Applications of the SAMMIE CAD system in workplace design

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Introduction

Computer Aided Design (CAD) is now firmly established in some industries as the normal method of originating and evaluating designs. Thus in aerospace it would be normal to have computer representations of proposed aircraft long before mock-ups or prototypes are available for functional evaluation. This implies that many aspects of the design may be finalised before there is any opportunity to carry out ergonomics evaluations of the work space or work tasks which will eventually confront the operator. Other industries are not so advanced in using computers in design, but would benefit from the ability to carry out ergonomics evaluations early in the design process. It is natural therefore to look for CAD systems which have the capability of considering human as well as mechanical, structural or other aspects of design.

SAMMIE. System for Aiding Man-Machine Interaction Evaluation, is one such system which has been used in this way for some years. It assists in the building of a computer model of the workplace which can be viewed and manipulated on a graphics screen in ways which will be familiar to users of modern three-dimensional solid modelling systems. In addition. and most importantly, it includes a model of the human operator which is used as an evaluative tool.

This paper very briefly describes the characteristics of SAMMIE but concentrates on describing applications of the technique to workplace design. In the main these applications originate from design consultancy carried out in recent years, and include supermarket checkout facilities, visibility studies in underground trains, and a machine shop environment.

The SAMMIE System

Details of the SAMMIE system can be found elsewhere (Case, Porter and Bonney, 1986 and 1989) and only a brief description is given here. Workplace modelling facilities are provided by a relatively simple form of boundary representation solid modelling (Requicha, 1970). Solid shapes are represented by plane-faceted polyhedra :which are usually specified by the user as primitive shapes such as cuboids, cylinders. cones, prisms, etc. These are combined with spatial and relational information into a hierarchical data structure which permits the modelling of certain functional aspects (such as the opening of a car door). Interaction with the model is via a menu system and most of the normal CAD system facilities are available. Thus the model may be displayed in various ways (with hidden lines removed, colour or monochrome, etc.) and viewed as appropriate (i.e. in plane parallel projection, orthographic projection or perspective). The model may be edited to change dimensions of objects, reposition or reorientate them, and to change functional relationships (such as changing ownership within the data structure).

A man modelling facility is based upon and completely integrated with this workplace modelling system. A pin-joint and rigid link approximation is used to define the model's structure and this is encased in solid modules of 'flesh', (as shown in Figure 16.1). All aspects of this are data-driven and most are accessible to the user, thus ensuring that the model represents the desired user population. The joint-to-joint dimensions (or limb lengths) can be specified in a variety of ways including the selection of percentiles from population data. Similarly the flesh shape is controlled by somatotype specification (Sheldon, 1940). Articulation about the joints is possible so that working postures can be created and evaluated. Commonly used postures (for example standing and sitting) can be directly called from a menu, while others can be retrieved from previously created databases which may be specific to an application area. Alternatively, the model may be moved interactively a joint at a time, or reach algorithms may be employed to predict postures related to a task. In all cases joint extension is constrained to remain within maximum limits which once again are defined by user-accessible data. It is also possible to evaluate postures against

