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1. introduction

Increasing demands for safety, quality and usability of man-machine systems, especially for industrial control applications, make the research 'copies related to the design of user-centred and user-adaptable man-machine interfaces (MMI) which are easy to understand, to use and to maintain the centre of special attention worldwide.

Recent studies have shown that more than half of the contemporary software programs use a graphic interface which accounts for almost half of the total application code and, also, requires half the time allocated to software development and maintenance. Reducing the cost and time needed for the software development is therefore an important issue in MMI systems design. One trend already noted is an increasing use (for 74% of the projects, Ramstein, 1995) of software tools to create and maintain the interfaces. MMI interfaces for industrial control applications, however, have different requirements than the software for which most of these tools are developed, that is non-real-time office and home applications.
Such man-machine interfaces can be regarded as distributed knowledge-based software systems which comprise knowledge about the end-users of the system, i.e., user models, knowledge about the technical system, i.e., application or technical system (TES) model, and also different kinds of interaction models, i.e., dialogue-, task-, presentation-models etc. The development of efficient software architectures and design methods for such, more often also multimodal, interfaces will most likely be among the major issues for the future of MMI design. One of the popular attitudes is the extension of existing graphic interfaces (such as MS-Windows, Macintosh and X-Windows) with minimum changes. Integrated approaches such as MMAAR (Micro/Macro Agent Architecture) consider also distributed applications comprising handwriting, gesture and speech recognition on different hardware platforms (Julia and Cheyer, 1995). Object-oriented design of multi-media MMI supported by adaptable interface toolkits is described, e.g., in (Little et al., 1994).

One of the most frequently employed user modelling (UM) methods is the so-called stereotype approach which considers typical characteristics of user classes (groups) in the application domain of the system. Shell systems which provide some typical UM representation, inference, consistency maintenance, and automatic user classification have recently appeared (Kobsa, 1995). Adaptive explanation techniques based particularly on user modelling are in most cases developed for intelligent tutoring systems (Goldstein, 1993).

Recently developed visualization techniques, such as the Ecological Interface Design by Vicente (1995), the application of Multilevel-Flow Modelling by Lind (1981) to visualisation, and the integration of these techniques (van Paassen, 1995) attract more and more research interests.

High dimensionality and also uncertainty of these "heterogeneous" knowledge-structures, as well as required cross-disciplinary design solutions make the MMI design process even more complicated than the one for traditional knowledge-based *systems.* Systematic integrated user-centred approaches to knowledge-based interface design and software toolkits which effectively support both usability and re-usability of MMIs, as well as creativity and overall job satisfaction of the designers as end-users of these toolkits become of high importance {see, e.g., Averbukh and Johannsen, 1994a, Kawai, 1992).

New life-cycle paradigms for early end-users participation in designing and evaluating the MMIs become of tremendous importance for efficient MMI software production as well.

Technology for efficiently designing such MMIs for process supervision systems including a general design methodology, a set of software tools for supporting designers of MMIs, and two applications, i.e., power plant and cement plant applications, have been the target of the BRITE/EURAM Project 6126 AMICA "Advanced Man-Machine Interfaces for Process Control Applications".
This report summarises the results of the AMICA Project regarding its claimed objectives, as well as future exploitation and perspective enhancements.

The project lasted 39 months (January 1,1993 - March 31,1996) and has been carried out by a Consortium of 5 Partners: CISE (I) as prime contractor, ENEL (I), FLS Automation (DK), University of Kassel (D), and GEC-Marconi S3I (UK).

Project results are to be applied in the large market of process automation and simulation. The main application areas encompass: power generation and transmission, cement, steel and pulp production, industrial and military simulators, chemical plants and waste burning.

In several of these market segments, the Partners of the Consortium have a leading position: ENEL represents over 15% of the European market for power generation and control, with CISE which is one of its major suppliers of advanced automation equipment. FLSA has a considerable share (over 20%) of the world market for cement plant automation, and its parent company, F. L. Smith & Co AS, has over 50% market share for cement plant engineering and production. GEC-Marconi in turn is the largest European manufacturer of training and simulation devices.

The next section focuses on the overall Project objectives and relevant advanced methodological solutions. In the third section, the description of the AMICA Toolkit for MMI designers is given. The developed simulated environments for both target control applications are specified in the fourth section. The proper applications and the results of their evaluations are given in the fifth section.

