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Geometric Reasoning for Ergonomic Vehicle Interior Design

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Summary

The design of vehicles is heavily constrained by legislation and standards. The design of the passenger compartment presents particular challenges due to the variation and uncertainty connected with human activity. Computer aided design systems that address the ergonomic problems are available, but do not generally support the application of knowledge such as standards and legislation. This paper describes the combination of two aspects of the problem (a geometric model of the product and a knowledge base related to performance requirements) in the field of interior packaging of cars. The geometric modelling system handles the spatial aspects and supplies information to an appropriate expert system. The expert system evaluates proposed designs and sends suggestions for improvements back to the design system. The KES expert system and the SAMMIE computer aided ergonomics design system have been combined to investigate aspects of reach to controls, visibility of instruments and mirror design.

1. Introduction

Many aspects of vehicle design are heavily constrained by the need to meet various national and international legislation and standards with regard to structural integrity, safety and functional performance. Vehicle manufacturers need to consider world markets and thus have to accommodate the differing requirements of particular national markets whilst seeking to reduce product variability for efficient manufacturing and distribution.

Interior packaging (the design of the driver/passenger compartment) presents particular difficulties in satisfying legislative requirements due to the extreme variability of the human occupants and the desire to produce an environment that not only meets the standards, but is also ergonomically sound and aesthetically pleasing. Computer aided design systems are available which assist in the ergonomic evaluation of human workplaces but in general these are neither specifically aimed at vehicle design nor constructed to handle ‘knowledge’ such as standards and legislation. Furthermore, traditional computer aided design systems have strengths in geometric representation and evaluation but provide little support in terms of reasoning about the modification of designs to meet design criteria.

2. Legislation and Standards

In many areas of the application of expert systems the acquisition of knowledge is a major difficulty, but in a highly regulated and controlled area such as car design the problems are more to do with how to handle the vast amount of information that is available. The designer is faced with a set of criteria that must be met (the legislation), but this in itself does not meet the overall objective of an 'optimised' design. An example from some of our early work with computer aided ergonomics demonstrates the point. EEC Directives from 1971 through to 1988 [1] define the requirements for rear view mirrors, but as with most legislation of this type it covers many types of road vehicle with a single set of requirements. The legislation can be summarised by figure 1 where areas of the road required to be seen are defined relative to the driver's ocular points which in turn are related to the vehicle (an articulated truck is symbolically illustrated) plus constraints on the size, location and curvature of the mirror.

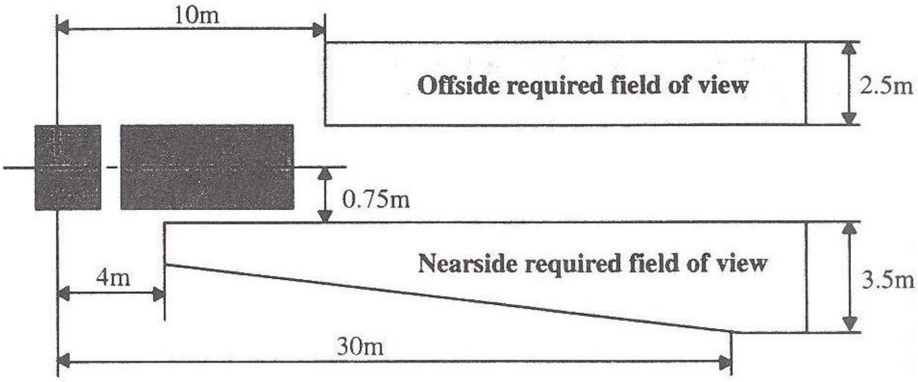

Figure 1. EEC Directive 71/127- Required Fields of View

Unfortunately difficulties occur when such general purpose legislation is applied to specialised vehicles such as a bus which was the subject of some early SAMMIE work [2]. Our objective was to use the SAMMIE computer aided ergonomics design system to ensure that mirrors designed for the bus complied with the legislation, but also made the 'safety area' adjacent to the entry and exit doors visible to the driver through rear-view mirrors and accommodated a range of driver sizes and seat adjustment without the necessity for mirror adjustment (none of which are required by the legislation). The point is that legislation provides a necessary but incomplete set of design evaluation criteria and must be integrated with other design aspects.

