LERNIE VIII

L. Biek, B.M. Hawker*, N.E. Lindsey** & G.N. Lupton***

Ancient Monuments Laboratory, 23 Savile Row, London W1X 2HE
*Atomic Energy Research Establishment, Harwell, Oxon, OX11 0RA
**Department of Civil Engineering, City University, London EC1V 0HB
***Transport & Road Research Laboratory, Crowthorne, Berks, RG11 6AU

Most of the necessary words have already been printed (Biek 1979). In basic terms, our overall aim is to recreate past life from coloured shapes in the ground. The primary need is to capture what we see as excavated - directly and more objectively than is humanly possible - and to store it for instant access by any enquirer. Invisible qualities such as chemical composition can be added to the basic information. Statistical and comparative routines offer up-to-the-microsecond assessment of specific data or general situations and particularly areas of research. One incidental advantage, in the global context, is the absence of language barriers; another, the inability to accept persuasive 'literary' arguments.

Display is in good quality colour TV and directly interactive. Inspection in the round and movement along selected routes through model or recreated environments can be accurately visualised. Image processing provides instant, precisely scaled typological parallels. Development is towards stereo-pairs of digitising TV cameras directly linked to the data analysis system.

Fig. 1 compares current general practice with a scheme for a program to replace it, operating 'in parallel' as against present work 'in series'. The important difference lies in the principle, rather than in obvious benefits of speed, reliability, coherence and feedback. Like the STRATA program (Wilcock this volume) it makes possible an altogether new, instant lateral approach.

Photogrammetry (NEL)

For the best results a pair of identical cameras is rigidly mounted and suitably aligned on a base, an accurately measured distance apart; synchronous exposures ensure identical conditions. Two classes of camera are used:

(i) metric, specially constructed to have minimum lens distortion and rigid geometry, i.e. known focal length, etc., and give very precise measurement. This is possible with a simple stereoscope and parallax bar, but many sophisticated plotting machines and stereo-comparators are also in use. In these, stereo pairs of photographs of various sizes are transformed into either graphical records (plan, elevation, cross section, contours) or 3D coordinates of points on the stereo-image (model).

(ii) non-metric (including 35mm), which is quite adequate for records and interpretation.

Captive balloons and radio-controlled model planes are used to cover a site or large area. Special applications include, for example, stereomicrographs of metallographic sections (Minter & Piller 1979). Generally output still depends on human selection of significant floating marks on the model. Computer-digitised coordinates are printed out or stored on tape or disc, displayed, or recreated into the model. Stereo-TV monitoring (with recording and playback facilities) is used in atomic reactors. Work in progress is perfecting individual-pixel-addressable Array camera pairs without film to give digitised storable data directly. On the other hand there is the D.I.Y. reflex plotter as a drawing aid (Scott 1981).

PHASE	ACTIVITY/RECORD	NEED/COMMAND	MACHINE SEGMENT				
			RECORD/ SEARCH	COMP	INTEG/ PLAN	LEARN	R&D
PRE	Literature search	PREPARE		x	x	x	x
	field/specialist						
	surveys		x	x	x	x	x
	planning						
	Site organisation	DIG	x			x	
	survey		x	x	x	x	
	drawings/photos						
	plans	SPECIALIST					
	sections	EXAM:					
	features		x	x	x	x	
	details	FIELD/LAB:					
	finds						
		CONSERVE	x	x	x	x	x
POST	Results:						
	typological	COMPARE (STATS)					
	environmental						
	technological	EVALUATE					
		INTERPRET					
		INTEGRATE					
		REVIVE			x	x	x
	publication	AVAILABLE					
	museum/archive	EXHIBIT/STORE	x				

Figure 1: Dig organisation: cumulative data flow from planning stage to 'disposal'. Columns down – present optimum, with alphanumeric computerisation (e.g. Jefferies 1977). Rows across – direct digitised stereo-image capture with automatic on-line analysis, (incl. comparative retrieval) and 'learning' database.

Pl. 1–7 illustrate the types of record to which the method has recently been applied. They are best seen with a normal pocket stereo-viewer but can be fused without, directly by squinting (Cooper 1977; 1978; Karara 1979).