2. Project objectives and advanced approaches

2.1 Objectives of the project

The final objective of the Project was a proven technology for the design of customised adaptive user interfaces for process supervision systems which can be easily adjusted to the specific tasks and needs of different user classes, e.g., operators, engineers, maintenance personnel etc. Two different control applications, i.e., the control system of combustion in a thermal power station (so-called ADEPT, i.e., Amica and DiogEne for Power Plants) and the control system of clinker manufacturing in cement factories (the Cement Plant Application} were to be developed and evaluated using this technology.

The general design methodology originated from the ESA (European Space Agency} - Standard ESA PSS-05-0 Issue 2 for software development. Specific adaptations were made in order to organise a more rational development life cycle regarding generic advanced functionalities of MMI which support easy adaptation of interaction facilities to the specific needs and expectations of particular user classes in specific task situations, the Toolkit for the developers of such adaptive interfaces, and the two applications mentioned above (Guida et al., 1994).

For this purpose the overall organisation and relevant functional structure of the MMI was focused on the following main knowledge-based sub-systems: Dialogue, Presentation, Explanation, and Modelling facilities for developing/updating the models of end users, i.e., User Model, and the models of the Technical System , i.e., TES model. Such structure can be viewed as an elaboration of the UIMS (User Interface Management System) approach towards better consideration and more efficient software implementation of human-centred approaches (see, e.g., Johannsen, 1992).

2.2 Functionalities of Advanced MMI

The overall organisation of an advanced MMI, is based on distinguishing between the following three main agents of interaction:

- human end users grouped into different classes regarding their tasks in performing the job, expertise etc.,
- Technical System (TES) which comprises both technological processes with traditional automation arid supervisory control systems (Field System) and advanced diagnostic or decision support systems (Target System),
- man-machine interfaces as adaptive interaction media between the end users and the Technical System.

The functionalities of the MMI are designed in order to provide end users with advanced interaction features, particularly, by improving

- the dialogue capabilities in the sense of better information exchange and support of the user behaviour in supervision and control applications,
- the presentation capabilities in the sense of better understandable pictures and symbols, higher transparency and more coherence between pictures in dynamic sequences,
- the explanation capabilities in the sense of satisfying user needs with respect to a better understanding of the field system,
  the justification capabilities in the sense of relating the outputs of the target system to a normative set of criteria and beliefs of the users in order to make decisions of the target system acceptable for the users,
- the understanding of the Technical System by a model which represents an easily intelligible survey and which supports focusing of intention in the case of an emergency.

Starting from the above depicted objectives, an advanced man-machine interface covers at least four technology areas to realise the demanded capabilities as follows (Johannsen and Averbukh, 1993):

a) DIALOGUE: The Dialogue System provides functionalities for organizing and supervising the communication between the user and the MMI within a mixed initiative interaction, where both the MMI and the user can take the initiative to send information to the counterpart.
b) PRESENTATION: The Presentation System is the channel by which the communication between user and MMI is physically realised. It has to perform the interaction in a suitable way by paying attention to the perception abilities and visual (or multimodal) preferences of the human user.
c) EXPLANATION: The Explanation System covers information mainly about the technology and behaviour of the Field System (explanation facility) and about the reasoning process and the conclusions made. by the Target System (justification facility).
d) MODELLING: The embedded User- and TES-models reflect static and dynamic, i.e., situation-dependent performance characteristics of the end users and of the Technical System respective y, in order to adjust their interaction media and to provide suitable data exchange.

Different paradigms for user modelling were analysed as a part of the AMICA methodology. Psychological, particularly communicative and cognitive, as well as linguistic aspects were particularly taken into consideration. Two different categories of user characteristics depending on the period they are relevant to, i.e., so-called short-term characteristics and long-term user characteristics were conditionally distinguished. Within the AMICA methodology, those user-characteristics are considered as long-term, which are “quasi static”, i.e., do not depend on particular job, task and/or situation and hardly change during a rather long period of interaction. Such essential user characteristics, as professional skills and psychological factors which reflect, e.g., the dominating communication style of the user can be considered as long-term ones. “Short-term” user characteristics, such as stress, frustration, and fatigue are situation-dependent and can change rather often, e.g., from shift to shift, and even during one shift.