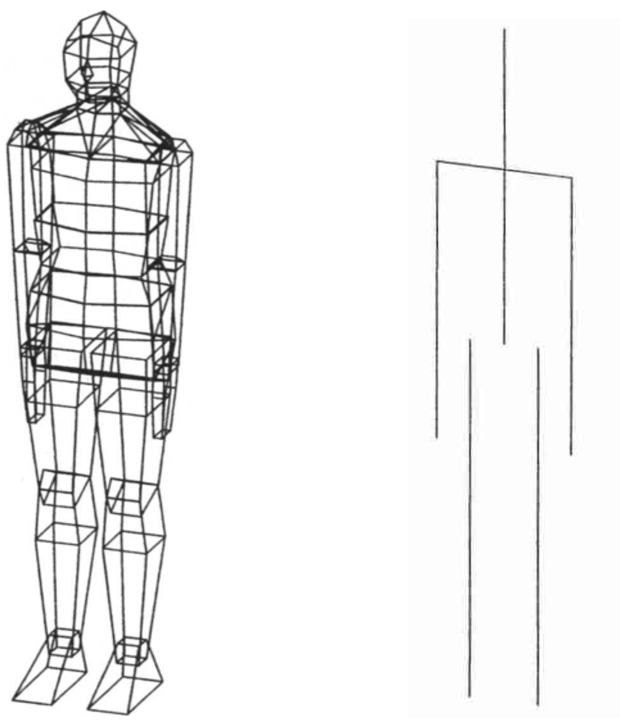

Figure 16.1. *The man model showing the 'stick' and 'flesh' representations*

'normal' constraints which could for example represent desirable working postures. Special purpose facilities are provided to allow the assessment of reach within areas or volumes of the workspace. An envelope of reach (maximum or normal) can be predicted for any surface of the model dependent on the anthropometry of the man model. Similarly, volumes of reach can be predicted (Figure 16.2). Extensive vision assessment facilities are provided over and above the normal model viewing techniques described earlier. The view as seen by the man model can be displayed, permitting a visual field assessment which is particularly useful in cockpit situations where visibility is potentially obstructed by the bodywork of the vehicle. A three-dimensional vision chart (Porter, Case and Bonney, 1982) has been developed to give a characteristic of all around visibility. For similar purposes, Aitoff projections (Figure 16.3) can be produced to assist in compliance with MIL standards (MIL850B,1970).

