Contributed paper

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Liquid crystal display unit for reconfigurable instrument for automotive applications

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Nowadays, the car drivers are faced with a rapidly increasing flood of information. In addition to established information systems (car radio, vehicle monitoring, mobile phones), high class vehicles feature navigation systems almost as standard. In the current decade, driver assistance and collision avoidance systems will appear in vehicles. Hence, there is an increasing demand for supplying the driver with more information that helps him to drive safer and more economical. The price decline in the computer market and the availability of powerful graphic hardware and software concepts make it possible to enhance the classical functions of the instrument board to an interactive multifunctional information panel – an interface between information systems of the car and the driver. Therefore, the question of additional visual and cognitive stress, and a possible distraction of the driver by the large amount of information, and its complexity becomes predominant. Reconfigurable instruments, based on a microprocessor controlled active matrix colour display, provide a powerful alternative to the usual mechanical/electromechanical instrument clusters in vehicles. They will help to strengthen passive safety, they adapt to user and situation requirements, and they are easy to install, to configure, and to maintain. Reconfigurable instruments in future cars will have a high impact on traffic since they can provide the driver with much more information, presenting it in a way that is flexibly matched to the importance of particular data and to the ergonomic properties of the driver. The functions are manifold and span from classical driver information like speed to navigation prompts and ultimately to video and multimedia access.

Keywords: liquid crystal displays, reconfigurable instruments, automotive dashboards.

1. Introduction

If we visualise the broad range of available information and consider what kind and amount of information is necessary, appropriate or desirable for the driver and other passengers, we necessarily obtain four different display zones characterised by differing requirements as regards the performance of the relevant display medium. These four communication centres in the vehicle are:

- instrument cluster for information relevant to the driver at the edge of the driver's primary field of view,
- windshield for information relevant to the driver, in the primary field of view, for display without the driver having to take his eyes off the road and without the need for visual accommodation,
- centre console for information relevant to the driver and the front seat passenger,
- rear passenger compartment as a mobile office or simply as an entertainment zone for the children.

Dynamic information to which the driver must promptly respond should be displayed as close as possible to the primary field of view, i.e., in the area of the instrument cluster. If it is intended to achieve a high level of attention, e.g., in the case of warnings from a distance-warning radar unit, or if the information in question is guidance information which must be followed at short notice, the obvious choice is to display this information channel with the aid of a head-up display (HUD) on which the information is reflected into the windshield and/or through a voice output.

Statical information, i.e., status information or operator dialog in the form of prompts, should be displayed near to the operator-control unit in the centre console.

Information aimed at entertaining should be kept away from the primary field of view. This information should be placed in the lower zone of the centre console and should be aimed at the passenger or available in the rear passenger compartment. This is also the ideal location for the mobile office. The passenger seat backrest is an appropriate location for the laptop's display and keyboard.

The development of the instrumentation over the years shows a clear trend (Fig. 1). Starting from simple instrumentation of the fifties, visual output of information for the driver has focused almost exclusively on the conventional instrument cluster. More and more information was accommodated in the available installation space.

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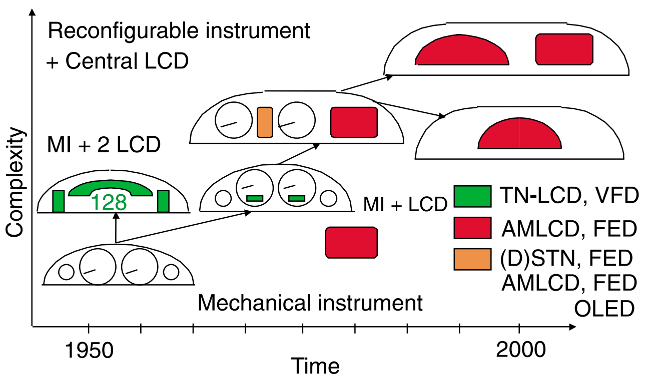

Fig. 1. Evolution of the instrument cluster towards a Driver Information System.

Single instruments were superseded by instrument clusters, mainly due to the cost and ergonomical reasons. Hitherto, instrument clusters in cars consist mainly of mechanical pointer instruments and coloured indicator lights. Only few digital instruments displays (e.g. the odometer, the clock, the thermometer, and the radio receiver) are present in the dashboard. In modern cars these instruments mostly use passive liquid crystal displays.