Visualisation and animation (GNL)

At T.R.R.L. a general purpose PRIME 750 minicomputer interfaced with an Advanced Graphics Display Terminal (Freeman 1977; Blek 1979) is used with a range of equipment (storage tubes, intelligent terminals, plotters, etc.). Precise images are generated in 3D, true perspective and accurate colour within an interactive system of rapid updating capacity and virtually limitless colour range. Line drawings of one phase in a multiperiod plan can be displayed as full colour shaded images for visual analysis. The Computer Aided Design Centre's THINGS is used for model creation and their GREYSCALES for model visualisation. The former is enhanced at T.R.R.L. giving better visualisation of objects defined by a rectangular grid of 3D coordinates (Lupton 1981).

Pl. 8 was produced from a contour plot (made by NEL of the urn shown in Pl. 7) digitised in a form suitable for a rectangular grid and handkeyed into a PRIME storage file. A 27-line FORTRAN program sufficed to read in the data and call up the THINGS subroutines which created a 3D model of a segment of the urn in a form suitable for visualisation. This consisted of 1139 data points and 1056 planes, close to the frame maximum. Using GREYSCALES the model was viewed from a variety of positions by issuing commands to the program. The views took about 10-15 seconds to generate and were recorded directly from the monitor screen as 35mm transparencies. With a computer-controlled camera an animated film sequence can be made.

Among envisaged developments are a subroutine for THINGS to process contour data into a triangular rather than rectangular grid, direct access from digitised photogrammetric data to A.G.D.T. and overlaying of several segments so as to portray the whole object.

Image comparison (BMH)

At A.E.R.E. a PDP-11/60 computer with 248Kbytes of memory and 200Mbytes of disc storage capacity, two display devices and, since December 1980, a Stanford Technology Corp. I^2S/70E display/processor is used (Hawker 1978). Only four others exist in Britain but similar devices are made here (including PPL's 121LMD and CADC's GEMS and BUGSTORE described by Biek (1979)). The device has 4 stores each for 512 x 512 elements in the range 0-255 (i.e. 8 binary bits).

Using an RT laboratory TV camera, but any 625 line camera is suitable, video images can be digitised in real time to 512 x 512 elements by 8 bits of which 6 bits are significant without noise reduction. Images of two mediaeval iron keys of different sizes (Pl. 9a, b) were compared by using first a digital cursor interactively to locate the top and bottom of each key, and then the translation and shrinkage facilities for one of the images to bring both into register. After converting both into binary form it was possible to display a 'difference' image (Pl. 9c). Using a 'Laplacian' operator the binary images were transformed into outline diagrams and a corresponding difference image was obtained (Pl. 9d).

Such processing can be made automatic by suitable lighting and thresholding, use of maximum cordlengths to achieve register, and normalising some specified parameter if and as necessary; and for the actual comparison by subtraction and area assessment, or using radius lengths from centres of gravity, or feature extraction.

Storage of digital image data is always bulky: one key used 100Kbytes; one magnetic tape could hold over 100 such images. Access to images near the centre of the tape could take minutes; but storage for a outline would take only 2Kbytes so that 5000 could be stored on one tape.

Similar comparisons are equally feasible for any other type of image, for example, image processing of scanning electron micrographs of charcoal structure (McGinnes et al. 1976). At A.E.R.E. they are used to study urban growth from LANDSAT pictures (Carter & Smith 1981) and in X-radiographic inspection systems for quality control (Burch 1980a; 1980b).

Expert systems

Modelled on highly interactive structure-fitting software (Heller et al. 1977; Bernstein & Andrews 1979; Buchanan 1979; Wilson 1980) modules are being programmed for specific chemical diagnosis in archaeology (see Fig. 2). In effect this amounts to direct routine archiving by specialists of their accumulating experience. It corresponds to publication but is arranged in a bare logical sequence accessible to artificial intelligence. Study of expert systems (Michie 1980a; 1980b) has shown: the power of patterns of key concepts, from which standard unit rules can be built up; the need and ease of programming

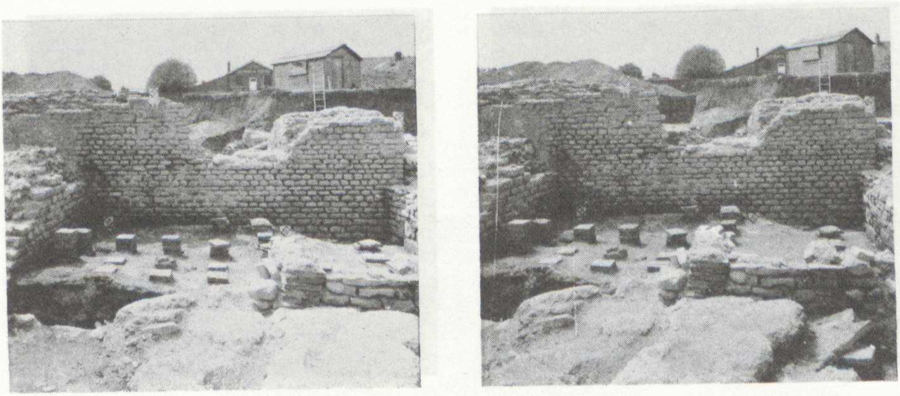


Plate 1: Stereo-pair:
Roman bath house at Dorchester, Dorset.

