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SCIENCE AND ENGINEERING RESEARCH COUNCIL
RUTHERFORD APPLETON LABORATORY

COMPUTING DIVISION

DISTRIBUTED COMPUTING NOTE 626

issued by
Dr D A Duce

VISITS

Notes of a Panel Visit to Dr M Sloman & Dr J Kramer, Imperial College, 13 May 1982.

18 May 1982

DISTRIBUTION:

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Investigators/Sloman

PRESENT:

Dr M Sloman (Imperial)
Dr J Kramer (Imperial)
J Magee (Imperial)
R Allen (NCB-MRE)
Dr I C Wand (York)
Dr D A Duce (DCS Coordinator)

Objectives

The objectives of the meeting were to gather further information on the appication from Drs Sloman and Kramer for a Cooperative Research Grant in conjunction with the NCB Mines Reserach Establishment and to make a recommendation to the Chairman of the DCS Panel.

1. Project Overview

CONIC is an architecture for Distributed Computer Control Systems (DCCS). Funding to date has been from SERC and NCB. The project involves 2 staff at IC, Morris Sloman and Jeff Kramer. Three RAs (Jeff Magee, Kevin Twiddle and one other) work on the project.

The application environment is the monitoring and control of real time process systems. Physical distribution involves distances of 1-2Km for an industrial site, but up to 20Km for a coal mine. Present day systems involve of the order of 100 stations (each containing more than one microprocessor), future systems will involve 10's of 1000's. It is characteristic of such systems that they will be relatively static over periods of months to years. Such systems also have a long lifetime.

1.1 Application Requirements

The ability to introduce control in a phased way is very important, i.e. commencing with a stand alone system, through a subsystem to integration plant wide.

Hardware and software both need to be extensible, both through replication of existing components and the incorporation of new components or functions. On-line modification without stopping the system is also very important. The system should not be tied to a specific transmission technology.

1.2 Scope of CONIC

CONIC is an integrated set of techniques and tools for the construction and management of large DCCS.

The network architecture consists of interconnected subnets, each of which is a microcomputer based station.

The software methodology is based on the interconnectable reusable modules with strict interfaces.

The distributed operating system provides a multitasking kernel, message passing and resource management.

The communications system provides interstation message transfer.

The management system supports the configuration, control and maintenance of a large DCCS.

The software structure is:

```
        system manager
              |
     applications software
              |
       operating system
              |
    communications system
       |         |        |
    kernel    kernel   kernel
    station   station  station
       |         |        |
     transmission medium
```

A typical hierarchical DCCS would be a set of stations linked into subsystems which are connected by a plant wide communications system to a control room, linked through a packet switched network to remote company headquarters.

Subnets are connected by store and forward gateways with redundant paths, i.e. a mesh of subnets. Communications within a subnet is broadcast. The benefits of this approach are that it provides a lot of extensibility, stations may be added to subnets and subnets to the system. Localised communication is mostly within a subnet. This improves fault isolation; routing is simple (only necessary between subnets) and redundancy can be incorporated as appropriate.

This structure is very flexible. It can be matched to the functional or physical structure of the plant. A subnet can be a subsystem or machine or, say, a roadway in a mine. Network technologies can be mixed, for example rings and highways. New technologies can be incorporated and different transmission rates can be accommodated beacuse of the store and forward gateways, for example high speed for direct control and lower speed for plant wide communications.

1.3 Software

CONIC supports modular software components, with standard well defined interfaces and known (static) resource requirements. Coordination /cooperation are supported. Software management facilities include system building from components, control of components start/stop, on-line modification and queries/debugging.

1.4 Software Architecture

A system consists of a number of disjoint software components. Components are allocated to stations to implement control functions. Components communicate by message passing.

System configurations are modified and extended by adding modules (program modules) which communicate through strongly typed ports.

Programming facilities provided are communication and i/o to devices. A module consists of a number of tasks (sequential processes).

CONIC supports three interconnection patterns between modules, one to one (command response e.g. start motor), one to many (alarm, status), any to one (server, e.g. read value of sensor).

The requirement for continuous operation means that on-line modification and extension must be possible. Systems are assumed not to be computation bound, which implies there is no need for dynamic migration of software components (in any case devices are only attached to one processor) and that resource allocation can be static.

Modules consist of a fixed number of tasks, entry ports (holes through which messages enter the module) and exit ports (through which messages leave the module).

