A Network of Medical Work Stations for Integrated Word and Picture Communication in Clinical Medicine

H.U.Lemke, ITI

March 31, 1979

First draft of ~~application~~ specification; Copies (for internal distribution only) to DJ, HSS, HS

Content

1. Introduction

1.1 Information Management and Evaluation in Medicine

In the process of medical diagnosis and therapy, information is usually represented by means of the written word, pictures, graphics and the spoken word. For a particular patient the sum-total of this information may be labelled the medical record (MR). In the interest of a patient oriented health care system there are a number of important if not vital requirements on how the information in the MR should be organized and used, e.g. there should be

a) access to the information in the MR at the right place in the right time by the right people,
b) maximum utilization of information for diagnostic and and therapeutic purposes,
c) reliable linkage of all patient specific information into one MR.

In addition there are some desirable features of data representation and processing for the medical practioner, e.g. there should be

d) uniform, structured and easy to understand data representations of MR's,
e) easily extendable MR's,
f) save, protected and easily accessable MR's,
g) speedy statistical data gathering facilities on MR's,

and most important of all

h) flexible conferencing and consulting mode facilities using MR's and all modes of communication (i.e. word, picture and voice communication).

It is suggested in this document that each of the above requirements for information management and evaluation can be maximally satisfied by using medical work stations (MWS's) in a distributed computing network. A convenient network topology for this purpose is a ring of MWS's as shown in Fig.1.

A ring communication facility is very attractive for interconnecting MWS on a restricted site allowing high bandwidth with very simple control. Communication of a MWS to resources outside the local ring network may be achieved through microprocessor controlled bridges or gateways to other rings or global network facilities. These possibilities, however, shall not be considered further in this document, the interested reader is referred to (1), (2) and (3).

The development of a ring network of MWS's is currently being carried out by the COMPACT group at the Institut für Technische Informatik of the Technische Universität Berlin. The principle application of the MWS's is for the management of neurological disorders and includes a system for the Computerized Management, Processing and Analysis of Computed Tomograms (COMPACT).

Computerized management of computed tomograms (CT's) is taken to imply the association of textural information with CT's. However, transmission of CT's for communication and filing purposes are also considered to play an important role in CT management and may be effectively supported by the ring.

Processing and analysis of CT's are seen in the framework of image analysis, pattern recognition and computer graphics. All of the above facilities are based on a set of processes which represent the technical capability of the system.

1.2 Technical Capability

In the following is a brief summary of the processing facilities which a distributed MWS system should provide. It is assumed that all internal information in the system is represented in digital form.

Medical Work Station

a) Word Processing
   e.g. input and editing of constrained and free format text, searching, scrolling and panning of text for e.g. patient history, taking

b) Signal and Image Processing and Analysis
   e.g. preprocessing, segmentation and ~~pattern regonition~~ analysis of one- and two-dimensional data of ancillary investigations

c) Computer Graphics
   e.g. graphic ~~display~~ representation of one-dimensional signals, two-dimensional images and reconstructed three-dimensional objects

d) Communications
   e.g. transmission of voice, text, picture and graphic data; filing of (voice), text, picture and graphic data; hardcopy, command language interpretation

Ring

a) Local Network Facilities
   e.g. graduated (incremental) work stations with resource sharing, process to process communication, concurrent transceiving, information security,

conferencing mode

b) Global Network Facilities
e.g. bridge and gateway controls

Central to this set of facilities is the interactive command language interpreter which controls the user interface with the system as shown in Fig.2. Its main design features are:

1. Common syntax of driving commands for word, signal image, graphics and communication processing
2. Syntax and semantics as much as possible in line with "medical thinking"
3. Menu implementation
4. User oriented software (e.g. "sympathetic software")

Fig.3 shows the data flow between the main software modules of an idealized MWS. Not all facilities may be offered at every MWS, however, the command language interpreter for driving modules will always be present.

1.3 Clinical Efficacy

Clinical efficacy addresses itself to the question of assessing the impact of a technique on diagnostic and therapeutic procedures. As regards signal and image processing for computed tomography (CT) and following a definition of diagnostic impact given by the Institute of Medicine (4) it is save to state that the extend to which CT scan information has come to replace other diagnostic procedures including diagnostic imaging, surgical exploration and biopsy, it has proved itself to be efficacious. For many disease patterns it has become the primary diagnostic tool.