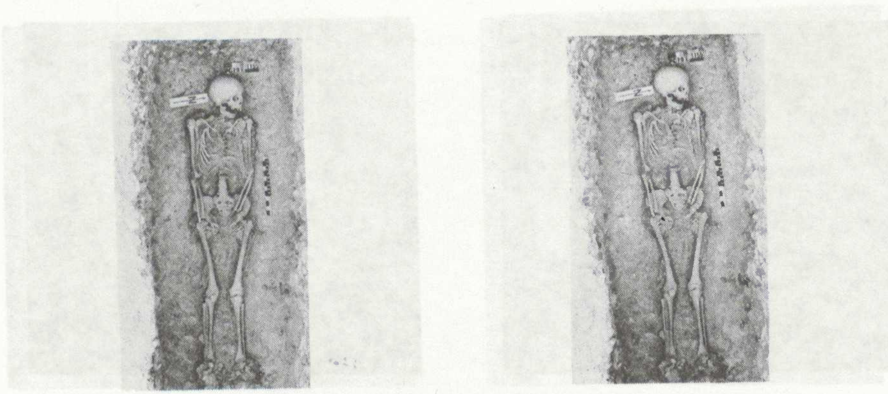


Plate 2: Stereo-pair:
Roman burial at Poundbury, Dorset.

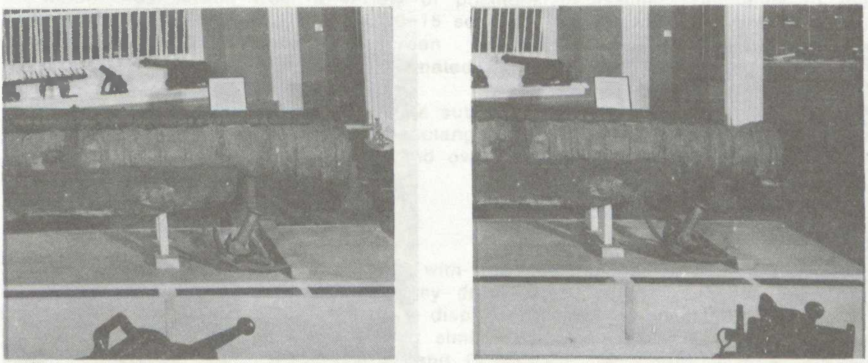


Plate 3: Stereo-pair: Detail of 'Mary Rose' iron cannon.

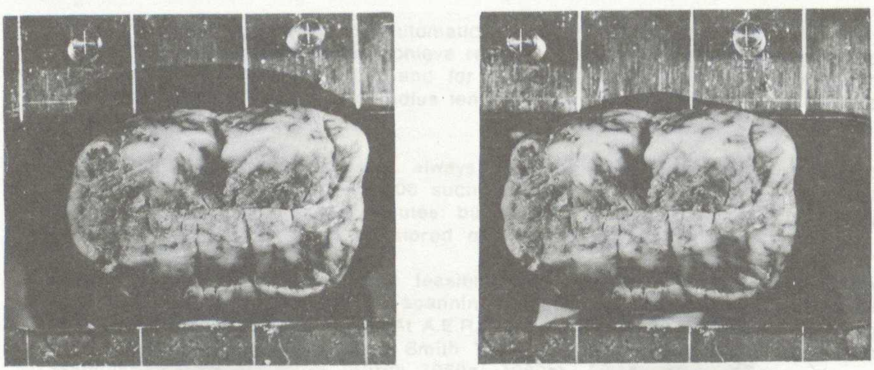


Plate 4: Stereo-pair: <u>Ursus deningeri</u> molar, Westbury-sub-Mendip, Som. (1 div = 10mm).

Plate 5: Stereo-pair: Detail of stone statue (original) at Wells Cathedral, Som.