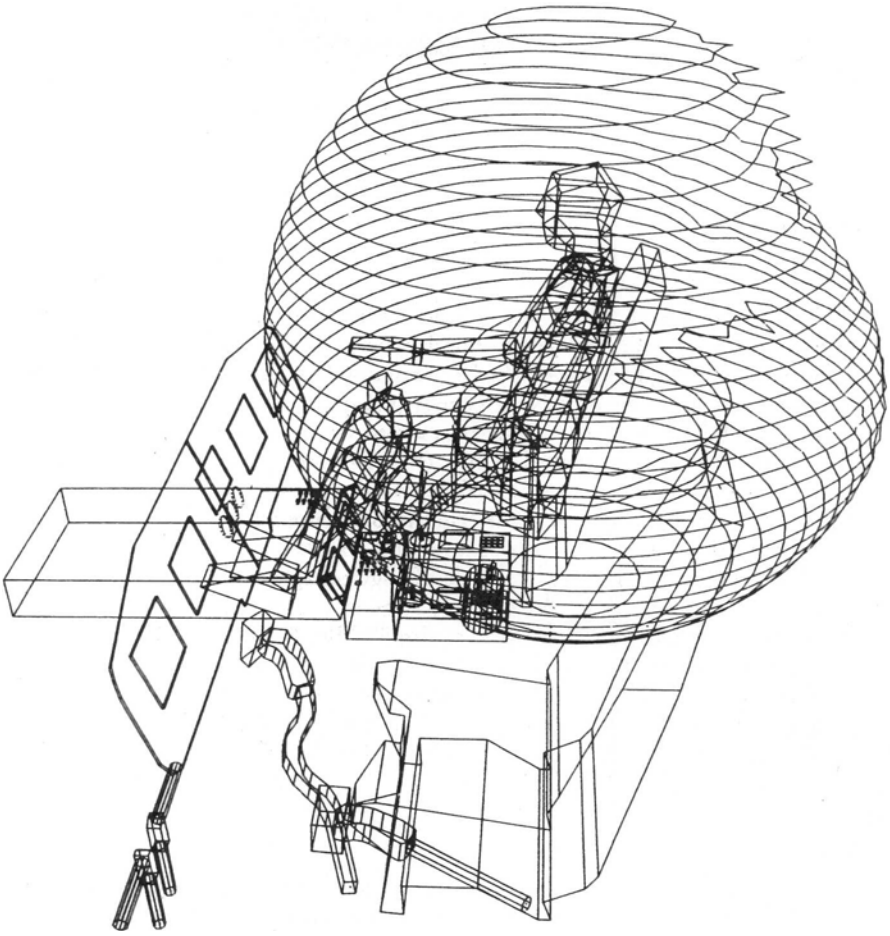

Figure 16.2. *Use of the volumetric reach facility within a helicopter cockpit*

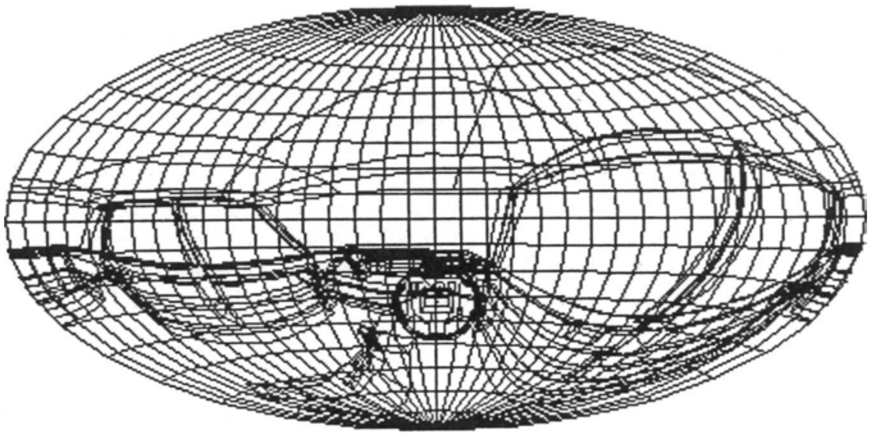

Figure 16.3. *Typical Aitoff projection showing 360 degree visibility from a car*

Applications

Reach zones for agricultural tractors

The driving of agricultural tractors presents several areas of difficulty which would not normally be found with more conventional vehicles. The working environment is likely to be noisy and rough terrain can lead to an uncomfortable ride, a problem which may be exacerbated by extended driving periods perhaps in extremes of heat or cold. The controls are likely to be more complex than a road vehicle, since in addition to the driving task, the driver would be expected to operate a variety of agricultural implements. Alleviation of these difficulties may be tackled in several ways and recent tractor designs have shown a marked improvement in the standard of environmental comfort for the driver. In terms of easing the work task, improvements could be made if controls were located for convenience of reach rather than ease of engineering design. SAMMIE was used to investigate these problems at the feasibility stage of tractor design (Porter, 1979), and a need to determine suitable reach zones was identified (see Figure 16.4). Further work (Reid *et al.*, 1985) provided a general framework for defining zones of reach as volumetric envelopes for males and females of various percentiles. More importantly, these zones related to working postures rather than to artificial laboratory conditions. Using SAMMIE, extensive sets of data were generated which later formed the basis of a British Standard (BS6375, 1987).

Supermarket checkout facilities

Supermarket checkouts provide a typical example of the use of SAMMIE to compare existing workplace designs with proposed alternatives. Models, as in Figure 16.5, were built of the old and new designs and the man model was specified to reflect the anthropometry of the expected user population. In this case anthropometry was based upon British adult females aged 19 to 65 years and was obtained from Pheasant (1984). This was deemed to represent the major users of the equipment although some brief use was also made of

