International Innovation In Artificial Intelligence

Artificial Intelligence Applications Institute

Four decades of world-leading research and teaching in AI at Edinburgh

Two decades of innovative applications of AI at AIAI

Examples of key achievements include:

- **Formation** - a knowledge-based design system to lay out all British Telecom Yellow Pages directories and to create a new business area for Pindar Set Ltd for responsive marketing support and catalogue layout systems. Winner of an award for innovative applications of AI in 1998.
- **Expert Provisioner** - a rule-based system for the RAF Logistics to assist with procurement of spare parts. Saves £30m per annum for the RAF and is now being deployed to the British Army and Navy.
- **EASE** – a rule-based system deployed throughout Europe to estimate occupational exposure to hazardous substances for health and safety regulations.
- **Fraud Detection** – case-based reasoning has been applied to screen applications for financial products with MCL Software.
- **GhostWriter** - plan generation and multilingual presentation for aero-engine maintenance procedures with British Aerospace and Dassault Aviation (France).
- **O-Plan** and **I-X** - command, planning and control agents to support non-combatant evacuation operations, US Army military operations in urban terrain, multinational coalition operations, disaster relief, search & rescue, etc.
- **Optimum-AIV** - planning system for assembly, integration and test of Ariane IV payloads for the European Space Agency.
- **EUMETSAT** - specification of the telecommand system for the European Meteorological Spacecraft Control Centre.
- **International Standards** - inputs to the development of standards for process specification, workflow, enterprise modelling, etc.

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Advanced Knowledge Technologies
The next generation of knowledge lifecycle technologies

Description:

◆ Multi-million pound 6 year collaboration between 6 university groups:
  - ◆ Aberdeen: cooperative KA & knowledge refinement;
  - ◆ Edinburgh: lifecycles & ontologies;
  - ◆ Open Univ: internet-based services & knowledge modelling components;
  - ◆ Sheffield: text analysis & information extraction;
  - ◆ Southampton: two groups with skills in multimedia, ontologies, agents, knowledge acquisition, etc.

◆ Aims to identify or invent the next generation of technologies for capture, modelling, publishing, reuse and management of knowledge.

IF-Map Architecture

KRAFT-IX Ontology based Collaboration support

Results:

◆ IF-Map: uses Information Flow theory to merge two ontologies, based on a reference ontology.

◆ F-Life life-cycle editor, life-cycle interpreter and property checker: uses a formal life cycle calculus to describe property alterations during transformations.

◆ ExtrAKT Ontology Constraint Extraction Tool: finds ontology constraints in existing declarative knowledge bases & extracts them.

◆ KRAFT-IX Collaborative Support tool: integrates open-architecture workflow system with remote constraint solving system.

Further work:

◆ The ultimate goal of F-Life is to permit assembly of distributed software components over the Semantic Web, to perform complex transformations on large repositories of knowledge.

◆ The aim of KRAFT-IX is to provide a distributed virtual knowledge-based (and agent-based) workflow system.

◆ The overall aim of AKT is to provide seamless, intelligent, personalised access to and reasoning across the Web and other knowledge sources.

The ExtrAKT Ontology Constraint Extraction Tool

Universities of Aberdeen, Edinburgh, Sheffield, Southampton & OU
Funded by EPSRC as an Interdisciplinary Research Collaboration
http://www.aiai.ed.ac.uk/project/akt/

CoAKTinG
Collaborative Advanced Knowledge Technologies in the Grid

Description:

◆ Support e-Science collaboration by integrating tools for & demonstrating utility of:
  - ◆ intelligent task-orientated messaging, collaborative planning, issue, activity and constraint management;
  - ◆ peripheral awareness of the online presence, availability, attributes and location of colleagues, documents, & devices;
  - ◆ real time conversational mapping of meetings, providing shared visual focus and group memory capture ;
  - ◆ multimedia meeting mark-up, replay & navigation.