The AMICA technology focused mainly on the long-term user characteristics (period between two test procedures more than one month) regarding the adaptation of dialogue, presentation and explanation of the MMI systems. Short-term ones are mainly considered by the dialogue and the explanation systems (see AMICA D4-2 Deliverable).

For adequate User Modelling it is found quite essential to distinguish between

- objective vs. subjective characteristics,
- observable (or directly measurable) vs. unobservable characteristics {see Averbukh and Johannsen, 1994a).
- "passive", i.e., observation of characteristics of user behaviour during the real operation related to some "critical" operational situations, vs. "active" one in simulated operation environment , i.e., during special games, tests and other simulated situations or, also, a mixed "passive-active" one.
- "open-loop" adaptation of MMI vs. "closed-loop" one. Both of these adaptation paradigms are guided by the User Modelling functionality. The open-loop paradigm assumes observation of long-term user characteristics and considering them before the very first use of the MMI or periodically (not more often than, e.g., one per month) by setting up appropriate MMI services. The closed-loop paradigm assumes observation and dynamic updating of the short-term user characteristics and of the related MMI services.

The current AMICA technology regarding User Modelling is focused on the active observation of long-term user characteristics using simulated situations.

The TES modelling component concerns loading and managing of a model of the underlying technical system. The TES Model handles the several, up to hundreds or thousands of sensor values, in a way suitable to the needs of the actual user. The values are coming either directly from the process, a database maintained by a classic supervisory and control system or a simulation and are organised by the TES Model for use inside the MMI and for presentation issues,

'The central managing MMI functionalities are associated with the Dialogue System which tracks and provides all relevant information about current ongoing or interrupted dialogues, as well as about the communication- or task-situation in general. This information is used by all other systems in order to provide the end users with the information, i.e., layouts by the Presentation System and explanations or justifications by the Explanation System, which are relevant to the specific situation. The embedded models supply the information about current user- and TES-status in order to focus other MMI functionalities on users needs in every specific task situation. The further enhancement of the User Modelling facilities is proved as a perspective field for future research.

2.3 Integrated user-centred design methodology for Advanced MMI

An integrated user-centred design approach is proposed which considers end users participation starting from the very early phases of the MMI development life-cycle. The modifications and certain improvements of existing approaches considering the prime objectives of the project are made and summarised within the unified task-oriented design methodology (see, e.g., Averbukh, 1994).

• *Rational Life - Cycle*

There are many descriptions of systems life cycles and associated methodologies and frameworks for systems design and development (see, e.g., the overview in Sage, 1992). The phases are usually sequenced in an iterative manner. The feasible adaptation is made regarding the objectives and constrains of the project, particularly, by splitting of the phases of design, development and laboratory testing with end users participation into two main parts regarding the two issues of the Toolkit. In its turn, the development of the second issue of the Toolkit was also splitted into two phases in order to have a considerable part of the software available at an early stage and to facilitate the incorporation of the evaluated functionalities in the applications. Such adjustments allow to rationalise the basic life cycle and to intensify the promotion of the most advanced solutions into applications, as well as to support early usability testing, also across applications. They can be recommended for efficient conducting of similar projects.

• *End-User Participation*

In order to better adapt man-machine interfaces to operational needs, it is necessary to take the knowledge of utilisation and/or operation from its users into account during the design process from the very early beginning of the design life-cycle via the so-called participative design approach (Johannsen, Ali and Heuer, 1995). The Hierarchical Task Analysis technique is considered as one of the most appropriate approaches for accessing and structuring all the [asks a user has to perform during the course of the work via human-machine interaction in process supervision (see, e.g., Kirwan and Ainsworth, 1992). The knowledge hierarchies are elicited via structured and unstructured interviews, questionnaires, observations, time-lines, walk- and talk-through etc. (Johannsen and Averbukh, 1993), coherently with the following structure:

goals <-> functions <->tasks <->plans (working structures) <->means(needs) <->criteria

regarding all three “interaction agents”, i.e., human users, technical system and MM1. The MMI is seen as the media for interaction between the users and the technical systems via dialogue, presentation etc. The explicit task analysis for cement plant application carried out at the Aalborg Portland Cement Plant allowed to find out concrete ways for intensification of the methodology (Heuer et al, 1993).