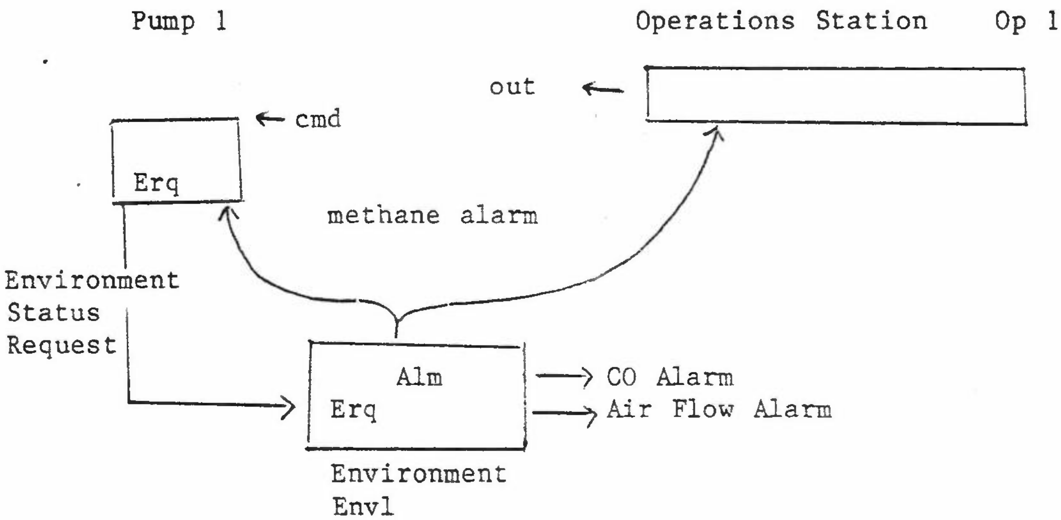
Ports are typed; port typing is equivalent to message typing. Typing provides a strict module interface (plugs and sockets).

Module interconnection and implementation are independent which provides flexibility for modification and extension.

1.5 Example

Consider a mine pump controller which, pumps water out of a sump. High and low water level detectors control the pump. However the pump may only safely be started if the methane level in the mine is below a safe level, so there is an input from an environment monitor.

Such a system might look like this:



A conveyor requiring an environment status input could be added without stopping the system by connecting its input port to Erq.

The configuration of this system is represented by the following statements in which modules are created at a specific station from predefined types:

```
create Pumpl:  pump controller at Station 2;
create Opl:    operatermod at Station 1;
create Envl:   environment at Station 3;
```

The following statements describe the linkage of the modules - connections from output ports to input ports:

```
link Opl.out to Pumpl.cmd;
link Pumpl.erq to Envl.erq;
link Envl.alm to Pumpl.alm, Opl.alm;
```

Initialisation:

```
start Pumpl, Opl, Envl;
```

Extending the system by adding the conveyor is performed by the statements:

```
    create Convl: conveyor at ...;
    link   Convl,erq to Envl.erq;
    start  Convl;
```

A typical module definition is:

```
 module operatormod;
    type   command = (ready, running, stopped);response = (ready,
           running, stopped);
           alarmreading = 1..10;
    entry port ALARM: alarmreading;
    exit port OUT: command REPLY: response;
 endmodule
```

Type checking is static; runtime checking is unnecessary. Runtime errors can only arise by corruption and in this case would be trapped by the communications system.

The CONIC language is sequential Pascal with the addition of tasks and communication primitives. Communications primitives behave similarly locally and remotely. Withdrawal is provided by long timeouts. Shared data is allowed within a module.

Request-Reply (bidirectional synchronous) communications syntax is:

```
    Transmitter                         Receiver
 send reqmess to exitport            select
    wait replymess  =  ...              receive reqmess from entryport
    timeout exp =  ...                  reply replymess
    linkfail  =  ...                    or
                                          when guard
                                          receive .. from ..
                                               =
                                               reply .. to ..
                                        or ...
                                        else timeout exp= ...
                                     endselect
```

Errors and exception handling are still very open areas. It is not clear what the application program should see of failures.

The CONIC language may at some stage be replaced by Ada; a research student is looking at this.

The syntax for unidirectional asynchronous communication is:

```
    send mess to exitport      select
                                       receive mess from entryport
                                 or..
                               else
                               andselect
```

A finite number of message buffers are provided at the receiver. Under overflow conditions the oldest buffer is overwritten. The programmer can control the buffer pool size. In control systems the overflow strategy normally used is to discard the oldest information. A queue size of 1 could be used so that the latest information is always provided in response to a select.

Ports are defined by the statements:

<u>exitport</u> ep: messtype
<u>with</u> multidestination (m)

<u>entryport</u> en: messtype
<u>with</u> queue (n)

There is no system buffering. The system can log when information is lost, i.e. buffers are overwritten.

1.5 What does CONIC provide?

CONIC is a way of specifying and constructing systems as a configuration of modules. The ideas in CONIC have been taken up by Renault and used as a specification language for a recent plant design.