Many other sources of information, however, apart of CT scans, must be considered for neurological disorders in the process of differential diagnosis and therapy. That is, information from the patient's history, examination and other ancillary investigations must be integrated with CT images. A MWS for a particular clinical discipline such as neurology provides a physician with a means to ~~vertically~~ integrate this information into a MR.

In the patient-physician consulting mode a MWS system may promote a shift in the physician's way of working from patient data evaluation towards patient data gathering and structuring. In the physician-physician conferencing mode emphasis may then be given to patient data evaluation. Clinical efficacy of a MWS system will be achieved when the potential of the two working modes are properly realized.

For the system being developed at the Institut für Technische Informatik, signal and image processing facilities at the work station are at first limited to the processing and representation of electro-encephalograms (EEG), magneto-encephalograms (MEG), and of computed tomograms.

Initially, only two work stations will be linked through a > 1Mb/s communication medium organized as a ring network. It is expected that this minimum system will eventually be installed in a clinical environment so as to gain some experience on the impact of this technique on diagnostic and therapeutic procedures.

2. Systems Overview

2.1 Work Station

Fig. 2 shows the main software components of a fully grown MWS. A cut down MWS, however, may only need a subset of these modules. This flexibility must be supported by the Interactive Command Interpreter, which is always present.

A possible hardware configuration on which the software could be implemented is shown in Fig. 3. Central to this design is the bus and its controller. Some interesting research lies ahead for deciding on its control strategy as well as on the number and type of microprocessors to be used.

Fig.4 shows a number of artist impressions of the MWS. The final selection on this design will depend on anthropometric and ergonomic studies as well as on subjective arguments.

2.2 Network

Fig. 5 shows a possible RING network configuration for interconnecting MWS's. Although not many standards for this type of distributed communication system are as yet established efforts to rectify this are on the way. Some related standards, however, exist, e.g. ISO 3309 for the frame structure as shown in Fig. 6. The access logic interfacing to a MWS can be kept fairly simple since some of the logical functions can be performed by a microprocessor.

The station unit contains the logic and buffers for transmitting and receiving. Incoming signals are regenerated and passed on by the repeater to the next station along the communication medium of the ring. Since this part of the system, i.e. repeaters and communication media, is not required for the project before 1982/83 (see time scales of section 4.5), fibre optic communication media with either single-fibre bidirectionally passively teed or single- and double-fibre unidirectionally repeated teed networks should be considered for their suitability.

Microprocessor bridges to other rings or gateways to long-haul networks could be inserted at appropriate places in the ring. These possibilities, however, shall not be further considered for this phase of the project.

2.3 Software Engineering Aspects

Some design criteria for the MWS and the network must be laid down to ensure a basis for the discussion and decisions on aspects of the design and implementation of the system. In the following are some of the important points to consider.

Generality,
limited to the area of processing and representation of MR's for disease patterns which indicate certain classes of neurological disorders.

User Convenience,
appropriate RT response, application-oriented communication language, anthropometric design of hardware, sympathetic software.

Flexibility,
bus should allow change of resources connected to it,
few restrictions on type of resources which may be connected to MWS.

Efficacy,
not a very stringend requirement.

Reliability,
probability of loss of patient record -> 0,
MTBF > 1 month.

Performance,
trend towards automatic processes of reasonable performance can be achieved (i.e. appropriate real time response of system).

Maintainability,
standard components and interfaces wherever possible,
modular design,
documentation with "Structugrams."

Adaptability,
implementation language -> PASCAL, BCPL, (FORTRAN) ?
operating system (language) -> MODULA, TRIPOS ?

2.3.2 Network

Generality, limited to local (i.e. in house or restricted site) communication, sharing of resources, process to process communication, concurrent transceiving while work on MR at MWS proceeds, security of data for transmission and filing, support of conferencing mode.

Flexibility,
upper limit on number of MWS or other resources < 250, few restrictions on type of MWS or other resource which may be connected to network, plug-in or switch facilities to connect to ring, multiple addressing.

Efficacy,
efficient line and buffer utilisation only for low bandwidth line (bandwidth is relatively cheap, controlling it is expensive)

Reliability,
probability of packet loss should not be serious, replication of vital services such as output facilities, MTBF > 1 month, monitor station ?

Performance,
transit delay (i.e. transmission + acknowledge) network, performance measurements under various loads, no hogging.