HyStream: meeting annotation and replay

BuddySpace: awareness of presence
Compendium: mapping of meetings

I-X/<I-N-C-A> Process Panels & Intelligent Messaging

Goals and technologies:

◆ To integrate multiple modes of collaboration.

◆ To enable replay of recorded and asynchronous meetings, navigated using process and issue-based ontologies.

◆ BuddySpace Instant Messenger (KMi/OU).

◆ Compendium for real time conversation mapping (KMi/OU).

◆ I-X Process Panels/<I-N-C-A> for Task-oriented messaging, planning and management (AIAI, Edinburgh).

◆ HyStream for multimedia mark-up (IAM/Southampton).

Further work:

◆ BuddySpace: Automatic maps, personal profiles, matchmaking services, zones of trust.

◆ I-X: Enrich exchange of concepts between I-X and Compendium and links between I-Space and BuddySpace to develop a 'meeting ontology'.

◆ Deal with issues supporting temporal, dynamic, and distributed resources

◆ Symbiosis with other ontologies and project.

◆ Inform meeting mark-up and personal presence using Smart Spaces (personal knowledge devices, etc.).

AIAI, Open University and University of Southampton
http://www.aiai.ed.ac.uk/project/coakting/

Course Selector

Helping students choose valid combinations of courses

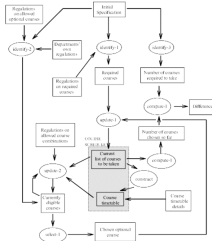### Description:

- Students in the Department of Business Studies at the University of Edinburgh have wide flexibility in their course choices
  - but timetable clashes rule out some courses
  - and Department regulations require some outside courses to be taken for 2 or 3 years.
- Directors of Studies used to spend 15-20 minutes explaining this to each of 50-60 students.
- Course Selector is a knowledge based system that advises on legal course combinations and sensible course choices.

Model showing inferences & domain knowledge

Benefits:

- Students no longer needed to navigate through the 800-page University Calendar.
- Automatically found timetable clashes (including one between two required courses for a joint degree).
- Directors of Studies now spent 5 minutes per student in the first week of the academic year instead of 15-20 minutes.
- Students can keep a disk of course choices from previous years to reduce the input required in later years.

Technical approach:

- Knowledge acquired from one interview and from the University Calendar.
- Knowledge analysed and system designed using KADS methodology.
- System implemented using CLIPS, "stripped down" for delivery on student lab PCs.
- Used 'negative truth maintenance' – course Y was marked as *un*available due to clash with course X, unless course X was deselected.
- Entire project took 8 man weeks.
- *Success due to good methodology and structure-preserving design.*

Model showing control & interactions

AIAI and the University of Edinburgh Management School
http://www.aiai.ed.ac.uk/project/courseselector/

EASE

Estimation of substance exposure for new industrial processes

Description:

- A knowledge based system to support occupational hygienists
  - When a new industrial process is developed,occupational hygienists must assess how toxic the substance is and how likely workers are to be exposed to it.
  - EASE supports the latter task.
- Key factors include:
  - Pattern of control: e.g. closed system.
  - Whether a closed system is ever breached e.g. for cleaning.

CommonKADS "model schema"

Benefits:

- Highlights potentially dangerous situations that may be neglected.
- Easier method of enforcing health & safety guidelines.
- Easier to update than paper manuals.
- Has been taken up by regulatory agencies around Europe.