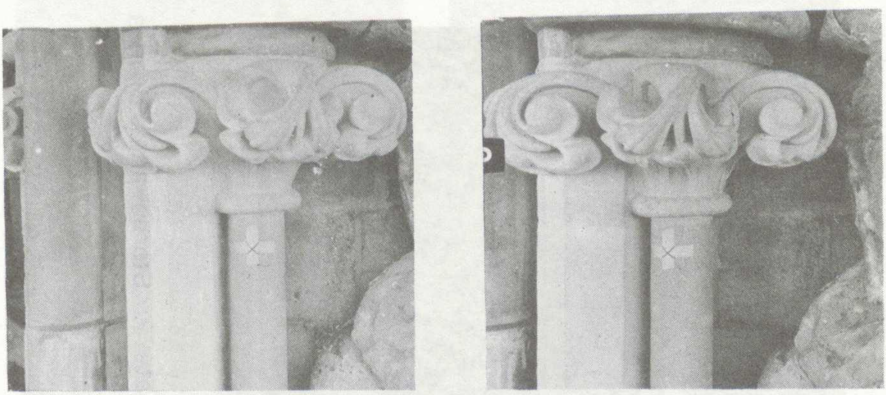


Plate 6: Stereo-pair: Detail of stone capital (replacement) at Wells Cathedral.

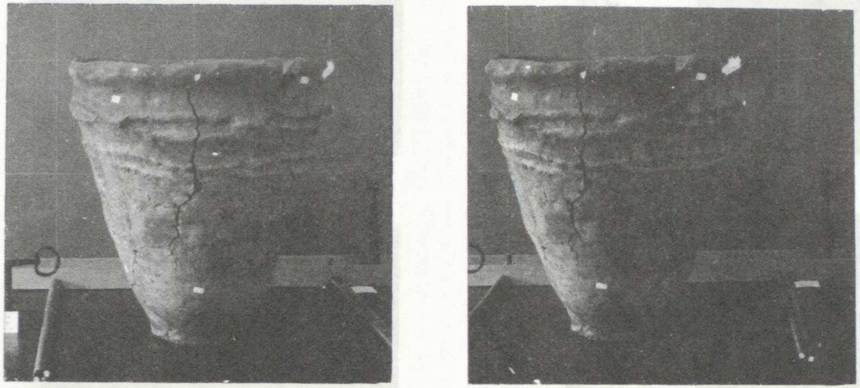


Plate 7: Stereo-pair: Bronze Age urn from Ardleigh, Essex.