CONIC is also a way of programming individual software modules (programming language); a way of controlling/extending/modifying a system on-line (management) and a uniform approach to software (minimal set of concepts).

1.6 Current State

The project currently has 5 LSI II's (1 x 11/23, 4 x 11/02) which are linked by a simple software loop with asynchronous V24 interfaces. The groups have deliberately chosen not to work at the network level.

<u>Kernel</u> (Pascal + 5% assembler)
- modules — ports
- tasks — message passing

<u>Operating system</u> (CONIC)
- creation/deletion of modules
- linking/unlinking of ports
- starting/stopping modules

<u>Communications</u> (CONIC)
- transport layer for virtual circuits and datagrams, though only datagrams have so far been implemented

<u>Utilities</u> (CONIC)
- debugger
- simple file server
- error logger
- linker

Preprocessor

CONIC language. Pascal and kernel calls uses YACC under Unix (modified to produce Pascal code) Pascal programs are compiled under RT11 (OMSI compiler)

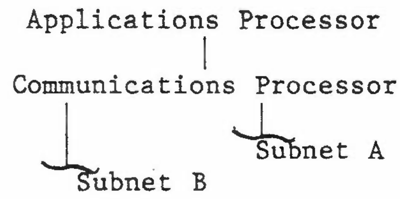
2. Research Directions

Discussion of the research content of the work revealed at least 4 distinct areas.

The general remark was made that CONIC has wider applicability than just Coal Mines. To demonstrate this the group want to build a CONIC system based on 'standard' LAN technology (ring or ethernet). Neither of these systems can be used unmodified underground because all electronics taken underground must be demonstrably safe in the most explosive air/methane mixture possible, so, for example, large reservoir capacitors are forbidden. For this reason NCB are developing their own LAN.

2.1 Station Architecture

They want to investigate the best way to build a dual station in which communications and applications software are run by different processors. They want to look at the interface between the two processors and at replicated network interfaces:



This area represents about 20% of the overall project research, and will go on in parallel with the LSI11 system development. The RA, Peberdy, will do this (about 50% of his time). They seem unfamiliar with other work in this area, and admit they have not given much thought to it yet.

SEEL have expressed interest in this area (letter attached).

2.2 Communications System

They want to look at network routing. Routing will be completely distributed. They will look at this area by simulation studies.

They also intend to look at communications management facilities and services (performance, maintainence and diagnostics). They have funds from Cost11/BIS in this area (travel funds); Sloman is the coordinator of this project which involves nine institutes.

ISO have recently established a management group and input will be made to this. This project involves Sloman (heavily) and the RA working on communications systems.

2.3 System Management

This project looks at system configuration, reconfiguration, changing physical and/or logical inter connections, configuration/status enquiry.

They have EEC money for collaborative work in this area with HMI (Germany), and INRIA, (2 year project). They hope to work closely with Professor Kopetz's group at HMI in Berlin.

They are considering using Prolog for the first attempt at a system database. They want to look at robustness, behaviour in the face of failure, what should be replicated, kept locally etc. Alan Lewis at Harwell has done some relevant database work.

Kopetz bases his approach on a global system time.

This area is expected to take about 50% of the whole effort on the project.

2.4 Software

Jeff Kramer is interested in defining the semantics of CONIC. This is difficult, much harder than for the language Jeff is looking at with Jim Cunningham in the other SERC funded project, as CONIC has more constructs and they have a more practical flavour. They tried hard not to invent another language. Ports, interfaces and modules are essential for distribution. The remainder of their work assumes that a system is composed of communicating modules with well defined interfaces. The interest is in message passing systems and their semantics.

Jeff feels that it is unlikely they will produce theorems from this work, but would hope to produce a set of tools, say to examine deadlock free properties.

Jeff hopes initially to look at the specification of the behaviour (maybe only partial) of individuals modules and then the behaviour of compositions of modules.

This area will involve Jeff, 1 RA (part-time) and one or more PhD students.

2 PhD students are currently associated with the project overall and they would hope to move to 4 or 5.

3. Coal Board View

Richard Allen gave the NCB's view of the project. The previous project started when NCB was on an upswing. Now budgets are extremely tight and it is difficult to fund anything.

NCB propose to fund this project as it is in an area of basic research in which NCB must be interested. NCB do not assume there will be concrete results, but hope there will be.

NCB were somewhat against the proposed modification of the OMSI Pascal compiler to produce a CONIC compiler. They felt the preprocessor approach was intrinsically sounder. NCB do not expect a fully engineered product - they would expect to develop this in-house. This point was discussed - the present system takes 5 mins to compile a 300 line CONIC program in an LSI 11/23. The only problem with the preprocessor approach is the need for the preprocessor to effectively build a full symbol table to do semantic checking which might more easily be done in the compiler.

