. detail specifications. From an overview, we can browse one or several major objects which give us a whole picture of what interests us. Then we can reach detailed objects (refined objects) at any level of detail we hope to focus on particular components. Bouncing back and forth between the general view (major objects) and particular, specialized detailed views (object components) should be supported. Tree like structure of objects for navigation and browsing is a common means to group the objects regarding a specified work or product. Easy regression and recovery should be also considered.

- There is a conflict between totality and detail, in that it is difficult to maintain an overall view while viewing details. It is often impossible to have the overall view while working with the lowest details. Similarly, it is impossible to show every detail when giving an overall view of the totality.

- Focused objects and their neighbourhood. Networking-like searching and browsing can be a second important means to organize objects for navigation while tree-like structure is a first one. The networking method provides us with looking at and searching objects with respect to their relationships with the objects surrounding them.

- If the above two methods are considered to be spatial searching and browsing, a procedure-oriented navigation means can support temporal searching and browsing. That is, walking through objects or activities in time sequence. Processing tasks, modelled in Enterprise Model, can be seen as time sequential search, with functions of back tracing.

- 3 dimension symbols. Even though a 2 dimensional schema provides a useful abstraction, it can sometimes be abstract and difficult to interpret. It can, for example, be difficult to relate an 2 dimensional schema to the real world object. Illustrating an object in a 3-dimensional space will produce a realistic effect on people. The realistic exists not only in the object being displayed, that people can observe its 6 sides (when the object is turning around in the space), but in its touchable relations with the objects around in the space as well. Furthermore, the use of 3 dimensional models which contain objects linked to abstract schemas, making it possible to go back and forth between the two, is insufficiently focused.

- Textual vs. graphical presentations. A combination of textual and graphical illustrations of objects is frequently used now. Based on the type of objects and people's interest, textual manner can be used as complementary to graphical one and vice verse.

Tool support

- Developing tools or using existing tools for browsing and searching. Many tools and methods have been provided as to navigate various sources for obtaining information, for instance, World Wide Web, which is based on the textual browsing facility. To use existing tools browsing and searching tools and methods, with the support of tools bridging facilities, can be a suitable way to manage the vastly complex objects navigation in different domains, problems, and products.

- Several problems, not present with printed schemas, arise when using computer tools. The presentation surface is small, much smaller than what is possible with paper. This means that fewer objects can be presented at time, given that the same level of detail is used. The computer screen has much lower resolution than paper. This makes it difficult to present small details with clarity. Furthermore, lack of physical contact with the medium makes it difficult to get a feel for the amount of information available and the structure of the information [Kindborg91].

Analysis and solutions

Navigation

It must be easy and quick to find the information that one needs. Above, we concluded that since computer stored information can not be "touched and sensed" in the same was as printed paper, it can be problematic in knowing which information is available. It can also be difficult to know whether one has found all relevant information on a particular subject. Moreover, there is a risk that one gets disoriented due to the presentation problems outlined above.

Despite these perception problems, a wide array of techniques has been provided for browsing and searching information, making it easier and faster to find what one is looking for.

Navigation and presentation are intimately related. The presentation will help the user to understand and navigate the underlying model. The way the user can navigate a large, complex model will help building an understanding of how it is structured and what it aims at.

Presentation

The presentation is a visual representation of an underlying model. The use of sound is much less developed, but has interesting potentials.

Information can be also presented using texts, pictures, and/or moving images.

Text is highly visual. Text can be structured and formatted in various ways, presented using colour, different layout for different information et cetera. Text can be interacted with, like hypertext in a WWW-browser and expandable text in an hierarchical outliner. Text can carry much visual structure. Different aspects of a model can be visualized using different indexes and layouts.

Pictures include drawings, paintings and photographs. A picture can contain objects which are presented at different levels, such as schematic, abstract, concrete, simplified, detailed, and embedded objects, et cetera.

Moving images can offer more information, in addition to that in still pictures. Dynamic processes, such as events, sequences, and flow can be communicated using animated sequences and/or taped video fragments. Different techniques can be combined, animating the flow of electricity or gas in an abstract schema, with related video showing real world images.

Orientation

A variety of techniques exist for giving an overall view of information, helping users to orient themselves with respect to the structure of the information, that is, to know where in the structure a certain piece of information is located. Most common are maps of different types, selective presentation of information, detail hiding, and simplified views [Kindborg91].

Maps. A schema is in itself a kind of map of a model. Maps can be of many types, showing both abstract and concrete representations of information.

Selective display. Like a geographical map showing political or economic views, schema map scan show selected information. Details could be hidden or emphasized, for instance using highlighting for a selected object type and its relations in the schema.

Relating detail and totality. When the detailed information is shown, it can be related to the whole using, for instance, miniaturized maps. Such a map is shown together with the detailed information, and shows the context of the detailed view. This technique is often used in news graphics and is also common in computer programs.