Maintainability,
important to keep to standard interfaces and frame structures, network (ring) transparency through network adapted operating system.

Adaptability,
should be considered, particularly for changes in communication media.

3. Procesess

3.1 Word Processing

Information using written words can be found at various places in a patients MR. As a minimum it usually consists of a

a) personal history
b) symptom and sign description
c) diagnostic description
d) therapeutic description

Computerization of this information can be supported by a comprehensive set of word processing function (Fig.7), some of which may be

a) input and display information using basic and extended character sets (e.g. a,b,c,...and ♀ ♂)
b) string searches
c) moving of text units (e.g. a single character, word, phrase, sentence, line or arbitrary sequence of chracters)
d) basic edits (e.g. copy, erase, replace, insert)
e) Preprinted and protected (i.e. unshiftable text)
f) table compilation under tabrack control
g) viewporting with appropriate scrolling and panning

3.2 Picture Processing

A basic set of routines for processing CT's may be grouped according to their subject areas.

Picture Prepocessing (Fig.8)
a) Noise and artefact reduction,
b) direct and indirect pixel manipulation,
c) preprocessing for segmentation.

Picture Segmentation (Fig. 9)
a) Boundary detection,
b) data extraction,
c) preprocessing for pattern recogniton and graphics.

Pattern recognition (Fig.10)
a) 3-D reconstruction,
b) feature extraction,
c) classification.

Facilities for executing these processes may not be available at every MWS. Some type of process to process communication is therefore needed between workstations.

3.3 Graphic Processing

Graphic processes may provide some enhancement to the picture processing facilities and allows three-dimensional display of reconstructed internal organs of the human body. Typical processes may be (Fig.11)

a) interactive restoration,
b) interactive enhancement,
c) interactive segmentation,
d) interactive data extraction,

as well as a number of 2- and 3-D display programs.

Many of these processes require interaction and like picture processing facilities some processes may not be carried out at the local MWS. Again interprocess communication must be supported by the operating system (see TRIPOS). It will also be an advantage to have a dynamic dialogue generation facility (see DYNDIAL).

3.4 Communication

Communication processes are concerned with transmission, filing and hard copy facilities for (voice), text, picture and graphic information.

This part is not an important subject of research in this project. Commercially available technology will therefore be acquired wherever possible.

3.5 Command Language Interpreter (CLI)

Main features of design:

1. Common syntax of driving commands for word, picture graphic and communication processing facilities
2. Syntax and semantics as much as possible in line with "medical thinking"
3. Menu implementation
4. User oriented (i.e. " sympathetic software")

4. Realization

4.1 MWS Software

An expanded view on the MWS software of Fig.2 is given in Fig. 12. Realization will be based on a structugram-like description of the modules indicated. Although many of these modules will initially be realized in software, particular modules may later be realized in firmware.

The filing facilities should be linked or be part of a centralized filing system accessable to the ring. If such an access, however, is not possible, a local filing system may be used initially.

4.2 MWS Hardware

With the exception of the bus controller, hardware support will be achieved through off-the-shelf microprocessing units. Special components such as Distributed Array Processors or "Data Base Engines" may be used for appropriate functions. The main bus and controller on which the various components are connected will support 32-bit data and address transfers for DMA and if possible DDT communication modes.

4.3 Ring Hardware

a) Transmission media,
   optical fibre

b) Transmission control,
   Station unit incl. unique address setting, registers

for transmitting and receiving, buffers for trans ceiving control, error checking and if active a repeater with independend power supply.

c) Interface for station unit to MWS, special purpose microprocessor with DMA to main MWS bus.

4.4 Ring Software

Given a suitable operating system supporting distributed interprocess and data communication the ring software required can be limited to buffer and line control and to interface the ring station unit to the MWS. Again, the boundary between hardware and software is shifting rapidly as standardized protocols, for example for HDLC, are being realized in off-the-shelf data link control chips (e.g. Western Digital Corp's SD 1933 or Motorola's MC 0854). The software will be part of the interface of section 4.3 c.

4.5 Tests

Extensive tests with a number of users and a comprehensive set of realistic MWS sessions must be carried out before any field trials in a proper clinical setting are possible. These tests are designed to expose bugs as well as to provide data for improving user convenience. To achieve the latter, users must have some medical background and should be appropriately rewarded for this activity (e.g. co-authoring papers).