The Coal Board propose to fund 2 RA's. Two people are currently employed on the project, Magee and Twidle. Magee will be funded by NCB, Twidle by SERC. Peberdy wants to join the project and would be funded by SERC. A fourth RA is to be recruited (to be NCB funded).

Without overheads, NCB would be funding 2 staff posts, value £87K. They will continue loan of the LSI 11/23 system and will loan a data transmission subsystem, value about £25K.

At the Mines Research Establishment, NCB will monitor the project. They will attempt to implement CONIC on their own equipment and will try an application to assess the system. They expect their main efforts to be in the network subsystem area.

NCB do not expect to be able to try an application before the final year of the project. They will review the project annually at which point they might decide to increase their contribution. Loaning equipment is easier for them than providing money!

HMI in Berlin want to use CONIC (Prof Kopetz). NCB's attitude is to encourage usage.

4. Private Session

The views of Dr Wand and the Coordinator at this stage were:

1. The area is industrially important. Sloman clearly has a lot of contacts in Europe in this control field and DCS would benefit from more input from the control area. The Imperial group are the only group in DCS working in this field. There was some concern that their effort might be becoming overly diluted over too many projects.

2. The Panel were not enthusiastic about the proposed modifications to the OMSI compiler to compile CONIC directly. This could easily become a sink for a large amount of effort.

3. The group should not implement a dual processor station without thoroughly examining other work in the field first, especially Grimsdale's work.

4. Maintenance and equipment charges seemed high. It was agreed that the applicants should be asked if, given that funds are tight, is there any area of the work they would be prepared to sacrifice.

5. The proposed project seemed to represent a very large amount of work if all the proposed areas were studied in depth.

5. Discussion

The applicants were told the Panel's views.

During discussion of point 2, Richard Allen stressed that NCB did not wish to see them modifying the OMSI compiler.

During discussion of point 3, it emerged that this aspect of the project had not yet been carefully thought out. The work would be done in conjunction with colleagues from the Electrical Engineering Department, but their names had not been added to the application as they were not contributing to the essential aspects of the work. On point 4, it emerged that Richard Allen, though personally interested in the station architecture work had been directed by higher authority in NCB not to fund hardware developments. It was agreed that this area was not in the critical path, though Imperial had not considered loosing it.

6. Recommendations

After further private discussion, it was agreed the following recommendations would be made to the Chairman of the DCS Panel.

1. Component costs for 3 new stations should be deleted and maintenance charges reduced accordingly.

   (a) NCB admit that they are not funding this area.
   (b) Much work is being done in this area elsewhere of which the proposal does not take cognisance.
   (c) The proposal is not well worked out in this area and it is separate from the other strands of the project.
   (d) If SEEL are seriously interested in this work, it should be a separate cooperative project with them.

2. The cost of the OMSI Pascal compiler source should be deleted.
   (a) NCB do not want the group to direct effort in this way.
   (b) It is not clear that modifying the compiler would be the trivial task the group seem to think it is. It could consume a lot of manpower.

3. Cost for Ethernet interfaces should be deleted.

(a) The group have not made the case that communications superior to the V24 links currently in use are necessary for work to progress.

(b) NCB are in any case intending to loan a network subsystem Integration of ths into the CONIC system may well require a non trivial amount of software effort.

With the above changes, costs become:

Staff 2 x RA 1A	72842
Travel	3480
Maintenance & materials	18000
	94322

Maintenance is reduced from £18K to £12K. This figure needs to be checked.

With these changes the Panel would recommend the award be graded Alpha 1 (low).

SEEL
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3 Young Square, Brucefield South Industrial Park,
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Tel: Livingston 411 503

OUR REF: AWKE/JMF

YOUR REF.

DATE 7th May 1982.

Dr. Morris S. Sloman
Department of Computing,
IMPERIAL COLLEGE OF SCIENCE AND TECHNOLOGY
180 Queen's Gate
London SW7 2BZ

Dear Dr. Sloman,

Further to our recent conversations, I would like to confirm this company's interest in the work you are doing on distributed process control.

At SEEL our two main activities are the manufacture and sale of local area communications equipment and microprocessor based industrial process control systems. We ultimately see these two activities merging, but this will be achieved only if a distributed system architecture, such as that envisaged by project CONIC, is implemented successfully.

We hope that your plans for continuing the project are successful and we would like to find some way whereby SEEL could collaborate with you in this development.

Yours sincerely,

A.W.K.Erasmuson
Technical Director.