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SAMMIE: AN ERGONOMICS CAD SYSTEM FOR VEHICLE DESIGN AND EVALUATION

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SUMMARY

SAMMIE (System for Aiding Man-Machine Interaction Evaluation) is a CAD system which enables the ergonomics/human factors evaluation of vehicle designs to commence at the earliest stages of the design process. Evaluations of postural comfort and the occupants' clearances, reach and vision should be undertaken from the concept stage when design modifications are easier and cheaper to implement than at the pre-production stage. In order to achieve this, the package offers 3D modelling of vehicles and their occupants. Details of the package and its application to vehicle design are presented.

INTRODUCTION

Computer aided design methods are increasingly being used by engineers as they provide considerably more flexibility than conventional techniques. However, most CAD systems available today do not provide a means of considering the inter-relationships between the equipment being designed and the people who are to use it. This is despite the increasing complexity of equipment and the social, economic and legislative pressures which are forcing ergonomics to assume its rightful place early in the design process. Traditional methods of ergonomics lend themselves to the evaluation of existing designs, prototypes or mock-ups and commonly involve extensive fitting trials using a carefully selected sample of the current or future user population. Unfortunately, by the time the design is ready for such an evaluation, many of its features are likely to be fixed. This can clearly hinder the development of a design if it is to meet the original ergonomic specification. Often, time consuming and expensive modifications may be required to meet the specification because it is no longer possible to change any of the fundamental aspects of the design. This typically results in an inefficient design process or the development of a product which does not meet the full ergonomics specification. Both of the above are undesirable in the vehicle industry because the first increases the development and production costs whilst the second is likely to reduce the volume of sales with prospective purchasers choosing competitors' models.

SAMMIE has been specifically developed to enable the ergonomics/human factors evaluation of equipment and vehicle designs to take place at the concept stage of design. Basically, it is a design tool which allows 3D computer modelling of vehicles and their occupants. This permits evaluations of postural comfort and the occupants' clearances, reach and vision to be conducted on the earliest designs, and even from sketches.

THE SAMMIE SYSTEM

The system is currently available on Prime computers and will shortly be implemented on the VAX range. These minicomputer versions typically use refresh graphics display such as the IMLAC, or alternatively a Tektronix T4010/14 emulating terminal may be used. During the next stage of development, versions will be produced for stand-alone or networked engineering workstations such as the Sun and Apollo.

The major features of the system are:

- a 3D modelling system for equipment and workplace (e.g. a vehicle)
- a 3D man model for ergonomic evaluations a user-friendly man-computer dialogue
- specialist facilities for generating reach volumes, mirror views, reflections, visibility charts, sequences of movement, modifications etc.
- Equipment and Workplace Modelling

The data describing the 3D models are normally prepared off-line from engineering drawings or sketches, although it is also possible to create models interactively at the graphics screen during a design session. Models of considerable complexity can be built from a range of primitive shapes such as cuboids, prisms and cylinders whereas non-regular solids can be constructed from a description of their vertices, edges and faces (see Figure 1).