4.6 Field Trials

Field trials should be carried out in a real hospital environment, possibly between departments such as neuropathology, clinical neurology, radiology, radiotherapy, and neurosurgery. To obtain access to such an environment an extensive PR effort is necessary. This task will be made somewhat easier if interested and suitable members of the medical profession join the project at an early stage.

4.7 Timescale and Costs

Activity	Timescale	Equipment	Personnel	Cost (DM)
Specification	Jan.-Dec.79	--	--	--
Design	Jan.80-Sept.81	1st MWS	--	80k
Implementation	Oct.81-Dec.83	2nd MWS + Ring	2xBAT 2a	100k+240k
Testing	Jan.-Dec.84	--	1xBAT 2a	60k
Field trial	Jan.-Dec.85	--	1xBAT 2a	60k
				540k

Specification and design will be carried out by personnel of the COMPACT group with assistance from diploma and Ph.D.students.

During the design phase some "experimental" implementations will be carried out in parallel (diploma-thesis) to provide bottom-up design information.

Personnel costs for the implementation, testing and field trials should be met through outside fundings.

5. Social and Related Issues

5.1 Social Issues

In the past most applications of computers in the medical field have been concerned with financial and statistical data processing or simulation and very little attention has been given to an approach similar to the one followed in this project. Some indirect requirements for a MWS are however expressed in a table compiled by Gene Thomson and Isa Handelman (5) showing a few unmet needs in health care, see Table 1.

In particular the needs for

a) integration of preventative, diagnostic and therapeutic care,
b) single medical record, available at patient contact,
c) radiological interpretation,
d) physician service monitoring and education

may well be satisfied by a system of MWS's.

The introduction of MW's will almost certainly effect the pattern of work by the physician as well as the hospital as a whole. Only a very gradual introduction can therefore be attempted even at a medical setting which does not discourage new technologies and procedures.

5.2 Economic Issues

With continuous reduction in the cost of microprocessors and associated equipment the total hardware cost of a MWS by 1985 can be assumed to be less than 50kDM.

Soft- and hardware developments are estimated to be between 8-12 man years.

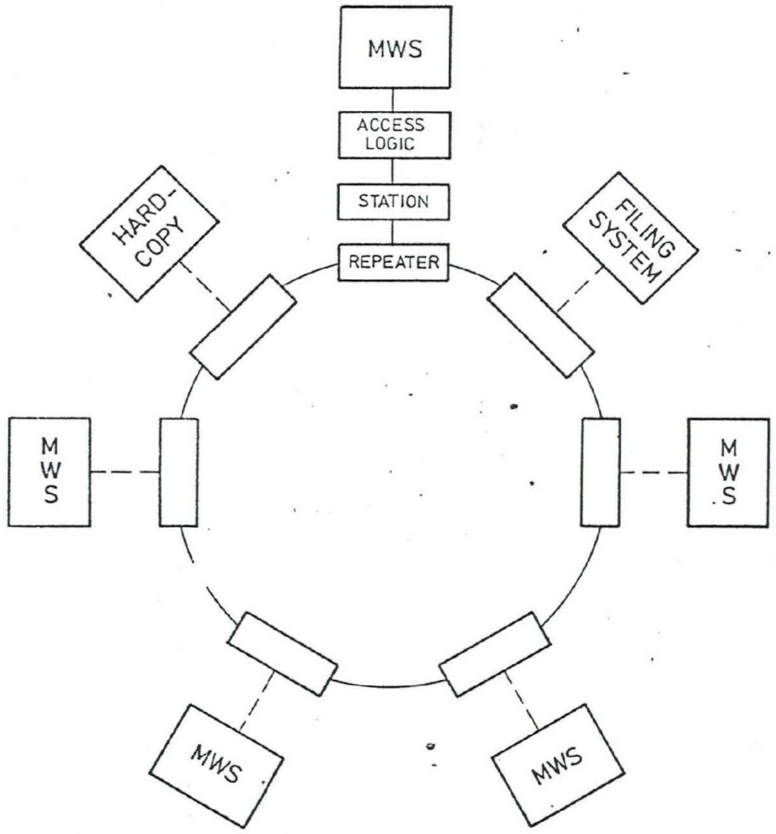

FIG.1 MWS IN A DISTRIBUTED COMPUTING NETWORK (e.g. RING NETWORK)