• *Logical Model and Require ments (Re)-Engineering*

The important step of the methodology involves a functional specification of the MMI. Combining the straightforward approach to functional decomposition via the so-called logical model, recommended by ESA guidelines, with parallel activities regarding task analysis and relevant end user participation proved to be quite efficient in bridging conceptual models of MMI designers with actual mental and performance models of end users and, hence, bridging initial with detailed user requirements. The upper level of the MMI logical model comprises the following functionalities (see Fabiano et al., 1994): handling inputs and outputs from/to both users and technical system, user- and TES-modelling, explanation and justification, tracking interaction, and supervising dialogue. The last two functionalities are central ones, as they are responsible for on-line monitoring of all interaction processes in the MMI, interpreting the current situation and the status of the embedded models, and for managing them by providing the user with the appropriate facilities.

- *Concurrent Engineering Approach*

New concurrent engineering approaches were efficiently used, particularly, to ensure transferability of advanced solutions to industry and other research, as well as to the applications during the concrete project life-cycle. They are combined with open systems architectures and object-oriented technologies, also to provide the extendibility, adaptability and evolution of the AMICA Technology and MMIs without systems redesign and recompilation (see AMICA D4-2 Deliverable).

- *Task-Oriented Design*

The majority of modern concepts of task-oriented Man-Machine Interface design, particularly for large scale distributed systems, typically focuses on presentation issues of interaction and on allocating information packages and the appropriate presentation media according to the specific human tasks, i.e., what information should be displayed (see, e. g,, Baldassari, et al., 1991; Duncan and Praetorius, 1989). In the frame of the AMICA Project, a more sophisticated user-centred approach on task orientation of all interaction knowledge structures which support and, in a certain sense, control the interaction process is examined and implemented (Johannsen, 1994, Averbukh, 1994, Fabiano et al., 1994).

- *Quality Control and Adaptation*

Advanced MMI functionalities of Tracking Interaction, Supervising Dialogue and User Modelling are to focus especially on the problems of so-called "in-process inspection" of the quality of human behaviour during interaction with the computer. From the integrative point of view, both the interface development tools and the interface software systems themselves are considered as persistent subjects of quality control and adaptation, Different strategies for increasing the usability of interfaces by both on-line and off-line adaptation and for the further management of these knowledge structures are proved to be. quite efficient for both applications. E.g., such user characteristics, as professional level, psychological characteristics <assertiveness, self-sufficiency), physiological (gender, age) etc. which are quasi-independent from the concrete communication situations are to be used for the off-line adaptation of the MMI layouts, of embedded models etc., i.e., before the very first use of the MMI and/or not more frequently than every 1-2 months. On the other hand, supervising or "in-process inspection" of dialogue-, interaction context-, presentation- and other relevant statistics allows to recognise the significant mismatches between the predetermined parameters of the MMI and of the embedded models and to update them on-line appropriately.

3. AMICA Toolkit for MMI Designers

3.1 Programming languages and development tools

The AMICA Toolkit architecture is developed by using two software development tools, GMS and COGSYS (see relevant ManuaIs}. The programming languages C(C++) are widely used in addition to these development tools. ANSI C compi~er is also used as it is necessary for running two selected software. tools, i.e., GNIS and COGSYS on the same UNIX piatform.

- GMS, the Graphical ModeHing System, is a tool alIowing to graphically design screen layouts by connecting graphical objects. These objects can be linked to (software) procedures or variables. For these reasons, inside the AMICA tooikit architecture, GMS is responsible for the realisation of every presentation functionality, i.e., accepting inputs from the user, both commands and data; presenting outputs to the user, both on MMI request or on user request; communicating to the COGSYS part of the AMICA architecture, both commands and/or data.

ActuaHy, the GMS side of Ihe AMICA toolkit architecture mediates the communication between the user and the COGSYS side of the MML It is also responsible for managing all the graphicai aspects related to the presentation, like the managing of the GMS graphic models.

- COGSYS is a blackboard based tool for the development of real-time knowledge based systems. The. content of the COGSYS blackboard is considered as a representation of the MM1 status. The main reasoning functions of the MM1 take place around the blackboard and their effects will be communicated to the. user through the ft.mctionalities implemented with GMS.

3.2 Toolkit architectural design

The following figure depicts the general AMICA Toolkit architecture based on a data driven concept with additionally concurrent independent modules which do not use the COGSYS backboard but communicate with other Toolkit modules through the appropriate inputdoutputs. The communication channels between COGSYS, GMS and the technicaI system are also highlighted.

