

Intelligent environments

NUTEK – PROMODIS application

Overview

In this project we will develop the concept of *intelligent environments* as an interaction paradigm for distributed computing. The development will be based on the following main theoretical concepts:

- Physical information spaces
- Virtual information spaces
- Intelligent environments (where physical and virtual information spaces meet)
- Information tokens
- Information faucets
- Shared, mobile personal information spaces

To demonstrate and evaluate these concepts, experimental environments will be developed. Initially, these will be:

- An environment demonstrating token-based distributed computing
- An environment demonstrating shared, mobile personal information spaces

After developing and evaluating these environments, new environments will be constructed based on the experiences gained from this work. Some of these second-generation environments will be implemented in a “real” setting, e.g. a hospital, a library or a super-market.

The results of the project will take the form of:

- Demonstration environments
- Scientific papers and reports
- Ph.D. theses in whole or part based on the project
- A final evaluation and summary of findings

The project is proposed to run for three years, 98-07-01 – 01-06-31.

Applicant

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Company partner

Telia Research, Nya Informationstjänster / Interaktionsdesign

PROMODIS cluster

This application is part of “Landsortsklustret”

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Role of project partners

The role of the company partner, Telia Research, Informationstjänster

The project's commercial partner, Telia Research Informationstjänster, is interested in developing the IT services of the future, services for which there may not yet be an evolved market. In this project, The Viktoria Institute will work with practical issues regarding distributed information services, with focus on implementation and interaction issues. Telia Research will bring a commercial focus to the project, and will work in conjunction with the Viktoria Institute to develop realistic services based on the concepts created in the project. Conversely, the Viktoria Institute will help construct interaction techniques to be used in services which Telia Research have developed.

The role of this project in the PROMODIS research cluster

The theoretical concepts and practical demonstration environments developed in the *Intelligent Environments* project will be of importance in bringing concepts and techniques developed by other projects in this cluster into practical use. By constructing interaction techniques for distributed and modular computing, this project will give an indication of possibilities and problems which may otherwise go unnoticed.

Furthermore, in the second-generation experimental environments that will be implemented in the project, many of the techniques developed in other projects in the cluster may be put into practical use. For designing advanced intelligent environments, we see a very great need for effective software and algorithmic solutions to the various problems of distributed computing.

Introduction

Intelligent environments: An interaction paradigm for distributed computing

The NUTEK PROMODIS program is concerned with research on the programming of distributed and modular systems. In this program, projects will develop software techniques for distributing computation in one way or another – to clients via the Web, across several computation servers, to mobile devices, etc. However, it is not enough to distribute the computing power: this power must also be made available to the user in some way. In this project we will develop the interaction techniques necessary to access this distributed computing and information processing power.

The use of distributed computing should be effortless: if a user want to do an information-processing task, be it read her e-mail, check out tomorrow's weather via the web or run a spreadsheet, she should be able to do it at any time, any place. Computing power should be as easily available as water – just turn on the tap, and have immediate access to all your personal data and any computational resources that you need.

However, if this vision of computation as easily available as water or electricity is to be realized, there is need for a radical rethinking of how we interact with computers. The ordinary desktop computer is a stress-inducing, even frightening device for many users. Screens, keyboards and mice are not well suited for the kind of interaction that distributed computing implies; they are developed for the office desktop and adapt very poorly to other situations. To make computation available to everyone, anywhere at any time, information processing devices simply can not be designed in the same way that computers are designed today. We need to take the stress out of human-computer interaction, and base tomorrow's interfaces on the natural affordances of everyday life.