Technical approach:

- Initial prototype developed by UK Health & Safety Laboratories.
- AIAI and HSL staff collaborated in developing new system:
  - HSL staff trained in AI techniques.
  - Used the CommonKADS methodology for modelling knowledge.
  - Used CLIPS and wxCLIPS (AIAI product) for software.
  - *Success through technology transfer and knowledge modelling.*
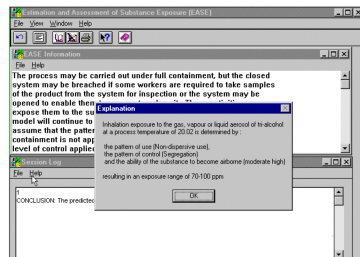
EASE Interface

AIAI and the Health & Safety Laboratory
http://www.aiai.ed.ac.uk/project/ease/

Enterprise

A framework for enterprise modelling & integration

Description:

- Major UK initiative to promote use of knowledge based systems in enterprise modelling.
- Enterprise Toolset developed to support
  - Capturing aspects of a business;
  - Planning of user tasks based on procedures;
  - Execution of process models;
  - Integration of off-the-shelf tools;
  - Standardised representation & communication.

Technical Capability (Entity)	Cognitive Capability	Business Capability (Entity)
➢Analysis (Device)	➢Understanding	●Marketing
•Requirements Analysis	➢Reasoning	●Customer Liaison
•Hazard Analysis	➢Creativity	➢Commercial
•Quality Analysis	➢Knowledge	●Contracts
•Testability Analysis	➢Authoring (Document)	●Bidding
➢Testing	➢Management (Device)	●Commissioning
➢Review	➢Development (Device)	●Procurement
➢Assessment	Physical Capability (Entity)	➢Personnel
➢Modelling	➢Manual Capability	➢Financial
➢Engineering	•Repair	
➢Design	•Removal	
➢Integration	•Fitting	
➢Maintenance	•Connecting	
➢Use	•Replacement	
IT- Capability	➢Sensory Capability	
➢Database Capability (Data)	➢Project Capability (Project)	
•Storage	•Management	
•Structured Storage	➢Planning	
•Hierarchical Storage	➢Organising	
•Relational Storage	➢Controlling	
•Unstructured Storage	➢Communication (Entity)	
•Retrieval	•Request	
•Search	•Respond	
•Calculation	•Inform	
•Simulation	➢Co-operation (Entity)	

Further work:

- Lloyds Register uses the Enterprise toolset for more effective modelling and re-engineering of business processes for strategic planning.
- Unilever used the toolset within its R&D activities.
- IBM UK used the Enterprise ontology in modelling its own internal organisation.
- The conceptual approach was carried forward into the Task-Based Process Management research project.
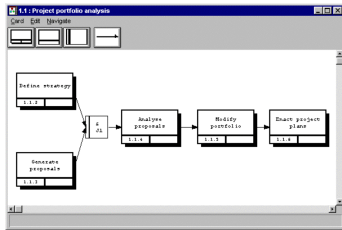
The Enterprise Procedure Builder

Results:

- Procedure Builder for capturing process models.
- Task Manager for integration, visualisation, and support for process enactment.
- Agent Toolkit to support development of agents in an agent-based architecture to support integration of COTS tools.
- Enterprise Ontology for standardised representation & communication.
- Bid Manager demonstrator developed jointly with Pilkington Optronics.
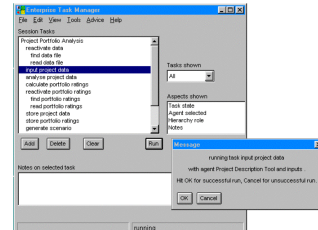
The Enterprise Task Manager

AIAI, Logica, IBM UK, Lloyds Register and Unilever
Funded by the DTI Intelligent Systems Integration Programme
http://www.aiai.ed.ac.uk/project/enterprise/

Expert Provisioner

Accurate prediction and ordering of aircraft parts

Description:

- A knowledge-based provisioning support system.
- Removes mundane form processing and prevents misinterpretation of special codes.
- Brings together information formerly stored on paper forms and index cards.
- Prompts user to investigate where necessary.
- Developed and distributed on networked Windows PCs.