An extensive range of relevant legislation has been collected [3], primarily from national and international organisations such as BSI, EEC, ISO and SAE, but also from car manufacturers' internal standards [4].

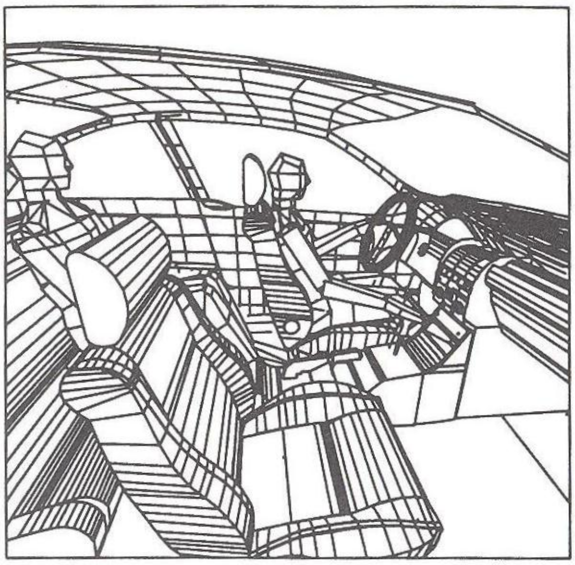

Figure 2. Interior Ergonomic Evaluation of the Fiat Punto using SAMMIE

The computer aided ergonomics aspects of the overall system are provided by SAMMIE. This is essentially a three-dimensional solid modelling CAD system that contains a human model for evaluating aspects such as reach, fit and vision [5]. Human related car design legislation frequently reduces the consideration of the driver to a small number of design points such as the H-point and the eyepoint, and these are often evaluated through the use of a physical manikin (the SAE manikin). The computer modelling approach (figure 2) permits much greater flexibility in modelling ranges of the human population, varying by height, weight, reach capability, etc. At the same time it is possible to represent the more limited situations required by standards (one way of doing this is to generate a computer model of the physical manikin). Most importantly however, computer modelling allows ergonomics and compliance with legislation to be determined during design rather than as a post-design activity on a real prototype car.

3. Expert System

The expert system needed to have the ability to handle the kinds of information that were required and have a suitable mechanism for communication in both directions between the expert system and the geometric modelling system. Many expert systems meet these requirements, and KES [6] was selected as it was available to us on workstations and PCs. The production rule inference engine was used for rules such as:-

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if
        pedals:accele >distance gt 50 and
        pedals:brake >distance lt 100
then
        pedals:controls >styling = good ergonomics
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This particular rule is evaluating pedal spacing and says that if the accelerator and brake pedals are separated by between 50 and 100 millimetres then this is a good ergonomics configuration. Where appropriate the source of this rule can be displayed and of course the knowledge base can be modified to reflect changes in standards or to introduce rules that relate to specific types of vehicle, national variations in legislation, etc. A limited rule base has been implemented for research purposes and is mainly concerned with the geometric and spatial aspects of seats, pedals, instruments, controls and mirrors.

4. Geometric Reasoning

In the example in the previous section a value is required for 'distance'. In a stand-alone expert system this would be requested from the user or sought from some static database. By integrating the expert system with the design system (see section 5) it is possible to extract this information directly and in a way that dynamically responds to changes in design. A geometric model will not necessarily maintain data relating to the distance between two objects and hence this is a very simple example of the need for geometric reasoning. i.e. the modeller has to be able to respond to requests for geometric/spatial information by initiating algorithms that act on its internal data structure, Frequently the semantics of the request need careful consideration, as in this example where 'distance' is interpreted as lateral spacing. More complex geometric reasoning situations are encountered when investigating visibility of dashboard instruments by the driver. This requires consideration of the eyepoint (which varies with human anthropometry and seat adjustment), location and size of the instruments and obscuration due to the steering wheel. These are currently handled by performing a series of evaluations to cover variable aspects and by decomposing the overall problem into a series of simpler geometric inquiries.