Some notable research is currently being done on the possibilities of making computer interfaces more natural and making the interaction more relaxed. Key concepts in this area include:

- *Calm technology*: As championed by Mark Weisser of Xerox PARC, calm technology has been proposed as the solution to the technology stress that might appear when computers are distributed everywhere (“ubiquitous computing”). Calm technology applications make information available in the periphery, without drawing unnecessary attention. A good example is the “Dangling string” demonstrator, where a collection of hanging wires give an indication of network activity by “shaking” in accordance to the amount of traffic. (Weisser and Brown 1996)
- *Tangible bits*: A term coined by Hiroshi Ishii at the MIT Media Lab, tangible bits implies an attempt to achieve the “seamless integration of people, bits and atoms”. Many interesting demonstration units have been built, such as the MetaDESK and AmbientROOM, demonstrating this blurring of the line between the real and the virtual. (Ishii and Ullmer 1997)
- *Graspable interfaces*: These are a class of interfaces developed by William Buxton and others at the University of Toronto and the Alias/Wavefront company. Their original concept of “bricks” has been expanded to several notable applications, e.g. a drawing program. Their novel re-designs of existing devices, e.g. the three-degrees-of-freedom “rocking mouse” are also worth studying. (Fitzmaurice and Buxton 1997)

Common with all these approaches is a view of computation as something that can be incorporated with common activities, rather than something that has to be performed in special settings with specialized machinery. In the project Intelligent Environments, we will take our inspiration

from these previous efforts, but develop them in novel and innovative ways. Central to this effort will be the concept developing environments where two types of *information spaces* are seamlessly integrated: a *virtual*, and a *physical*. To understand the difference between virtual and physical information spaces, consider these examples:

- A *physical information space* is a place in the “real” world where information is stored. Good examples are bookstores, libraries and a person’s desktop. In a physical information space, information is associated with places, so that it becomes easy to “browse” the information (in a bookstore or library, books of the same kind area typically on the same shelf, and new and noteworthy books are prominently placed to attract attention). On the other hand, in such spaces it is very difficult to search for specific details, e.g. keywords, and it is hard to apply any kind of information processing to the information stored in them.
- A *virtual information space* exists only as electronically stored information. Good examples are the World Wide Web or the contents on a person’s PC hard-disk. Virtual information spaces have the advantage that they take up very little physical space compared to physical information spaces, and it is very easy to do exact searches in them. On the other hand, they are very difficult to navigate, making “browsing” for information difficult. Also, collaborative work involving several people in such environments presents many problems.

Virtual Reality applications, where users navigate a 3-dimensional world modelled in a computer, have been proposed as a solution to some of the problems of navigating virtual information spaces. However, very little evidence exists that there are any advantages to adding this extra level of abstraction in the form of a 3-dimensional interface to an information space, especially not when this interface is to be navigated with inherently 2-dimensional tools (mouse and screen).

Instead, we propose a merging of the real and the virtual, in the form of *intelligent environments*. In an intelligent environment, the real and the virtual worlds meet. The aim is to combine the advantages of the two, so that physical spaces become enriched with electronically stored information, and so that virtual spaces become easier to navigate and interact with, by utilizing the natural affordances of the physical world. In the following, we will describe our vision of these environments, and how to achieve this vision.

References

1. Fitzmaurice, G. and Buxton, B. (1997). An Empirical Evaluation of Graspable User Interfaces: towards specialized, space-multiplexed input. In *Proceedings of CHI'97*, ACM, March 1997. Available as: http://reality.sgi.com/gordo_tor/papers/gf/CHI97.GraspUI/GraspExpt.html
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Theoretical concepts

We will now outline the main theoretical concepts that form the background to this project. The main aim of the project will be to make practical implementations that demonstrate these concepts. As a result of this work, these concepts will be refined and evaluated, and new concepts may emerge. The concepts are:

- *Physical information space*
A collection of information that exists in physical form (see Introduction).
- *Virtual information space*
A collection of information that exists only in electronic form (see Introduction).
- *Intelligent environment*
A space where physical and virtual information is seamlessly integrated (see Introduction).
- *Information tokens*
An information token is a physical object which is associated with some electronic information. It is called a token because it does not contain any information itself; it is only a representation of some information. Although information tokens do not contain any computational power as such, they can perform almost the same functions as if they did. In particular, tokens may be *sticky*, which means that information may be added (it “sticks” to the token) while the user is interacting with it.
- *Information faucets*
In line with the thinking of computation being “on tap” everywhere, like water, we suggest the metaphor of an *information faucet*. From such a device (a screen, a speaker, or some other device) information may be “tapped”. By bringing an information token close to a faucet, the associated information becomes available. A simultaneous combination of several tokens may bring up new information from the faucet. Since it may not be practical to use the same technology for all faucets, information available through a faucet has to be *degradable*, so that it can make sense whether accessed through a tiny LCD-screen, a speaker system, or a multi-media PC.
- *Mobile personal information spaces*
Every person has electronic information associated with him or her. This may be take the form of e-mails, text documents, bookmarks to web-pages, official records, etc., which create this person’s *personal information space*. Typically, this space is currently only available at the person’s desktop computer. However, a *mobile* personal information space is available anywhere, be it through a mobile computing device or an information faucet. Personal information spaces may also be *location based*, so that some aspects of a person’s information space are only available at specific physical locations.
- *Shared personal information spaces*
Shared virtual environments, where people work together while not being in the same physical space, have been the subject of much research in the area of Computer Supported Cooperative Work. However, a *shared personal information space* as defined in this context, exists when, and sometimes *only* when, a group of people are in the same space. Such a space may be associated with a specific place, or be accessible whenever a group meets, regardless of the location. In this space, people may work together on the same project, through information faucets or mobile devices, and be sure that the same work environment will appear again the next time they are gathered.

Experimental environments

During the project, the main task will be to build and evaluate experimental environments demonstrating the theoretical concepts described above. These environments will be integrated in the daily life at our research institution, so that we can get continuous practical evaluations of them. Initially, two experimental environments will be implemented, as described below. When these have been evaluated, new environments will be designed based on the knowledge gained. For obvious reasons, the specifics of these second-generation environments can not yet be specified in detail.

As mentioned, the experimental environments will demonstrate the theoretical concepts of this project. Furthermore, it will be possible to implement and test techniques developed in other projects in the PROMODIS research cluster, and incorporate them in the environments. In this way, our experimental environments may serve as a demonstration venue for many of the research projects in the PROMODIS research program. It will also be possible to implement and evaluate services suggested by the company partner in the environments.

Experimental environment I: Token-based distributed computing

This is an environment where information processing functions are associated with everyday objects. Since these objects contain no information in themselves, we call them *information tokens*. By bringing a physical object (token) near an *information faucet*, the information associated with the object can be accessed. We will use a token-based environment, because implementation will be easier, cheaper and more realistic than embedding processing power in each individual object, while still giving access to essentially the same functionality. The information gained from implementing and evaluating this environment will be very valuable when considering more advanced environments, as well as for considering the possibilities of making such environments available on a larger scale.

Implementing this experimental environment can be done in many ways. Initially, we will use ordinary barcodes, as already seen on a wide variety of products. Barcodes are cheap, easy to decode (any computer with a digital camera can do it), and very importantly they are already present on a great number of every-day goods. This makes the task of turning an ordinary object into an information token as simple as associating some information with its barcode ID number, adding a barcode sticker if it does not have one already. The disadvantage is that identification has to be done consciously (by “showing” the object to the information faucet/digital camera) which may make the interaction less natural. However, this is a small price to pay, and may actually be an advantage in many situations, since it makes the margin for error smaller. For a more advanced experimental environment, electronic ID tags such as those used by shops to guard merchandise against thieves may be used. Such tags have the advantage that they can be detected with no conscious action on the part of the user; on the other hand, they bring with them problems of range, are more expensive and not as generally available as bar-codes.

For information faucets, at first we will use ordinary PC workstations with digital cameras. However, these are too bulky and expensive to use in most situations. Therefore, we will also use cheaper and smaller devices, e.g. LCD screens and miniature speakers. We will also use a combination of an inexpensive multimedia game console (e.g. the Sony Playstation), a digital camera and a television set, for cost-effective multi-media faucets.