Fisheye views. Such views allows users to see the details in the part of a model to be focused, while the surroundings are shown on a less detailed level. The contextual information relates the details to the whole which helps orientation. [Furnas86].

Superimposed map. Many computer games superimposes a map on top of the detail view. This can be annoying initially, but is often quite effective when one is used to it.

Meta maps. Rather than just selecting what the map displays, a map showing the meta-level could be used to show a simplified view that is easier to grasp than the fully detailed map.

Browsing and searching

Despite the problems outlined above, the computer offer a wide array of techniques for browsing and searching information [Petterson91].

By browsing we mean free search by successive selection of information elements, where the user moves through the information space using various navigation techniques. By searching we mean query-based search, where a set of search results is returned to the user. These techniques can be combined. Both browsing and searching can be text and/or image based.

Browsing - Text. Hypertext browsers, like the Netscape WWW-browser is an example of text-based browsing. Outliners, like the File Manager in Windows, is an example of a text-based browser not using the hypertext metaphor. The browser in the Smalltalk programming environment is another example of such a browser [Goldberg83].

Browsing - Images. Hypertext browsers can also use pictures, clickable image maps with hot spots that links to other information elements. Zooming and panning are examples of navigation techniques that are not hypertext based. CAD-programs often use these navigation techniques. Zooming can be divided into optical zooming, where the image is enlarged or reduced, and structural zooming where the image content alters dependent on the level of detail.

Searching - Text. Text-based queries are by far the most common. This type of search could be extended from simple character-based search, to pattern-based and structure-based search.

Searching - Images. Structural aspects, like shape and colour, of an image could be searched. This is possible with, for instance, the Informix Illustra database tool. In a schema object patterns and object relations could be searched by specifying a query visually. One could also search by similarity, "Show all objects that has the same relations as this object". Pattern based searches can use a variable similarity factor, allowing the used to specify how close an object must be to match a query.

All of the above techniques could be combined. A schema browser could for instance use both hypertext-based browsing and zooming and panning. Search for object patterns or relations could be used in a browser to facilitate rapid navigation.

Object organization and tool support

There is a need for methods and tools that can handle and integrate information maintained by different departments in an organization, who are using different data formats and different computer platforms.

This requires an organization to make it possible to exchange information between different users and environments. Different standard and tools are often used by, for instance, the construction department and the service department. There is a strong need to find ways of using and integrating information produced by different departments, so that a concept navigation tool can make use of schemas, CAD-drawings and other data relevant to the end user.

For the user to fully utilize concept models, it must be possible to view and navigate models in ways such as those outlined above. The information must therefore include data that enables searching and browsing.

Conclusion

As we have discussed, a method and supported tool for effective and efficient navigation to complex objects and cooperation of different application environments proves to be indispensable. Problems that we may encounter in complex object browsing and navigation within heterogeneous application domains are practically critical to industrials of information intensive areas. It is necessary to build up an interoperable means to access different browsing and searching tools and information bases to enhance the usability of various information systems and the services thereof.

Furthermore, the process of development of navigation and interoperation facilities for complex objects in application domains should be based on a solid study of internal structures and external schemas of concepts (or objects) within concept model. For years, SISU has put lot of efforts in the concept model investigation and research and formed a set of applicable results for concept analysis, representations, and manipulations.

The applications developed by ENEA is one step towards more sophisticated ways of browsing and searching information. Of particular interest is navigation of complex working schemas, which is a common problem for many industrial applications.

We propose that the following framework in order to pursue issues within the use of complex schemas in the industry:

1. The application domain is focused on maintenance and reparation of heavy industrial products, such as trucks and construction equipment, where a service engineer needs to use complex schemas in his work, for instance electrical schemas. Computing environment is standard such as a personal computer running Windows 95 or Windows NT.

2. Schemas are stored in a format that makes it possible to extract information for the product structure. This structure is needed in order to facilitate efficient browsing and navigation. We suggest to investigate how to use standard formats such as IGES (Initial Graphics Exchange Specification) in our applications. IGES is a format for description of graphics data for CAD applications. The product structure needs to be linked to the CAD data. We also suggest to apply VMRS (Vehicle Maintenance Reporting Standards) techniques as a candidate for describing product structure and organization.

3. The browser used to browse and navigate the complex schemas should improve the quality and efficiency of the service engineer's work significantly. The browser should make it easy to find information at large, in the complex schemas, and to track dependencies and relations between components in the schema. It is essential that dynamic presentations and interaction techniques are used to compensate the computer's small display surface, hence to use the complex schemas in more efficient ways. In order to develop such a browser more efforts are necessary, and the related problems and possible solutions should be also clearly defined.

We believe that the solutions to our problems in complex object navigation and browsing are feasible and applicable in support of a variety of views of objects for real industrial use. The results we will obtain from this investigation will not only aid viewing complex objects in different foci and needs, but also provide facilitates for remote modelling and cooperation, both in textual and graphical manners, as well as in multimedia environment.

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