5. Implementation

The major issue in implementing the complete system was the method of communication between SAMMIE and KES. A variety of methods were available for achieving this including the embedding of SAMMIE within KES or vice-versa. This would have provided a close integration with performance benefits, but SAMMIE is a general purpose tool and there was no desire to produce a special version purely for vehicles. Hence a more indirect method of communication was implemented (which is also an effective method of prototyping in a research environment). Figure 3 illustrates the situation where the two systems remain independent and are linked by communication files. The user issues a request from SAMMIE to perform some evaluation involving referral to the expert system and this results in SAMMIE executing a number of macros that place geometric information in the communication file. This file is used by the expert system and may well be modified as a consequence of the evaluations (i.e. it could in effect be updated to contain design change recommendations). These changes can then be accessed by SAMMIE (under the control of the designer) and used to automatically update the geometric model. In a simple example, SAMMIE might enter a value for pedal spacing into the communications file, but the expert system might change this value so as to comply with one or more of its rules. A fragment of the communication file may appear as:-

dstatus = non-evaluated	(a flag to indicate whether or not pedal spacing has been evaluated against the knowledge base)
Accelerator to Clutch	= 90
Clutch to Brake	= 100

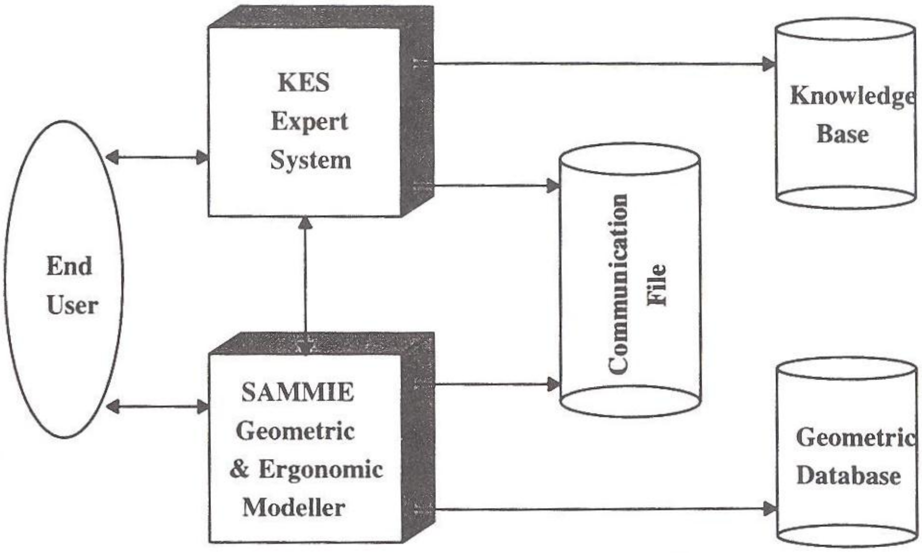

Figure 3. Communication between SAMMIE and KES

6. Conclusions

This paper has demonstrated that it is possible and desirable to associate an expert system with a computer aided ergonomics design system so that certain forms of design constraints can be made available to the designer. Legislation and standards are particularly suited to this treatment and these abound in the car industry. Only a limited knowledge base has been created for research purposes, and for practical use there is a need to extend this and to investigate how this 'ergonomics' knowledge base might cooperate with knowledge bases associated with other important aspects of car design.

7. References

1. EEC Directive 127 (as amended by Directives 19791795/EEC, 1982/205/EEC, 1988/321/EEC). The Approximation of the Laws of the Member States Relating to the Rear-view Mirrors of Motor Vehicles, EEC Council Directive, 1971.
2. Case, K., Porter, J.M., Bonney, M.C. Design of mirror systems for commercial vehicles, Applied Ergonomics, 11.4, pp199-206, 1980.
3. Md. Dan Md. Palil. An Ergonomics Design Knowledge Based Expert System. Phd Thesis, Loughborough University, 1996.
4. Ford Motor Company. FMVSS 111, Rear View Mirrors, USA, 1991.
5. Porter, J.M., Freer, M.T., Case, K. & Bonney, M.C. Computer Aided Ergonomics and Workspace Design. In 'Evaluation of Human Work. A Practical Ergonomics Methodology'. 2nd Edition. Edited by J.R. Wilson & E.N. Corlett, Taylor & Francis, London, pp574-620, 1995.
6. KES. Knowledge Engineering System, Knowledge Base Manual. USA, 1990.