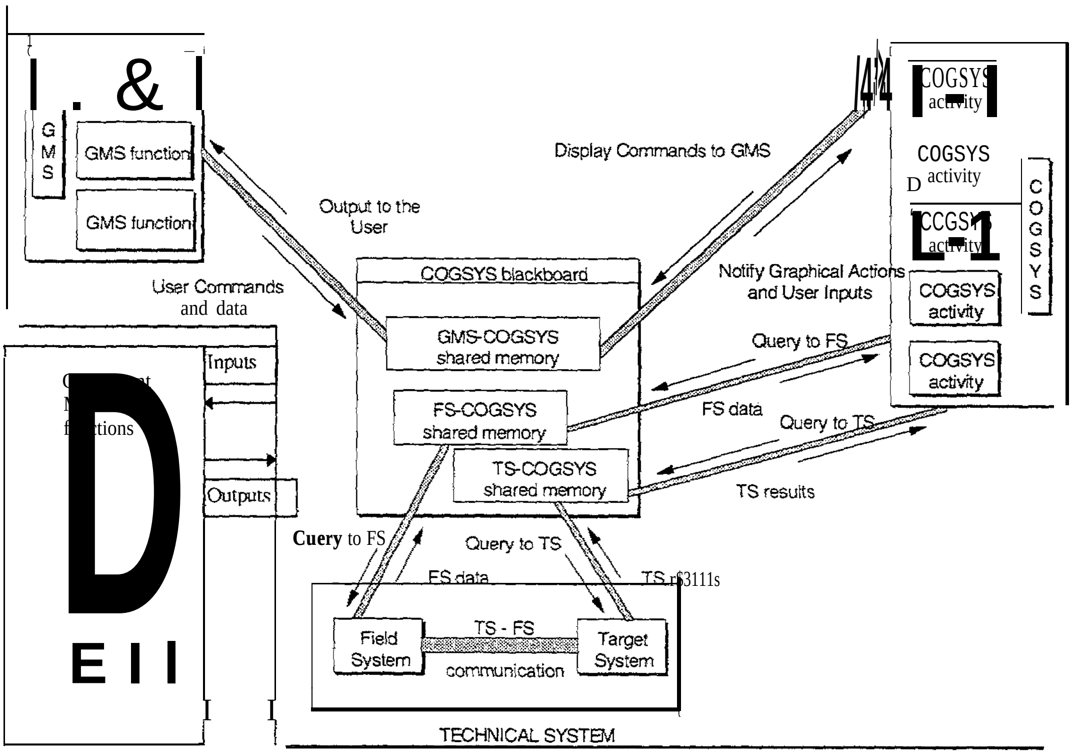

Fig 1: The AMICA toolkit Architecture: a communication view,

The communication among the different parts of &he architecture is implemented bj~ means oi shared areas of memory on the blackboard, as well as by additional communication protocois almong them.

3.3 Generic software components

The purpose of the A.MIC.% Toolkit is to provide a general framework for realising advanced MMIs in process control applications and a set of generic tools (software moddes) that can be selected, adapted and put toge~her in order to build a specific MMI application. The main design principles du~irig Lhe creation of the Toolkit are extendibility and reusability under consideration of the state-of-the-art and of recognisable trends in the design of contro~ rooms.

The basic functimmlities are realised by several software modules which are described below in more detaik.

- *Dialogue System*

The Dialogue System has to catch all aspects concerning the dialogue between the user and the Man-Machine Interface and consists of two parts, nameiy:

- Tracking Interaction
  - Interaction Logging
  - Tracking Interaction Context
  - Tracking Interaction Content
  - Log_book_visuaIiser
- Supervising Dialogue
  - Determining/Updating Current Dialogue Status
  - Quality Control of User-MMI Behaviour

The Tracking Interaction components keep up-to-date the main data structures which track the interaction acts between the user, MNII and ‘TES.

The functionality Logging establishes and maintains a protocol of the whole communication (according to the AMICA terminology: MM1 interaction) between the user [operator/ engineer/ maintenance personnel}, the MMI and the Technical System.

The functionality Tracking Interaction Context receives all interaction acts which are passed during the interaction process among all agents of communication and processes this data in order to determine the current status of other MMI subsystems.