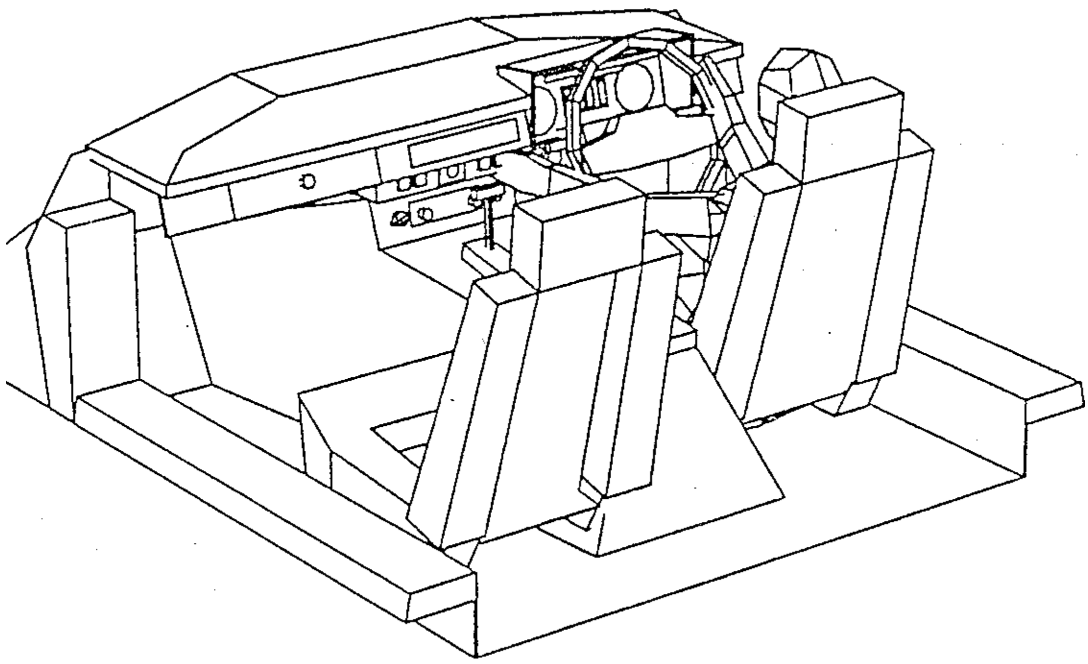

Figure 1: Perspective view of the interior of a car

In addition to defining the geometry, the designer is also able to specify any spatial or logical relationship between components of the models. This allows several items to be grouped together to form a seat or door which can then be moved forwards, reclined or rotated as appropriate. Constraints to the degree of adjustment permissible can be set prior to, or during, a design session.

Man Model

Whilst the 3D modelling of equipment and workplace is available on several CAD systems, SAMMIE is the only commercially available, fully developed system with ergonomic evaluation abilities supplied by a man model. The man model is a 3D representation of the human body with articulation at all the major body joints. (See Figure 2). Limits to joint movement can be specified and the dimensions and body shape of the man model can be varied to reflect the range of size and shape in the national population(s) who form the primary market(s). Existing 2D manikins as used in traditional design can be modelled within SAMMIE, although the data on which such manikins are normally based are now rather dated and do not reflect the general increase in mean stature reported over the last few decades. This secular change is a result of improved health care and nutrition and the mean stature has risen mainly because of a reduction in the number of very short adults. It is interesting to note that young people in Japan are now considerably taller than their parents because of their hamburger-enriched diet. SAMMIE can be used to model populations in America, Japan, Europe and elsewhere if the anthropometric data are available. Even within Europe, there are differences in body size that strongly influence vehicle design. For example, in a recent survey of cyclists in Britain, France, Germany and Holland it was found that the French had the shortest mean stature and the longest mean arm length (Porter & Houghton, 1984). This may explain why many British drivers comment that the steering wheel is too far away in Peugeot and Renault cars. An understanding of the variations in body size around the world is clearly important to ensure that any future vehicles can accommodate the targeted populations.