Technical approach:

- RAF Logistics Support personnel trained in AI techniques.
- Intelligent provisioning used as a worked example.
- Management interest led to development of prototype using CLIPS rule-based system.
- Senior management interest in prototype led to development of full system.
- Visual Basic and MS Access used.
- *Success through using the simplest technology adequate for the task.*

Original order form

Benefits:

- Reduces the uncertainty of procurement budgets near financial year-ends.
- Reduces wastage through over-ordering.
- Takes advantage of price breaks for large orders.
- Maintains consistency of order processing.
- Easy to use and to understand.
- Estimated savings of £30 million per year.
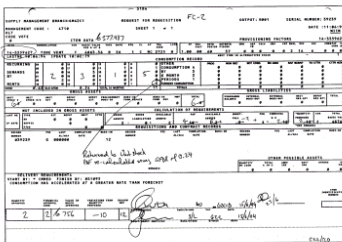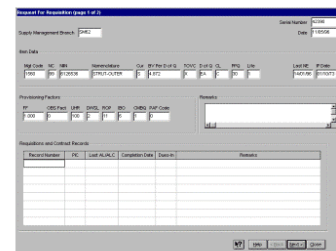
Order form in Expert Provisioner

AIAI and RAF Logistics Support Services
http://www.aiai.ed.ac.uk/projects/ep/

Formation

Knowledge-Based Layout of BT Yellow Pages

Description:

- ◆ A knowledge-based system for laying out Yellow Pages.
- ◆ Must include text entries, fixed size advertisements, headings etc.
- ◆ Allows programming of document styles.
- ◆ Allows dialogue-based modification and reconfiguration of programmed styles.
- ◆ Automatically lays out telephone directory according to style.

Technical approach:

- ◆ Layout styles are defined in a purpose-built object-oriented language, implemented in Lisp.
- ◆ Allows definition of page geometry, page items, layout strategy, and modular heuristics.
- ◆ Can be used by non-programmers.
- ◆ Pindar staff worked alongside AIAI during language development to obtain full working knowledge of the language.
- ◆ *Success through flexibility, usability & technology transfer.*
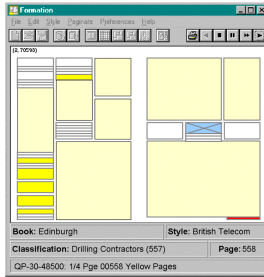
Benefits:

- ◆ Originally commissioned by Pindar Set to complete the contract to produce the UK Yellow Pages.
- ◆ Lays out directories at over 1500 pages/hour.
- ◆ Fast and flexible response to change requests.
- ◆ Small reduction in wasted space brings large cost savings.
- ◆ Generic and customisable, allowing production of a variety of Yellow Pages styles.

AIAI and Pindar Set
http://www.aiai.ed.ac.uk/project/formation/
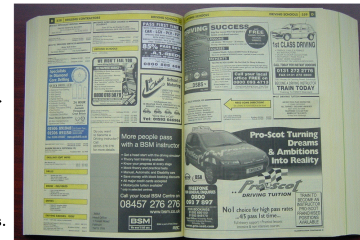
GhostWriter

Plan based generation of multilingual aircraft manuals

Description:

- ◆ An authoring environment to support production of technical documents by British Aerospace and Dassault Aviation.
- ◆ Each aircraft has a large number of maintenance & other documents, required in both English and French.
- ◆ GhostWriter supports generation of technical documentation in either language.
- ◆ It also gives advice about possible errors and omissions during the construction of a publication.

Technical approach:

- ◆ Maintenance procedures are written using a plan-based knowledge representation.
- ◆ Planning technology validates these procedures.
- ◆ Documents are then generated from this language-neutral representation.
- ◆ Procedures can be displayed using simple graphics.
- ◆ *Success through improved productivity and increased error checking.*

Benefits:

- ◆ Prototype has been used to produce documents for most of a complex maintenance procedure for the Falcon 900.
- ◆ The resulting texts are at a level close to that produced by human authors.
- ◆ Current version is interactive and semi-automatic.
- ◆ It also offers a potential speed-up in document authoring.