Some tasks that may be performed in such an experimental environment are:

- A user may have all the paper-based information related to a specific project, say the devel-

opment of a computer program, collected in a binder. By bringing this binder to an information faucet, the user may get instant access to all electronic information associated with the project (files of code currently being edited, web-pages containing related information, etc.)

- Off-the-shelf household products might be enhanced with embedded information. If a user buys a can of soft-drink, bringing the can to an information faucet may give access to promotional or informational material related to the drink.
- If a user performs an electronic activity when using an everyday object, the user may want to associate that activity with the object. For instance, the user who always listens to the morning news while drinking his coffee may want to associate the morning news-program with her coffee cup, so that the news are automatically heard when the cup is in presence of an information faucet during the morning hours.
- A book or magazine may be enhanced with electronic information. For instance, by bringing a book about Germany to an information faucet, current news about the country may be displayed. Similarly, by bringing a music magazine to an information faucet, a selection of the music reviewed in the magazine may start to play.

Experimental environment II: Shared, mobile personal information spaces

Much research is currently being done on mobile computers combined with position-sensing (GPS navigators). The services provided by such systems are generally based on the *absolute* position of the users. In this experimental environment, we will take a different approach, by utilizing the *relative* positions of people and objects. Rather than working with GPS navigators and other techniques for absolute positioning, we intend to enrich interaction by making use of the natural interaction space that is created when people meet. This will create a *shared, mobile personal information space*.

For this, we will use extremely short-range radio transmitters (typically only with enough range to cover one room). These will be coupled with a simple controller card and through this they will interface directly with a user's PDA (Personal Digital Assistant) or some other mobile computing device. By exchanging information only with the PDA:s of people in the very close proximity, a shared personal information space is created which is the sum of the actors involved.

Using this technique, a PDA can also become a *mobile information faucet*, mirroring the concept of information faucets developed in the first environment. By bringing her PDA to an information token, the user may get access to the information associated with that object. Similarly, the PDA may become a faucet displaying information about another person in the vicinity, or creating a shared information space based on the persons and the tokens in the vicinity. Again, all this will be accomplished with short-range radio transmitters (possibly in combination with the barcode techniques developed for the first environment), utilising the relative positions of people and objects, rather than absolute positioning.

Some tasks that may be performed in such an experimental environment are:

- Several people working on the same project may want to create a shared environment, consisting of all material related to the project. This material may be collective notes, project briefings, shared documents, etc., which become available when the people in the project are in the same room.
- If some material is only to be changed in consensus with all participants in a project, e.g. an important policy document, editing of this document may be "locked" so that it is only possible when all concerned are in the same space.
- A person may want to change her personal information space according to the localities, so that e.g. no information regarding work is available in the in the home (to avoid being dis-

turbed by professionally related e-mails!) The converse – access to no personal information when at work – is of course equally possible!

- By bringing her PDA to an information token, e.g. a book, related electronic information may be down-loaded and displayed, much as in the first environment

Second-generation experimental environments

Based on the experience gained from building the environments above, as well as input from the company partner, other projects in the cluster, and related work by researchers around the world, a number of second-generation environments will be constructed. Since these will be based on the experiences gained during the construction of the first environments, it is currently difficult to give any specific details on how these environments will be implemented and what their functions will be.

However, a special focus for the second-generation projects will be to demonstrate possible future information services, in cooperation with the company partner. An important goal will be to construct an environment which can be directly implemented and evaluated as a real-world service. Possible environments include:

- A hospital, where doctors may want to associate physical information (e.g. the papers in a patient's file) with electronically stored information (e.g. digital X-ray images)
- A library, where relevant and up-to-date electronic information may be associated with each library book, e.g. corrections to out-dated maps, music by a composer subject to a biography, etc.
- A super-market, where promotional or informational material may be associated with the products on sale

Another aim of the second-generation environments is to put the knowledge gained from other projects in the PROMODIS research cluster into practical use. For this reason, the second-generation intelligent environments may also become excellent demonstration opportunities for other projects in this PROMODIS cluster.