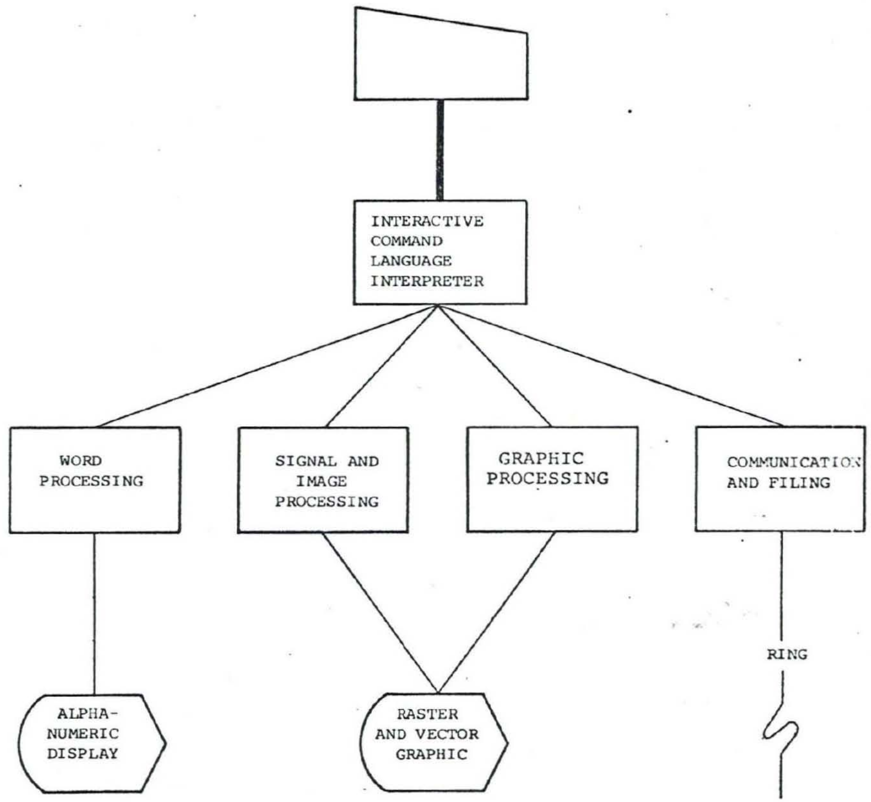

Fig. 2 INTERACTIVE COMMAND LANGUAGE INTERPRETER

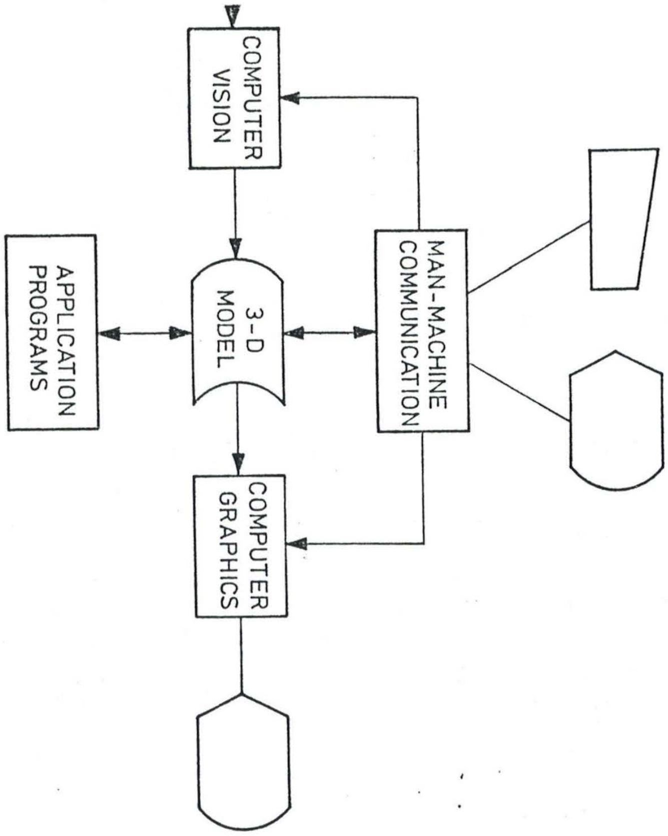