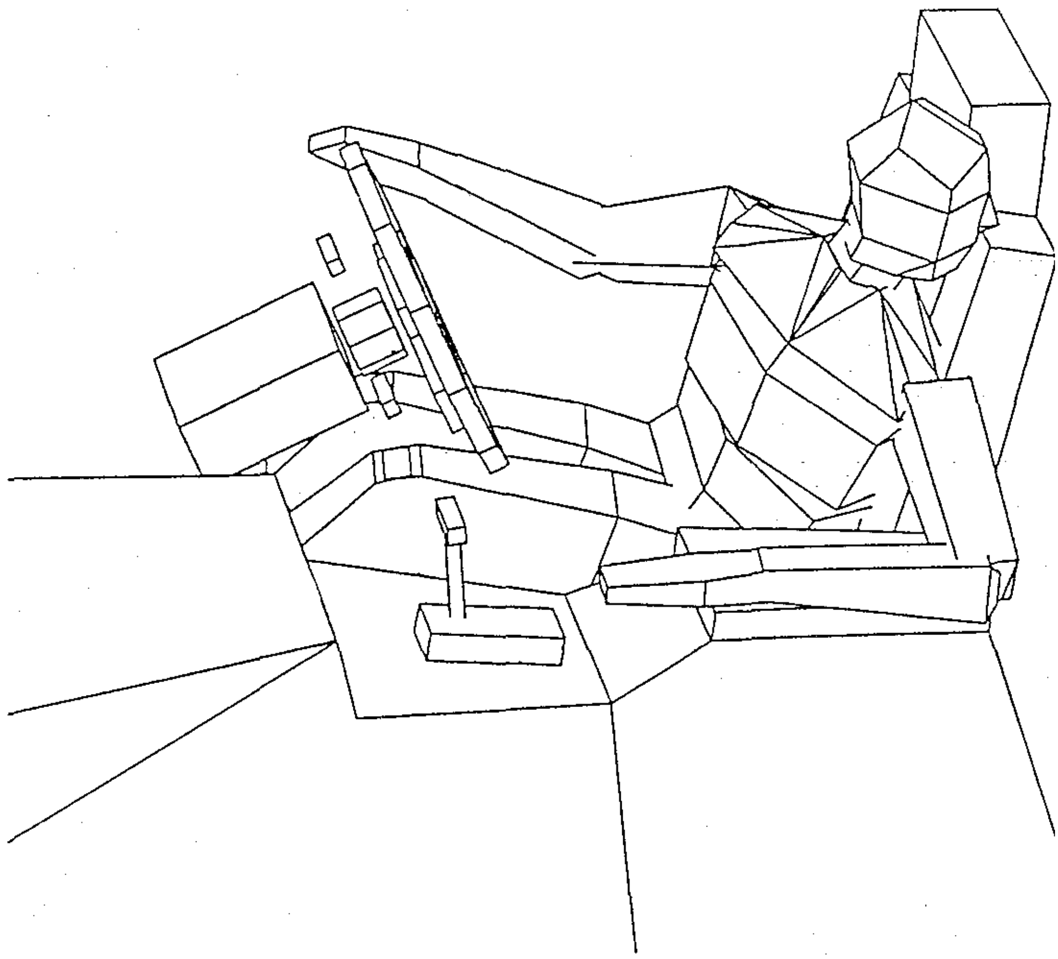

Figure 2: Simulations of the complex posture adopted whilst reversing

User-Friendly Dialogue

The system is designed to be interactive and no previous experience of computer languages is required. The user communicates with the computer by selecting various commands from those displayed on the right hand side of the graphics screen, using either the keyboard or by pointing with a light pen. These commands are presented in functional groups called 'menus' and only one menu is displayed at a time. For example, the view of the models on the screen is controlled by the 'view menu' which includes commands for locating the viewing point, the centre of interest, selecting plane parallel projection or perspective views and changing the scale of the displayed views. The other main menus include the following:

'workplace menu' for interactively positioning models or component parts of models in the workplace. Items can be positioned exactly to a known location and orientation or they can be 'dragged' to a desired position using the light pen or cursor.

'display menu' for selectively displaying only part of a model at a time. This allows any detailed modelling to be displayed only when required for evaluation.

'limb lengths menu' and 'joint angles menu' for changing the anthropometry and posture of the man model, respectively. A variety of anthropometric data bases and a library facility for storing postures once set are available.

'man's view menu' for displaying the view seen by the man model. Normal or peripheral vision can be selected and the view can be varied by moving the head or eyes.

'hidden lines menu' for removing those lines which should not be seen because they are located behind solid objects. Typically, the models are displayed in 'wire-frame' form so that all edges of a model are visible. This presents few problems to the experienced user but the removal of hidden lines is very valuable when presenting information.

'edit modules menu' for the rapid interactive changing of the model's dimensions as an aid to achieving the design optimisation.

The careful choice of meaningful command words means that inexperienced users can become proficient in the use of the system within a short period of time. The dialogue allows the designer to proceed through the design process in a manner determined by his own requirements rather than in a pre-determined manner. This latter approach would be valuable for legislative testing and the provision of such facilities is part of the development plan for the near future.