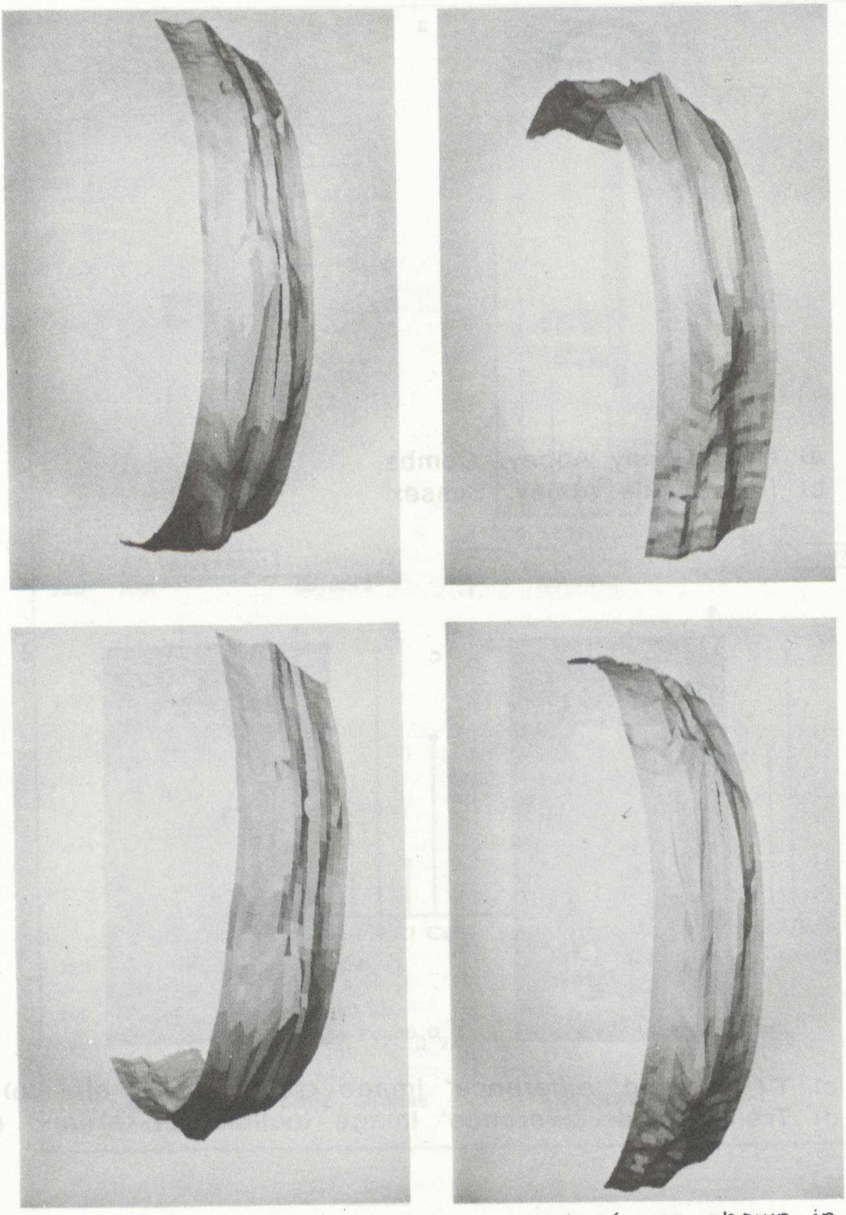
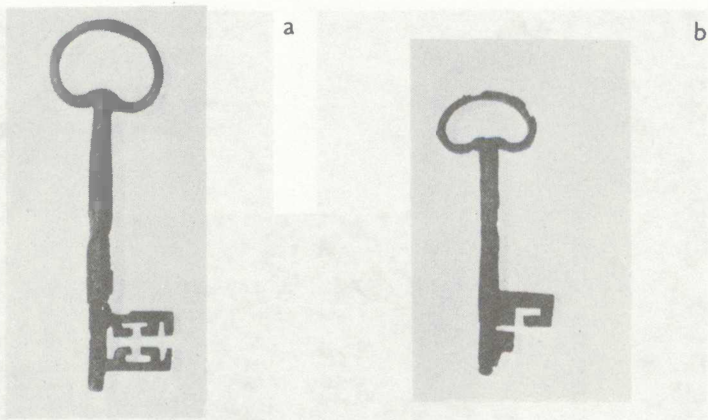
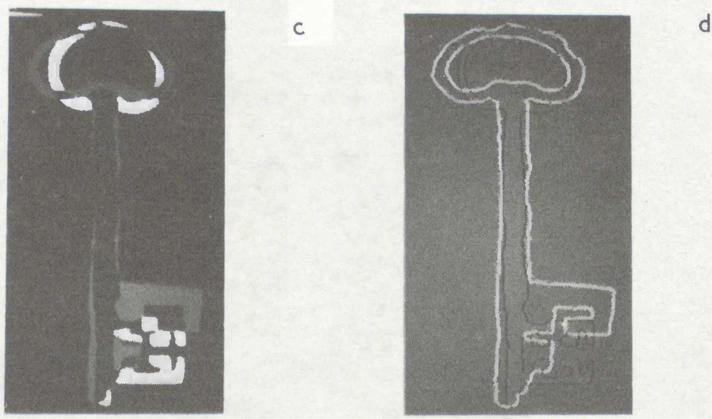


Plate 8: Visualisation of rim-segment of urn shown in Pl. 7.



a) from Denny Abbey, Cambs.
b) from Battle Abbey, Sussex.



c) TV digitised 'difference' image (solid) of (a) and (b).
d) Transformed 'difference' image (outline) of (a) and (b).

Plate 9: Mediaeval iron keys:

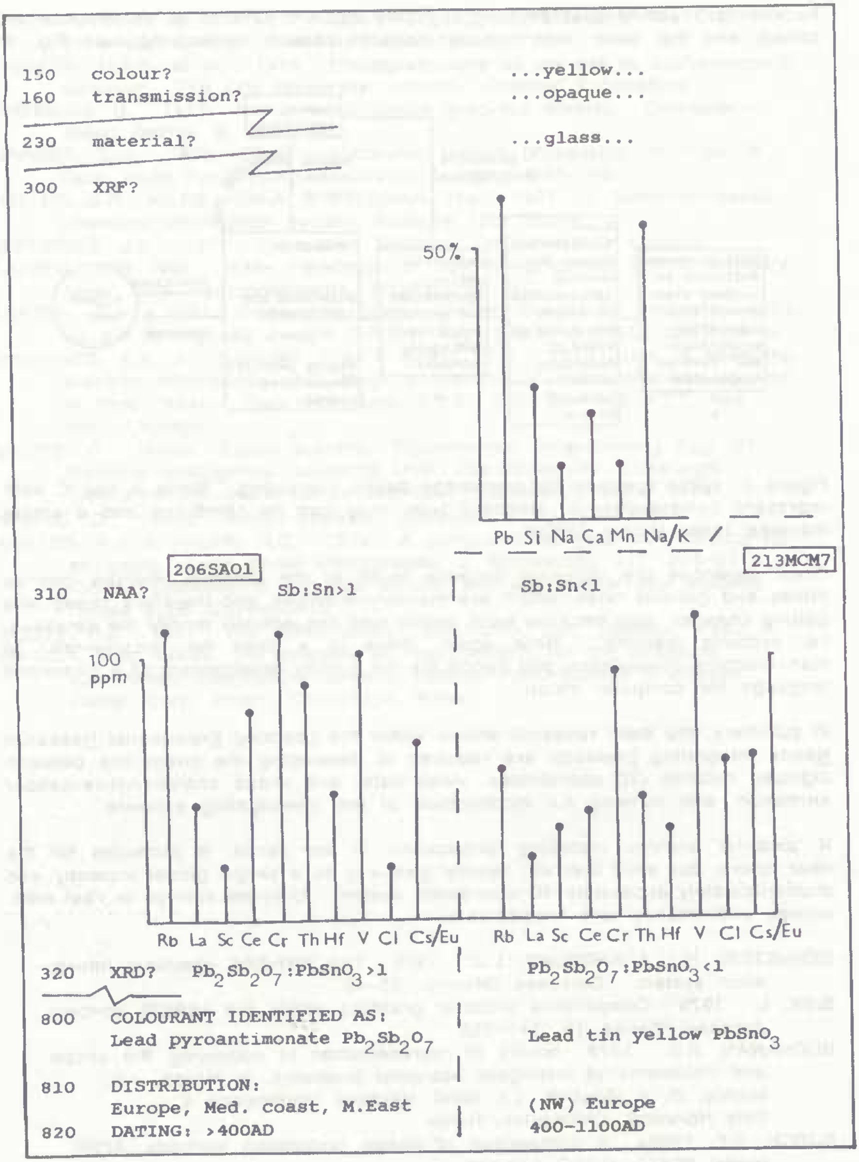


Figure 2: Systematic Chemistry in Archaeological Diagnosis (SCIAD) - module for opaque yellow glass (diagnostic steps only). The two histograms at 310 can be fused for comparison by squinting, like a stereo pair.

backwards; machine-programming of highly efficient patterns to be possible and cheap; and that such 'man-opaque' patterns require humanising (see Fig. 3).

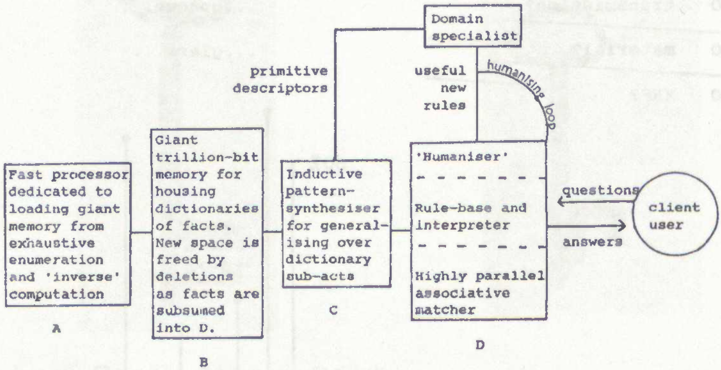


Figure 3: 1980s scenario for knowledge-based computing. Since A and C both represent computations of standard type, they can be combined into a single machine (after Michie 1980a).

Great advances are imminent because much of the program involves look-up tables and general rules, which are memory-intensive and therefore cheap and getting cheaper; also because each action rule can actually modify the database, i.e. produce learning. Here again, there is a need for 'picture-talk' in man-machine consultation and hence for the further development of a command language for computer vision.

In summary, the main research efforts within the Learning Experiential Research Needs Integrating Evaluator are required in developing the direct link between digitised records (3D coordinates, video data) and image analysis/visualisation/animation, with running A.I. modification of the investigating software.

A 'pictorial' archive, replacing 'publication' in any sense, is projected for the near future; but even that will rapidly give way to a single global instantly and multiarticulately accessible 3D-coordinate system. Ultimate savings in real time, energy and 'money' are incalculable.

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