Schedule

The project is proposed to run for three years, starting July 1, 1998. It will follow these four phases:

Phase 1: Establish competence and resources (Ca. 98-07-01 – 98-12-31)

This is the build-up phase, where we will survey existing technology and find the required competence and materials to carry the project through. In this phase, we will establish a research environment at the Viktoria Institute in Gothenburg, with all tools and equipment necessary for building the first-generation intelligent environments.

Phase 2: Development of first-generation experimental environments (Ca. 99-01-01 – 99-12-31)

Based on the competence and resources established in Phase 1, we will build the demonstration environments specified previously. We will continuously make evaluations of the work and develop new theoretical concepts based on our practical experiences. All work will be well documented in scientific papers and reports.

Phase 3: Development second-generation environments (Ca. 00-01-01 – 00-12-31)

Based on the development of the original experimental environments, several new environments will be built and evaluated. As this work is to be directly based on the knowledge gained in Phase 2, it is currently difficult to give any specifics about these environments. The aim, however, will be to develop environments which demonstrate viable new information services, and that integrate techniques developed by other projects in the research cluster.

Phase 4: Final evaluation and reports (Ca. 01-01-01 – 01-06-31)

In this phase, we will collect all material produced in the project (papers, reports, etc.) and make a final evaluation of the project. All documentation will be collected and made public (when possible, taking into account confidentiality issues) to make the substantial knowledge base generated by the project available to researchers and companies interested in continued research and development in the field.

Deliverables

Deliverables produced in this project will take the form of:

- *Demonstration environments*
These environments will be a practical way of showing the ideas developed in the project. They are important both for evaluation purposes, and for quickly communicating ideas with others involved in the project.
- *Scientific papers*
All research activities will be documented as papers, to be presented at international conferences or published in scientific journals.
- *Technical reports*
Material that is not suitable for publication (e.g. surveys of existing technology) will be made available as technical reports.
- *Ph.D. theses*
A number of Ph.D. theses will be directly or indirectly based on the project.
- *Final report*
A final report will collect all scientific results from the project.

Intelligent environments

NUTEK – PROMODIS application

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- Shared, mobile personal information spaces

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References

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A collection of information that exists only in electronic form (see Introduction).
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Every person has electronic information associated with him or her. This may be take the form of e-mails, text documents, bookmarks to web-pages, official records, etc., which create this person’s *personal information space*. Typically, this space is currently only available at the person’s desktop computer. However, a *mobile* personal information space is available anywhere, be it through a mobile computing device or an information faucet. Personal information spaces may also be *location based*, so that some aspects of a person’s information space are only available at specific physical locations.
- *Shared personal information spaces*
Shared virtual environments, where people work together while not being in the same physical space, have been the subject of much research in the area of Computer Supported Cooperative Work. However, a *shared personal information space* as defined in this context, exists when, and sometimes *only* when, a group of people are in the same space. Such a space may be associated with a specific place, or be accessible whenever a group meets, regardless of the location. In this space, people may work together on the same project, through information faucets or mobile devices, and be sure that the same work environment will appear again the next time they are gathered.

Experimental environments

During the project, the main task will be to build and evaluate experimental environments demonstrating the theoretical concepts described above. These environments will be integrated in the daily life at our research institution, so that we can get continuous practical evaluations of them. Initially, two experimental environments will be implemented, as described below. When these have been evaluated, new environments will be designed based on the knowledge gained. For obvious reasons, the specifics of these second-generation environments can not yet be specified in detail.

As mentioned, the experimental environments will demonstrate the theoretical concepts of this project. Furthermore, it will be possible to implement and test techniques developed in other projects in the PROMODIS research cluster, and incorporate them in the environments. In this way, our experimental environments may serve as a demonstration venue for many of the research projects in the PROMODIS research program. It will also be possible to implement and evaluate services suggested by the company partner in the environments.