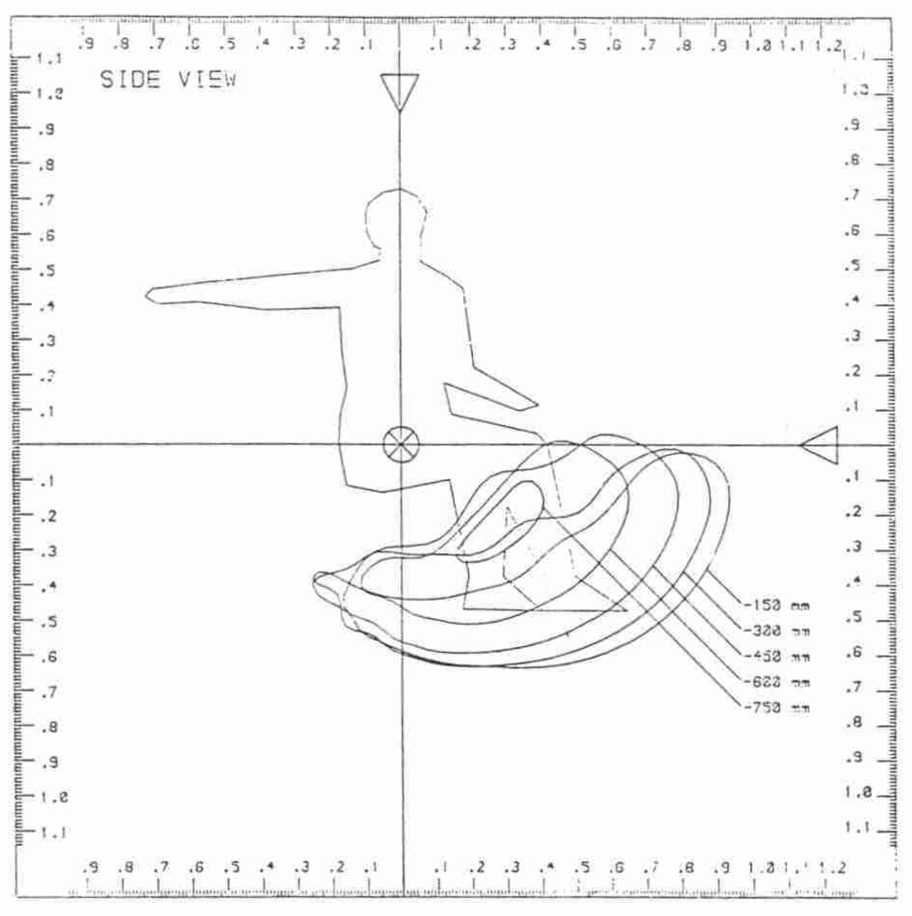

Figure 16.4. *Example of a reach zone for agricultural tractor drivers*

male anthropometry. The main criteria to be evaluated related to fit, reach and working postures whilst performing a variety of tasks from a standing or sitting posture. Thus 5th percentile females, 95th percentile males of both average and fat build were used to assess leg room, thigh clearance, seat height and foot support. Eye contact between the checkout operator and the customer was considered important and it was possible to evaluate this for a variety of counter heights, anthropometry, and sitting or standing operation. Other aspects of the work task evaluated included the determination of reach zones both maximum and comfortable (working limits for reach without stretching) for the specified user population. The layout of equipment such as the printer, scales, keyboard, or cash drawer was analysed with respect to reach, task sequence, functional grouping, and importance and frequency of use. The value of three-dimensional modelling of both workplace and operator, as opposed to just two-dimensional design of the workplace, is evident from the design recommendations made. In many cases these related to postural difficulties arising from the confined nature of the workplace, and the somewhat awkward postures required for some tasks. Thus for example it was shown that one design constrained leg and knee room to such an extent that some swivelling movements required to reach items of equipment were not possible for some of the large members of the user population. Traditional design methods would have been unlikely to discover these aspects until user trials were carried out on prototypes.