Fig. 3 3-D MODEL AND GENERAL SYSTEMS ENVIRONMENT

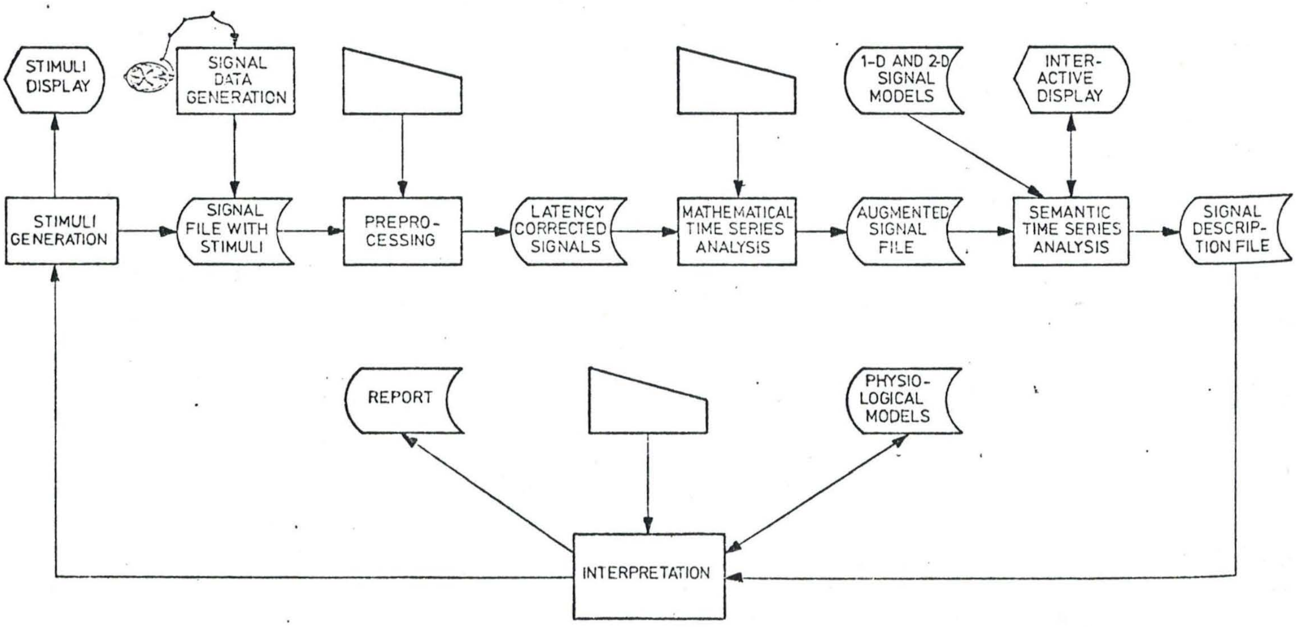

Fig. 4 FUNCTIONAL DIAGRAM OF EEG / MEG PROCESSING