Specialist Facilities

Several specialist facilities are available:-

Three-dimensional reach. This is computed and can be displayed onto modelled surfaces (e.g. dashboard, boot floor) or as a volume for both hands and feet (see Bonney, Reid & Gibson, 1983 for further details)

mirror views and reflections. These can be computed as a function of viewpoint (either legislative or derived from the man model's posture in a specific vehicle), viewing distance and the size, focal length and orientation of the mirror or reflective surface. (See Figure 3). These facilities have been used in the design of mirrors and as a check for internal reflections in the windscreen and side windows of buses, vans and heavy goods vehicles (see Case, Porter, Bonney and Levis, 1980, for details).

visibility charts. These charts provide the designer with 3D information concerning the external visibility characteristics of a concept vehicle. (See Figure 4). The chart allows the determination of blind areas at ground level and the maximum vertical visibility at any given location on the ground. For example, the chart can be used to assess the influence of window area and location upon the driver's view of the road, pavement, other vehicles, traffic lights, signs and pedestrians (see Porter, Case and Bonney, 1980, for further details).

sequences. This facility allows a series of discrete movements of a model to be run in rapid succession. This is useful for preparing an animated sequence for evaluation of a complex task.

modifications. This facility allows the movement of model components to be constrained to those available or specified in the vehicle (e.g. steering wheel or seat adjustment). In addition, a symbolic name can be given to the movement such as RAISE SEAT, thereby removing the need to remember and apply complex geometric transformations.

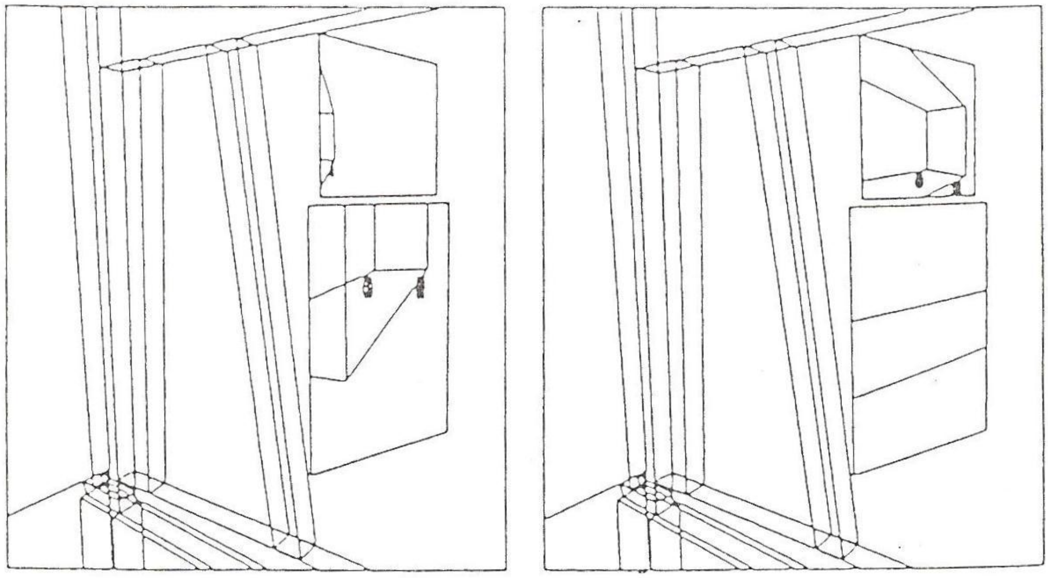

Figure 3: Trailer swing at 15 and 50 degrees viewed through the driver's door mirrors