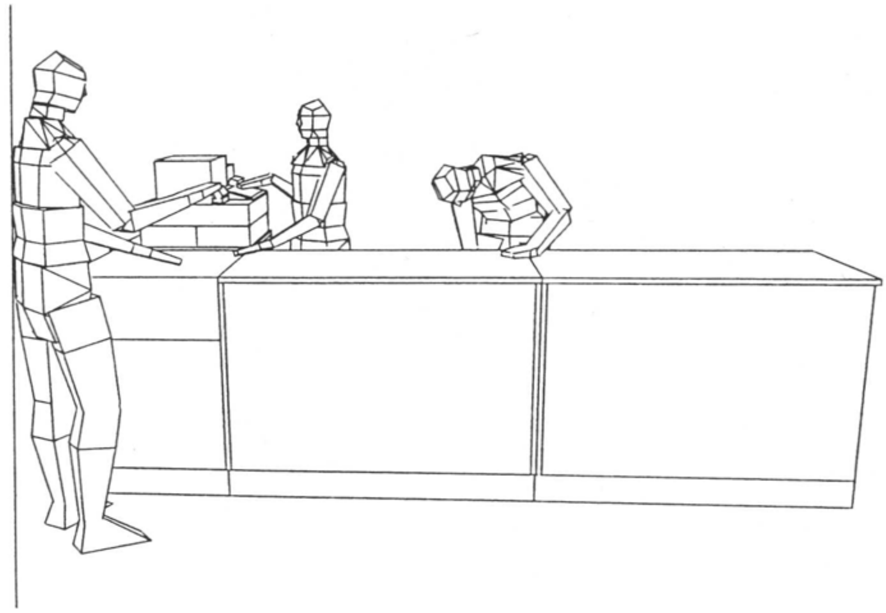

Figure 16.5. *Design of supermarket checkout facilities*

One-person underground train operation

SAMMIE is particularly useful for visibility studies, especially where the operator adopts unusual working postures. In the case of one-person operation of underground trains, the control of the automatic opening doors is in the hands of the driver. For safety reasons he would normally be required to leave his seat at each station and to look back down the platform to ensure that there would be no problem in closing the doors. With the heavy utilisation of the London Underground system, the extra delay as the driver returns to his driving position is to be avoided if at all possible.

An alternative working method is for the driver to remain in his seat and to view the situation on the platform via mirrors or video monitors strategically placed on the platform forward of the stopping position of the train. In this case the driver must be able to view the mirrors or monitors through the front and side windscreens. The viewing problem is further complicated by the necessity to use windscreen wipers which only sweep part of the screen surface. An earlier study had established the sizes and locations of the mirrors and video screens on the underground line in question, and these had been formed into envelopes representing the maximum viewing requirement on both the nearside and offside. Driver anthropometry was represented by 5th percentile female and 95th percentile male models which were permitted to adopt four working postures-sitting upright, leaning forwards, leaning forwards to the left and leaning forwards to the right. These postures were considered acceptable given the intermittent nature of the task. A general view of the situation is shown in Figure 16.6. Figure 16.7 shows one of a number of views as seen by the driver from one of the working postures. The study established that the proposed one-person operation was feasible for this aspect of operating the automatic doors from the seated driving position.

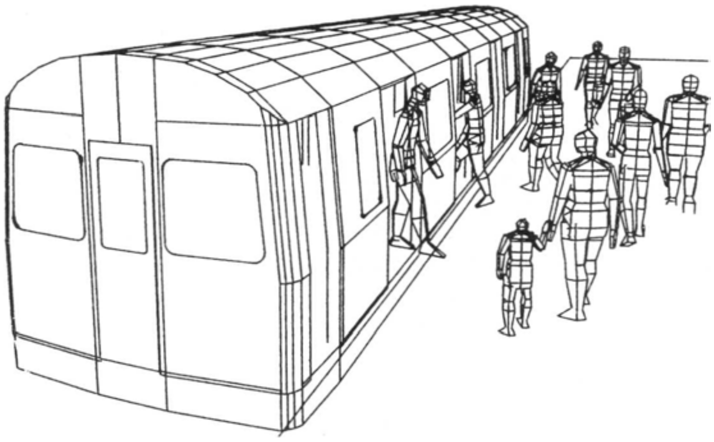

Figure 16.6. General view of passengers boarding underground train

Machine shop environment

Figure 16.8 shows part of a model of a machine shop which has been used to evaluate maintenance procedures for large and complex numerically controlled machine tools such as the Wadkin 3-axis, automatic tool-changing machining centre. The Coordinate Measuring Machine (CMM) which is also shown in the figure has recently been added to the model with the intention of studying the working postures that must be adopted to operate finely controlled equipment.