A Tornado aircraft with its accompanying technical documentation
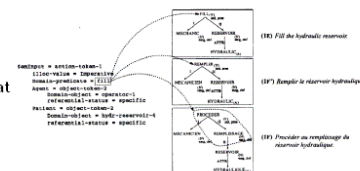
The internal representation used by GhostWriter

BAE SYSTEMS
DASSAULT AVIATION
British Aerospace, Dassault Aviation, & University of Edinburgh
**http://www.aiai.ed.ac.uk/project/ghostwriter/**

I-X
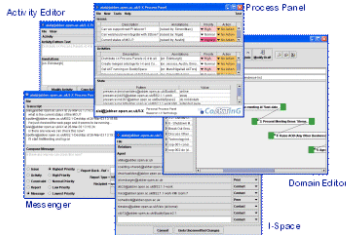## Intelligent Messaging, Event and Process Panels

Description:

- Can take on and handle issues, activities, constraints, and annotations/reports in the C^2 process.
- Intelligent messaging support.
- Intelligent workflow and process support.
- Uses a simple <I-N-C-A> ontology
  - Issues, Nodes/Activities, Constraints, Annotations.
- Operates anywhere in continuum from manual to fully automatic.
- Part of CoAX – Coalition Agents Experiment.
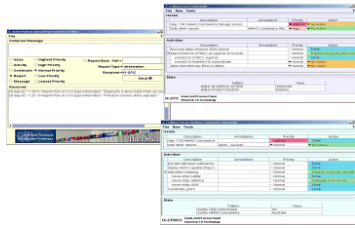
DARPA CoAX Demo

Further work:

- Intelligent Planning Aid ("I-Plan").
- "On-the-fly" repair and recovery during planning, execution and control of Coalition C^2 processes.
- Group collaboration facilities; links to other collaboration & video-teleconferencing aids.
- Improved process library editor.
- Improved "I-Space" agent relationship management tool and links to Grid Management Services.
- Improved deployment.

Results:

- Process Panels used for each command or country in CoAX demonstration.
- Flexible and loadable process models, process product descriptions and issue descriptions.
- Inter-agent commands, reports and message logging.
- Clarification of who says what to who else.
- Links to external capabilities.

I-X Process Panel Interfaces
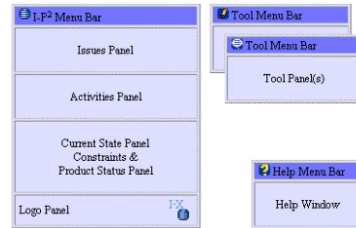
Schematic of I-X Process Panel Components

Optimum-AIV
Planning for Spacecraft Assembly, Integration & Test

Description:

- A knowledge-based system for planning and scheduling of spacecraft assembly, integration and verification (AIV).
- Aims to overcome simplified planning which manages temporal constraints but not resources or parallel activities.
- Commercial planning tools are either too simple to represent problems correctly or too complex to be used interactively.
- Used for planning the production of the vehicle equipment bays (VEB) for the Ariane-4 launcher.

Technical approach:

- A resource-driven scheduling mechanism facilitates the specification of different scenarios.
- Schedule development can be monitored while alternately using automatic mode/ manual mode.
- Notes conflicting demands for resources that cannot be solved automatically and supports the user in solving them.
- Allows monitoring of plan execution.
- *Success through involving & supporting the user in difficult decisions.*

Benefits:

- Rich description of AIV constraints is provided to user and used by the tool.
- Supports user in resolving resource conflicts.
- Clear representation & interactive capability allows assessment of several planning scenarios.
- Provides a single solution to both schedule management and the allocation of component equipment modules amongst competing VEBs.
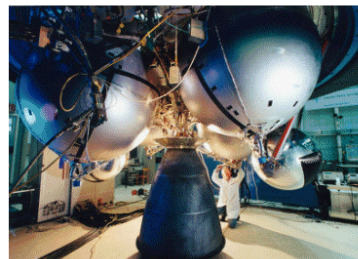
Images are copyright EADS. All rights reserved.