The Tracking Interaction Content functionality can be seen as an enhancement of the functionalities Interaction Logging and Tracking Interaction Context providing an overview of the interaction which has taken place in the past (M1etzko et al,, 1995).

The Log-Book Visualizer is to be used in combination with the diary and the trend facility by accessing the log file to diagnose past events, The diary gives the operator’s summary of the events, the trends facility gives the process parameters. The log-book may be questioned to precisely provide the operator’s actions on the plant and the reactions of the MMI, so revealing the connection between the past state of the process and of communication.

The Supervising Dialogue components keep track of the ongoing dialogues between the user and the Man-Machine Interface in the sense of watching the dialogue process as a more or less predefine order of communication acts. The module is divided into two single modules which check for completion or interruption of the sewmd dialogues (Determining / Updating Dialogue Status - DUDS) and, respectively, rate the quality of them (Quality Control).

The DUDS component tracks the behaviour of the user and the MMI and determines which dialogues are initiated, which are terminated and at what stage of execution the current diaiogues are, and which one is most likely to be the active. one (Mletzko et al., 1995).

The Dialogue Presentation module of DUDS visualizes a list of the dialogues recognised by the dialogue tracking system to be inspected by the user of the Toolkit, The Dialogue Statistics module gathers signikmt statistics about the behaviour of the tracking system and the interaction betweer the user and the Diakgue Presentation. These statistics are mainly intended for evaluation of th dialogue schemes. Two modules support supervising of parallel dialogues. The Resuming Checl module evaluates the dialogues on the stack and warns the user when work on a diaIogue must be resumed. The Completion Check module compares the dialogues on the stack to the dialogue schemes, and warns the user "when essential parts of a dialogue are omitted.

The quality control activity of the Supervising Dialogue is implemented in a sub-module whicl watches the quality of the diaIogue between the User and the MMI in terms of its Usability related to the effectiveness and efficiency of the user interface. and to user's reaction to tha interface. The Quality Control module provides a form of user modelling and a means for th incorporation of slowly changing user characteristics in the MM1 (Averbukh, 1995].

- *Presenmtiorz System*

The structure of the graphical part of the Presentation System is based on the selected graphica tool, which is GMS, while the knowledge based part will be held within COGSYS and is therefore, independent from the software components that provide the specification of th required output taking into account the current presentation context and specific constraints. A package for display of trends of plant variables has been produced. The overall presentatio system is composed of two main parts described below.

a) Presentation Resources - this is a frame where the GMS models, photographs and othe presentation media are held, this allows the construction of appropriate graphical scenes fo the process under consideration, The full range of possible media is general enough to be expanded when deemed appropriate for other applications and future changes in technology.

b) 'The controlling activity which manages the automated presentation of trends etc. by the AMICA system. The presentation system is controlled by a CC)GSYS activity which wil determine what will happen in a particular situation. The dialogue system provides a specification of the required output (content and form) for the presentation system.

As a result of the assessment of the user requirements for the two prototype applications, the fol~owing presentation facilities were considered generic enough to be also included as a part the Toolkit:
- the diary facility
- the trends facility.

The diary facility is implemented in C and GMS and runs as an external application with respect to COGS YS.. The creation of entries **is** supported by an interaction pattern offering legal entries for each data field, but also free text is aIlowed. Automatic functionalities are provided to facilitate messages insertion and retrievaL

The trends facility allows viewing of data from various time periods from the most recent two minutes to the Iast six weeks, each trends facility aHows monitoring of up to four variables in real time on a one second update rate. The data are presented as colour coded plots on the graph with the X and Y axes displaying the time and the vaIue of the variable being monitored, respectively. Usefui features are provided as scrolling over time and moving along the axis.

- *Explanation System*

ExpIanation)Justification components concern the activation, monitoring and evaluation of a dialogue plan aimed at providing the user with explanations about the field system and justifications about the reIevant target system. Explanatory dialogue plans relate to explanation goals and can be activated upon explicit user's request or MMI initiative. Interleaving of user's and MMI interventions is supported.

The Justification functionality consists of the identification and handling of the explanatory dialogue pian to provide the user with the requested justification. Explanatory dialogue plans are specified in terms of explanatory dialogue operators. Specific plan operators are set for the application domain and are then instantiated and executed according to a generic control mechanism in response to the specific questions of the user.