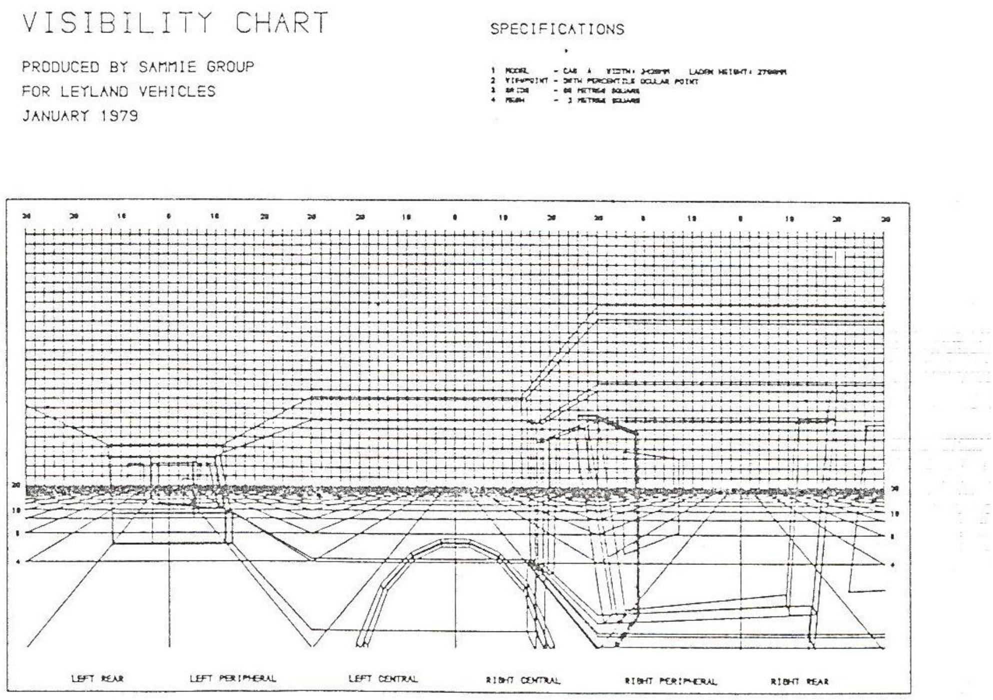

Figure 4: Example of a three-dimensional visibility chart showing a composite of the driver's view to the left, front and right of the vehicle

EVALUATION PROCEDURE

SAMMIE has been used extensively in the design and for evaluation of tractor cabs, fork lift trucks, buses, vans, heavy goods vehicles and cars. Brief details of case studies are also presented in Bonney, Blunsdon, Case & Porter (1979), Case & Porter (1980), Porter & Case (1980)and Levis, Smith, Porter & Case (1981).

A typical evaluation of a vehicle design would be conducted in the following stages:

i) Model the vehicle to a level of accuracy that is sufficient for- the ergonomics evaluation. Care must be taken to model the seat and its range of adjustment, controls and their points of rotation and travel, displays, mirrors, 'A', 'B' and 'C' posts, header rail and ceiling to a high level of accuracy. Exterior body shape is rarely modelled to such accuracy unless it influences external visibility.

ii) Determine the potential purchasers/users of the vehicle in terms of their nationality, sex distribution and age.

iii) Choose the most relevant source of anthropometric. (body size)data from those provided within the SAMMIE package.

iv) Specify the body size and shape of the man-models to be used in the ergonomics evaluations. If the vehicle is to be a family saloon, then the evaluation of the internal package should cover the range from 5th percentile female to, at least; 95th percentile male. (See Figure 5).

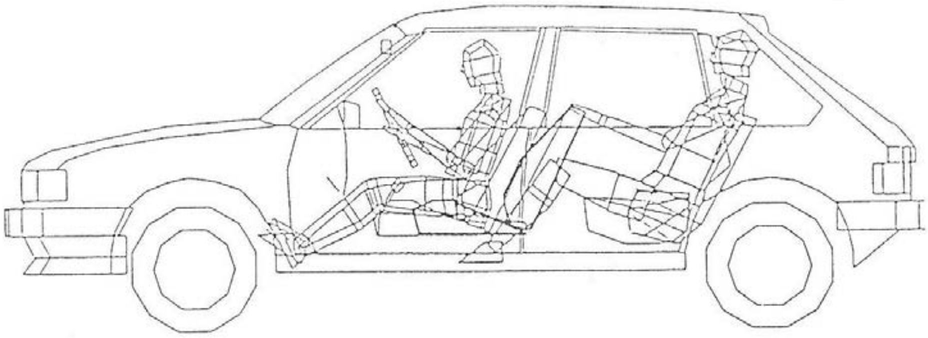

Figure 5: Use of different sized man models to evaluate the interior package

v) Evaluate postural comfort by positioning the various man models in the vehicle, making full use of seat and control adjustments, and ascertaining whether the joint angles are all within the recommended ranges. If this is not possible, then the package will need to be modified to achieve this requirement.

vi) Evaluate external visibility using the 3D Visibility Chart or by plotting certain driver views. Obscuration areas can be displayed at ground level and at any height above ground.

vii) Evaluate reach to controls, equipment; storage and maintenance areas by either instructing the man model to reach to specific items (see Figure 6), or to plot reach areas onto surfaces or to plot reach volumes inside the vehicle; Check clearances for control operation.

viii) Evaluate internal visibility to controls, displays, storage and maintenance areas. Check for reflections in windscreen and side windows.

ix) Evaluate mirror designs by examining the reflected field of view as a function of size, focal length, position and orientation of the mirror. Check also for obscuration of the mirror by window guides and for forwards obscuration by the mirror of traffic and pedestrians.