Search and Rescue

Intelligent planning & task support for search and rescue

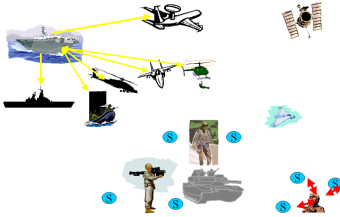### Description:

- Knowledge-based tools for RAF Search and Rescue
  - Selecting plans.
  - Generating "To Do" lists.
  - Automating status information.
- CoSAR-TS to share plans and processes between collaborating software agents in a Search and Rescue scenario
 - Uses DAML ontologies to support matching of resources to needs.

CoSAR-TS "downed airman" scenario

Benefits:

- RAF Search & Rescue was capable of
  - Automating administrative tasks.
  - Planning efficient use of helicopters & crew.
- Used to provide specification for fully developed system.
- CoSAR-TS
  - Enables cooperation between software and human agents.
  - Links models of coalition organizational structures, policies, and doctrines with intelligent task support software.

Technical approach:

- RAF Search and Rescue: O-Plan style planning based on CommonKADS model.
  - Linked to multiple user interfaces.
- CoSAR-TS: Shared intelligible models
  - tasks, structures, agents, capabilities, …
- I-X Process Panels for activity management.
- *Success through providing task support to human decision makers.*
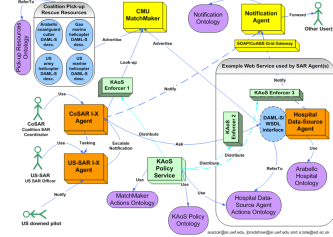
CoSAR-TS Demo Concept

RAF SAR: AIAI, DRA, Royal Air Force
CoSAR-TS: AIAI, IHMC, BBN Technologies
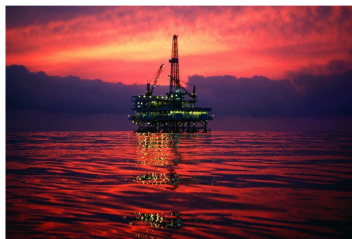**http://www.aiai.ed.ac.uk/project/cosar-ts/**

SPIRIT
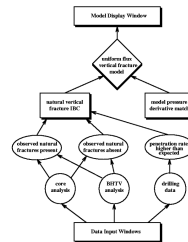
Knowledge-based interpretation of oil well tests

Description:

- Oil well tests require selecting an appropriate model to describe this particular oil well.
- This is difficult because:
  - It requires data from engineers, geologists, geophysicists & petrophysicists;
  - There is considerable uncertainty in data;
  - Different models sometimes produce the same response.
- SPIRIT recommends the most appropriate model to use.

Belief network

Benefits:

- Semi-automation of pattern recognition in pressure data.
- Reduced the non-uniqueness problem.
- Knowledge-based decision support.
- Integrates geological and engineering information with pressure data.
- Potential uses as a training tool and to carry out well test design calculations.
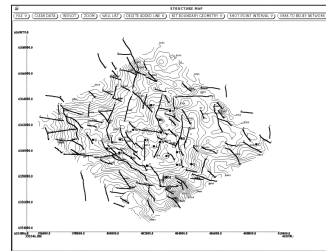
Technical approach:

- A pattern matcher matches (pre-processed) test data with theoretical models to compute model parameters.
- A belief network uses the non-numerical terms of a world expert to describe uncertainty, and reasons with uncertain data.
- Several external data interfaces were provided to aid interdisciplinary dialogue.
- First developed using KEE and Hardy; final prototype used CLOS and XView.
- *Success through reasoning with uncertainty & supporting multiple experts*

Data interface: geological structure

Acknowledgement for image of drilling rig in South China Sea: www.middlebury.edu

AIAI, Petroleum Science & Technology Institute (now ITF),
Enterprise Oil, Shell UK, Amoco, Bow Valley, Elf-Enterprise.
http://www.aiai.ed.ac.uk/project/spirit/