In common with most of the explanation generators reported in the literature, the activation functionality of Explanation is implemented using a skeletal planner.

The functiondities of the Explanatory Dialogue Planner Tooi are:
- specification of plan operators in a text file by means of a specific language
- parsing of the textually specified operators and creation of an on-line library of plan operators
- dynamic construction of explanatory dialogue plans for an identified dialogue goal
- execution of plans
- control over the pkm being executed with re-plarming features to adapt to the ciynarnicaliy changing state of interaction
- management of interleaving plans, providing for suspension and re-activation of plans

A set of rules has been developed which focuses on the discourse between the user and the system. The Expkmatory Dialogue Planner Tool has been specified and designed according to the Object Oriented analysis and design methodology. Implementation has been done using C++, which was seIected for its features of efficiency and modularity. In the frame of the Toolkit architecture, the Ex@natory Dialogue Planner Tool is designed as an external application with respect to COGSYS.

- **User** *Model*

So-called "long-teml" characteristics of end users which sIowIy change and may influence the MNfI " design are identified before its first set-up and/or periodically but not more often than once per two-three months. Special interpretation models are provided for interpreting user characteristics in the relevant MMI design features. ln the frame. of the Toolkit architecture, the User ModelIing Tool is ar extermd application with respect to COGSYS.

The facilities to load and to update the following long-term user characteristics which influence the overall MM1 design are provided:

- anthropological (gender, age]
- pmfessimml (user class, computer using skills, professional experience), and
- psychological (assertiveness, self sufficiency).

- **Technical** *Sysrem* Mdel

TES Modelling components concern loading and management of a model of the Technical Systen the COGSYS blackboard. The model is a hierarchical structural representation of the TES allowing access to interesting information at several Ieveis of abstraction. When the M.ND system starts-up, the TES Model is loaded containing information about TES structurisation and information connec~ed tc the objects (components, sensors, and computed values) (Mletzko et al., 1995).

D is possible to link objects both vertically as object-subject and horizontally as object-objec relations, allowing navigation through the TES structure top-down and vice versa and, also, at the same level of abstraction from one object to another connected object. This offers, at the same time the possibility for a hierarchical view [e.g., for maintenance in abnormal situations) and for a topological view; vaiues can be linked at the same time to several objects at different kwels o abstraction. To improve rapid prototyping additional facilities are provided : the Visualization Interface for linking the TES Model to the GMS visualization facilities; the Simulation Interface for linking the TES Model with a simulation program, and a plain TES ModeI driving simulation that generates test data intended to support developers of TES modeis. The above mentioned facilities are implemented in C using the COGSYS AppIica[ion Programming Interface.

4. Simulated environments for two control applications

Two numerical real-time simulators of the two target plants were developed in order to aHow the laboratory testing of the power- and cement plants applications.

4.1 Simulator for power plant application

The simulator for power plant application is a full-scale real-time simulator, based on the modified and enhanced model of the S.Gills power pIant. The basic model worked on a VAX system and included a stearnlwater side, an economiser, the downcomers, the furnace walls, the steam drum, the primary and secondary superheaters, and the gas side, the combustion chamber (1 -dimensional model) and the bypass. In the frame of the AMICA Project, this basic version was ported by ENEL to the real time environment on a Motorola system, enhanced with the models of air and flue gas systems and with a 3-ciimensional model of the combustion chamber and with the model of the boiler control system (see AMICA Deliverable D2-a). A set of “ simulation test cases was prepared and first used for validation of the simulator.

4.2 Simulator for cement plant application

The simulator for cement plant application is based on a quite sophisticated model of a cement mill configuration at AaIborg Portland, consisting of a roHer press, a cement mill, a sepax-separator, and the connecting e~evators and conveyor belts. A detailed model (both energy and material balances) of the cement mill was specially developed by FLSA and GEC-Marconi S31 and integrated with more simple known models for the roller press, the sepax, and elevators and conveyor belts using a fourth order Runge-Kutta method (see AMICA Deliverable D2-b).
The simulation program is implemented using COGSYS for high level control including communication between the program and its graphical interface and is fully configurable. A graphicaI configuratkm task & made in GMS and Mows, e.g., to enter disturbances on-line.
An additional 10-task was made to communicate with the newest FLSA operator work station (ECS/opstation) so that the simulation process can be ccmtroHed by ECS. The replacement of this stand-alone task allows to hook up the simulator to any other control system.
The program was developed on a VAX-station running VMS, and except for the IO-task, it was also ported to UNIX by GEC-Marconi S31 to allow experiments on advanced presentation techniques carried out by the BWTE-EURAM fellow at Kassel University (see van Paassen, “ 1995).