Experimental environment I: Token-based distributed computing

This is an environment where information processing functions are associated with everyday objects. Since these objects contain no information in themselves, we call them *information tokens*. By bringing a physical object (token) near an *information faucet*, the information associated with the object can be accessed. We will use a token-based environment, because implementation will be easier, cheaper and more realistic than embedding processing power in each individual object, while still giving access to essentially the same functionality. The information gained from implementing and evaluating this environment will be very valuable when considering more advanced environments, as well as for considering the possibilities of making such environments available on a larger scale.

Implementing this experimental environment can be done in many ways. Initially, we will use ordinary barcodes, as already seen on a wide variety of products. Barcodes are cheap, easy to decode (any computer with a digital camera can do it), and very importantly they are already present on a great number of every-day goods. This makes the task of turning an ordinary object into an information token as simple as associating some information with its barcode ID number, adding a barcode sticker if it does not have one already. The disadvantage is that identification has to be done consciously (by “showing” the object to the information faucet/digital camera) which may make the interaction less natural. However, this is a small price to pay, and may actually be an advantage in many situations, since it makes the margin for error smaller. For a more advanced experimental environment, electronic ID tags such as those used by shops to guard merchandise against thieves may be used. Such tags have the advantage that they can be detected with no conscious action on the part of the user; on the other hand, they bring with them problems of range, are more expensive and not as generally available as bar-codes.

For information faucets, at first we will use ordinary PC workstations with digital cameras. However, these are too bulky and expensive to use in most situations. Therefore, we will also use cheaper and smaller devices, e.g. LCD screens and miniature speakers. We will also use a combination of an inexpensive multimedia game console (e.g. the Sony Playstation), a digital camera and a television set, for cost-effective multi-media faucets.

Some tasks that may be performed in such an experimental environment are:

- A user may have all the paper-based information related to a specific project, say the devel-

opment of a computer program, collected in a binder. By bringing this binder to an information faucet, the user may get instant access to all electronic information associated with the project (files of code currently being edited, web-pages containing related information, etc.)

- Off-the-shelf household products might be enhanced with embedded information. If a user buys a can of soft-drink, bringing the can to an information faucet may give access to promotional or informational material related to the drink.
- If a user performs an electronic activity when using an everyday object, the user may want to associate that activity with the object. For instance, the user who always listens to the morning news while drinking his coffee may want to associate the morning news-program with her coffee cup, so that the news are automatically heard when the cup is in presence of an information faucet during the morning hours.
- A book or magazine may be enhanced with electronic information. For instance, by bringing a book about Germany to an information faucet, current news about the country may be displayed. Similarly, by bringing a music magazine to an information faucet, a selection of the music reviewed in the magazine may start to play.

Experimental environment II: Shared, mobile personal information spaces

Much research is currently being done on mobile computers combined with position-sensing (GPS navigators). The services provided by such systems are generally based on the *absolute* position of the users. In this experimental environment, we will take a different approach, by utilizing the *relative* positions of people and objects. Rather than working with GPS navigators and other techniques for absolute positioning, we intend to enrich interaction by making use of the natural interaction space that is created when people meet. This will create a *shared, mobile personal information space*.

For this, we will use extremely short-range radio transmitters (typically only with enough range to cover one room). These will be coupled with a simple controller card and through this they will interface directly with a user's PDA (Personal Digital Assistant) or some other mobile computing device. By exchanging information only with the PDA:s of people in the very close proximity, a shared personal information space is created which is the sum of the actors involved.

Using this technique, a PDA can also become a *mobile information faucet*, mirroring the concept of information faucets developed in the first environment. By bringing her PDA to an information token, the user may get access to the information associated with that object. Similarly, the PDA may become a faucet displaying information about another person in the vicinity, or creating a shared information space based on the persons and the tokens in the vicinity. Again, all this will be accomplished with short-range radio transmitters (possibly in combination with the barcode techniques developed for the first environment), utilising the relative positions of people and objects, rather than absolute positioning.