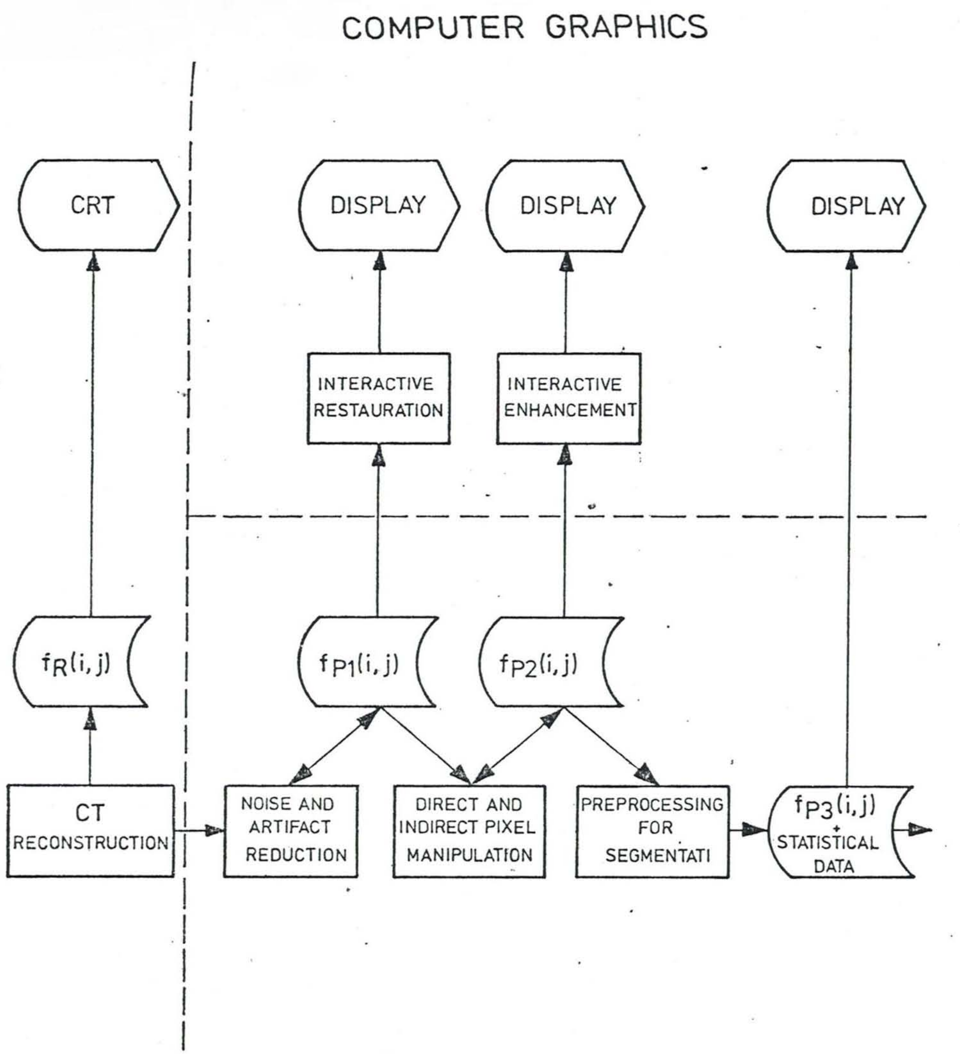

Fig. 5a PICTURE PREPROCESSING

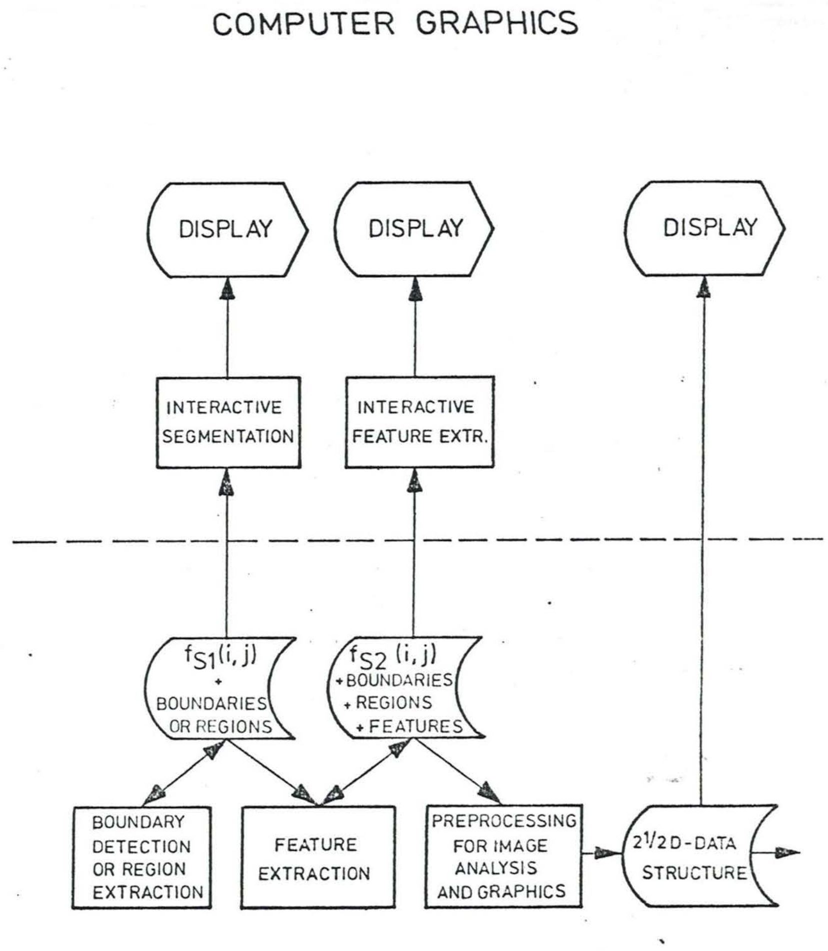

Fig. 5b PICTURE SEGMENTATION