If the design performs poorly with respect to any of the above evaluations, then a re-design is warranted with the final solution often being a compromise between the various problem areas. SAMMIE is ideally suited to be used as a tool by vehicle designers to achieve the optimum compromise.

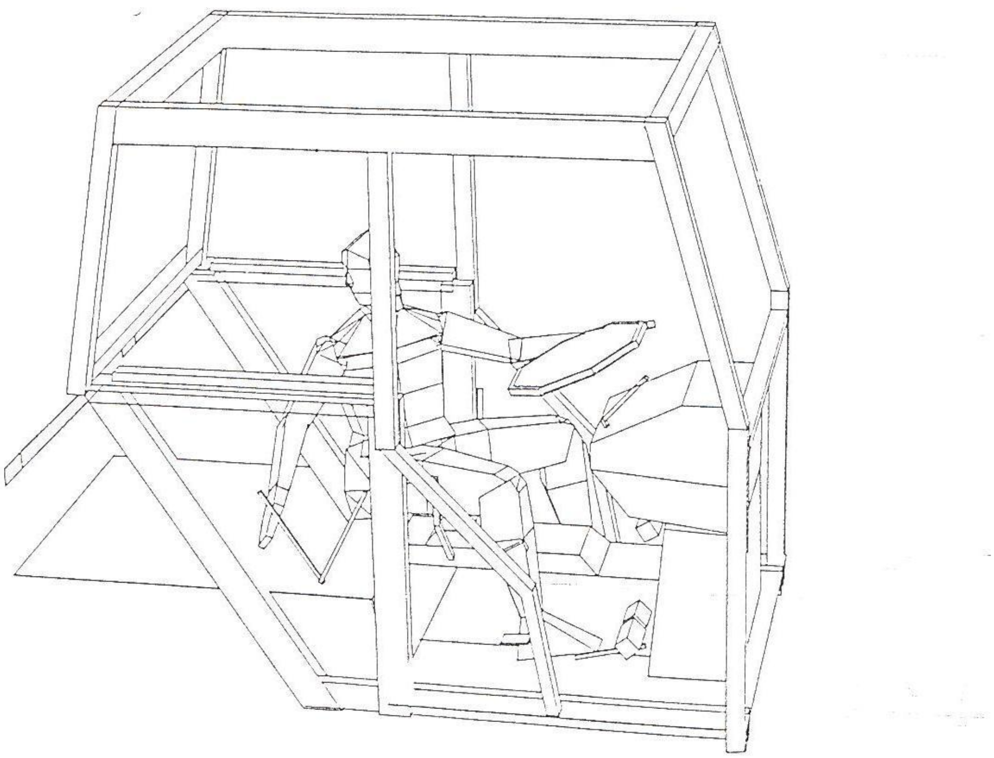

Figure 6: In addition to appraising individual controls for reach by a range of driver sizes, it is also necessary to consider the sequences of operations required in typical working situations. Part of such a sequence is shown here where the driver is reaching rearwards to operate the hydraulic control lever whilst controlling the forward motion of the tractor and looking forward.

CONCLUSIONS

The SAMMIE system has been shown to be extremely effective in highlighting and helping to solve design problems. In a recent study, two student ergonomists undertook projects of 10 weeks duration where they had to learn how to use the SAMMIE system and to interpret engineering drawings, to construct a model each of a production car from such drawings and then to conduct an ergonomics evaluation of the vehicle. The results from these evaluations were compared with those from an in-depth evaluation of the real vehicles by the Vehicle Ergonomics Group at Loughborough University; using owner questionnaires and selected subjects on a 60 mile test route. This comparison showed clearly that the postural, fit and visibility problems observed in the real vehicles could have been predicted using SAMMIE several years before production (see Porter; Stearn, Geyer, Smith & Ashley, 1984 for further details). The use of SAMMIE in the vehicle design process therefore offers an extremely cost effective means of ensuring a high standard of ergonomics input, and thereby competitive edge, to the final design.

ACKNOWLEDGEMENTS

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SAMMIE C.A.D. Limited has recently been formed by the authors and it will be marketing the SAMMIE system in addition to the design consultancy service that it currently offers.

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