5. Development and evaluation of two controJ applications

Both applications were initially prototype according to the user requirements and evalualed with end users participation using the existing simulating facilities. The final Applications were implemented as an extension of the initial prototypes and evaluated in the laboratory.

5.1 ADEPT - Power Plant Application

ADEPT (Amica and DiogEne for Power pIanTs) provides an advanced man-machine interface for DIOGEhTE (Diagnostic Generator di vapore - a diagnostic system for identifying malfunctions in the combustion process of a therma~ power plant), combining the presentation oi diagnostic results and other data from the plant with the provision of explanations and justifications.
It consists of the following main blocks unified within the generic architecture: GMS-based presentation side, COGSYS-based reasoning side, and two communication interfaces with the supervision system of S.Gills power plant (field system) and with DIOGENE [target system).
The following functionalities were included into the application with possible adaptation to two user classes, i.e., shift operators and maintenance technicians:

a) management of plant synoptics and other graphical materiaI,
b) management of trends for plant variables,
c) diary functionaiities with extended and automatic search support facilities,
d) advanced presentation facilities of DIOGENE results, and
e) justification facilities of DIOGENE results, with management of multiDle diagnosis, validation of sensors, historical diagnostic results etc.

Additional management facilities for efficient and robust integration of the different subsystems are also provided (see A.MICA Deliverable D&A).

The laboratory evaluation was based on the integrated environment (ADEPT + DIOGENE + Silmulator) and conducted through structured interviews. It allowed t; select and optimise the MMI functionalities for better usability, particularly easier access and navigation among different information sources, such as synoptics, trends, diary etc.

5.2 Cement Plant Application

The Cement Plant Application is developed as *an* advanced enhancement of the existing supervisory control system, so-called E(3 where the operator monitors and controls the plant using two to three operator stations. The application is based on one operator station and the rekwant A.M.ICA Panel interface is embedded as a non-overlappable window into the existing ECS interface.

The foHowing basic facilities can be adapted to the two user classes, i.e., operators and engineers:

a) the recipe function which supports the present action of process control parameters which are relevant to the selected recipe of cement,

b) the electronic diary function, and

c) the explanation function based on a causal probabilistic network (CI?N)

6. Conclusions

The evaluation of the results proves that the objectives of the project are achieved and efficiently applied in two different domains of control applications, i.e., power and cement plants.

The innovative means for achieving these objectives comprise

- advanced functional structure of MMI with embedded models of user performance and of the technical systems and supervision functions for dialogue and the overa~l interaction per se,
- consistent task-oriented approach towards MMI design and evaluation,
- open model- and knowledge-based architecture of MIMI,
- toolkit for the designers of advanced MMIs,
- application-related studies and software systems, i.e., ADEPT for power plant applications and relevant facilities for cement plant applications.

Both Applications have challenged and made possible

- to evaluate the described above design methodology and technology, particularly regarding end user participation,
- to analyse and to give evidence to the perspectives of future enhancements of the MhII functionaIities, as well as
  to verify and to expand the exploitation opportunities of the technology.

The evaluations, as weH as paraI1el activities of the partners on analysis of other markets and exploitation of the results prove the generic value of the results obtained for other application domains, e.g., supervision control in paper and chemical industry, in environmental protection and in training and simulation systems, particularly for pilot instructors etc.

The laboratory evaluations, as well as technological evolution and state-of-the-art allow to point out the foliowing perspective trends for future research and development:

- individual static and dynamic rnodelling of the human performance, i.e., for single individuals and for working groups (teams),
- methodologies and support technologies for task-oriented MMI design and evaluation,
- efficient technologies using multi-media and virtual reality for designing adaptive MMIs,
- ergodynamical studies of human-machine-environment systems, particularly, considering the working environments of human agents and their adaptation to the system through communication and, particularly, training (see, e.g.,. Vends and Venda, 1995),
  Kansei Engineering, i.e., studies of human feelings, images, impressions etc. to be considered in MMI design (see, e.g., Matsubara and Nagamachi, 1995).

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