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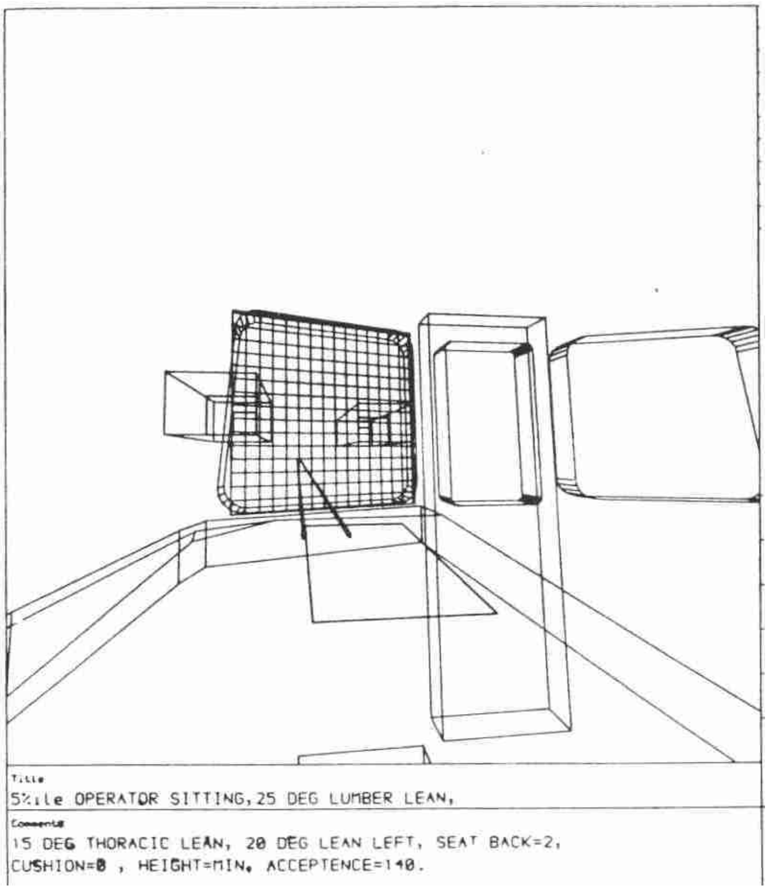

Figure 16.7. *Driver's view of mirrors and monitors from across the cab. View shown for the 5th percentile female leaning forward and towards the left*

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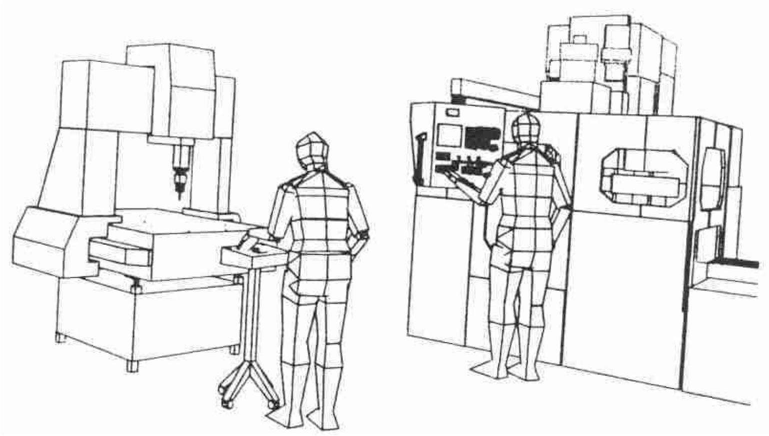

Figure 16.8. *Machine shop showing a Wadkin Machining Centre and a Co-ordinate Measuring Machine (CMM)*

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