Some tasks that may be performed in such an experimental environment are:

- Several people working on the same project may want to create a shared environment, consisting of all material related to the project. This material may be collective notes, project briefings, shared documents, etc., which become available when the people in the project are in the same room.
- If some material is only to be changed in consensus with all participants in a project, e.g. an important policy document, editing of this document may be "locked" so that it is only possible when all concerned are in the same space.
- A person may want to change her personal information space according to the localities, so that e.g. no information regarding work is available in the in the home (to avoid being dis-

turbed by professionally related e-mails!) The converse – access to no personal information when at work – is of course equally possible!

- By bringing her PDA to an information token, e.g. a book, related electronic information may be down-loaded and displayed, much as in the first environment

Second-generation experimental environments

Based on the experience gained from building the environments above, as well as input from the company partner, other projects in the cluster, and related work by researchers around the world, a number of second-generation environments will be constructed. Since these will be based on the experiences gained during the construction of the first environments, it is currently difficult to give any specific details on how these environments will be implemented and what their functions will be.

However, a special focus for the second-generation projects will be to demonstrate possible future information services, in cooperation with the company partner. An important goal will be to construct an environment which can be directly implemented and evaluated as a real-world service. Possible environments include:

- A hospital, where doctors may want to associate physical information (e.g. the papers in a patient's file) with electronically stored information (e.g. digital X-ray images)
- A library, where relevant and up-to-date electronic information may be associated with each library book, e.g. corrections to out-dated maps, music by a composer subject to a biography, etc.
- A super-market, where promotional or informational material may be associated with the products on sale

Another aim of the second-generation environments is to put the knowledge gained from other projects in the PROMODIS research cluster into practical use. For this reason, the second-generation intelligent environments may also become excellent demonstration opportunities for other projects in this PROMODIS cluster.

Schedule

The project is proposed to run for three years, starting July 1, 1998. It will follow these four phases:

Phase 1: Establish competence and resources (Ca. 98-07-01 – 98-12-31)

This is the build-up phase, where we will survey existing technology and find the required competence and materials to carry the project through. In this phase, we will establish a research environment at the Viktoria Institute in Gothenburg, with all tools and equipment necessary for building the first-generation intelligent environments.

Phase 2: Development of first-generation experimental environments (Ca. 99-01-01 – 99-12-31)

Based on the competence and resources established in Phase 1, we will build the demonstration environments specified previously. We will continuously make evaluations of the work and develop new theoretical concepts based on our practical experiences. All work will be well documented in scientific papers and reports.

Phase 3: Development second-generation environments (Ca. 00-01-01 – 00-12-31)

Based on the development of the original experimental environments, several new environments will be built and evaluated. As this work is to be directly based on the knowledge gained in Phase 2, it is currently difficult to give any specifics about these environments. The aim, however, will be to develop environments which demonstrate viable new information services, and that integrate techniques developed by other projects in the research cluster.

Phase 4: Final evaluation and reports (Ca. 01-01-01 – 01-06-31)

In this phase, we will collect all material produced in the project (papers, reports, etc.) and make a final evaluation of the project. All documentation will be collected and made public (when possible, taking into account confidentiality issues) to make the substantial knowledge base generated by the project available to researchers and companies interested in continued research and development in the field.

Deliverables

Deliverables produced in this project will take the form of:

- *Demonstration environments*
These environments will be a practical way of showing the ideas developed in the project. They are important both for evaluation purposes, and for quickly communicating ideas with others involved in the project.
- *Scientific papers*
All research activities will be documented as papers, to be presented at international conferences or published in scientific journals.
- *Technical reports*
Material that is not suitable for publication (e.g. surveys of existing technology) will be made available as technical reports.
- *Ph.D. theses*
A number of Ph.D. theses will be directly or indirectly based on the project.
- *Final report*
A final report will collect all scientific results from the project.