Even though the appearance of the instrument cluster did not change significantly from the early days of automotion, there was a steady development of the intelligence behind the panel. Today, data is provided by a CAN bus or as electrical signals, and is collected and interpreted by a micro-controller. Since customers anticipate a broad variety of instrument appearances, manufacturers today offer some ten different dashboard variations per model which requires enormous logistic efforts from the instrument provider.

When first navigation systems appeared on the market, an additional graphic display was added in the centre console area. These displays have been colour capable from the early beginning and have had a screen diagonal between 4 and 6”.

Over the course of time, the modern instrument cluster grew in size with additional areas for accommodating, in some cases, also graphics capable displays. These modules are better suited for display of functions relevant to the driver, e.g. service intervals, check functions and vehicle diagnosis for the workshop. Likewise, however, they may also be used to display route guidance information from the navigation system (i.e. arrows with turn-off information). Information shown in this area can be read quickly without the driver having to take the eyes off the road for a long period. Modules of this type are monochrome initially, but coloured in the next step.

The TN-LCD and the vacuum fluorescent display (VFD) technology are suitable not only for small display modules. Implementing large display areas or even whole-area LCD or VFD clusters poses no problems. However, these segmented displays do not allow a realistic simulation of mechanical pointers. Consequently, speed and engine speed are displayed digitally or as bar graphs. This form of display has not become popular in Europe, where after its introduction in seventies, digital instrument clusters have almost disappeared.

With the continuous decrease in displays prices it can be assumed that in the long term the conventional mechanical instruments will disappear and will be replaced by a graphics display with all the advantages of a flexibly programmable information medium. This technology defines their appearance by downloading a program at the back end of manufacturing line or even in the field. For the car-maker there is the advantage of having only one type of instrument for all cars of a model line [1].

In the region of the central console, sophisticated integrated information systems are being introduced in high-class cars, combining all additional information from information components in a compact display and an operator-control unit. Also the heating and air-conditioning systems are operated via the central keypad. Systems of that kind have a high degree of acceptance. Since this information is required by both the driver and passenger, it is necessary from the ergonomical point of view, to arrange this terminal in the centre console. This kind of information requires a graphics-capable display whose requirements as regards resolution and colour performance are determined by the most demanding function, navigation system with map display and/or video.

In the future we may expect that some car makers will extend the information content of this area by using a large graphics display in the centre of the car console, combining the classical instrument cluster with the centre console area display. This solution leads to a lower complexity and also lower price compared to the classical solution with an instrument cluster with integrated small graphics display plus a centre console display.

2. Current trends for future vehicle human machine interface

Designing such complex information systems, at first the question must be answered whether the driver can still cope with this flood of additional information with acceptable risk or whether demands placed on him create excessive distraction from driving the vehicle. This risk must be counteracted by carefully matching the ergonomic requirements of the human machine interface (HMI) to the system’s technical degrees of freedom.

It has been previously shown that a central information systems leads to an increased safety compared to the use of single information units as trip computers, radio, telephone etc. Measurement of eye movements was used to define the distraction from the road. When using the central information system, the driver’s eye is off the road for a far shorter period. Preference should therefore be given to a central information system from the point of view of road safety [2,3].

With increasing amount of presented information it becomes an increasingly challenging task to order the information in terms of importance for safety and driving comfort, taking into account its rapid changes during the ride.

Object-oriented and platform-independent software design for the system, and hardware and software co-design for the platform are methodologies that have been advanced for several years and are going to change the development paradigms massively. These techniques will support reusability, continuous engineering, concurrent engineering and maintenance of software and hardware components.

3. Possibilities of information output

Multifunctional displays in vehicles, whose contents can be arranged according to the situation or to the driver's wishes, must be structured taking into consideration the regularities of human perception. The use of variably configurable iconic and alpha-numeric elements (instead of traditionally decided locally fixed displays, messages and possibilities of interaction) means a turn away from the stable structures and the common design of the conventional interface. Thus, the output medium has to be adapted to the organisation of the human perception [4].

Each information channels of a human being has its unique characteristics which determine the type of medium used to present information as well as the method of its encoding. Every medium has different features which make it suitable for the output of particular types of information.

Optic output

- digital displays are especially suitable for the quantitative reading and for exact numeric values, e.g. the time,
- analogue displays are appropriate for approximate values in order to indicate a tendency, a change rate, and the alteration of the direction,
- signal and warning lights: present warning messages and draw attention, e.g. in case of a brake cycle failure,
- graphic displays: to present changeable conditions or configurations on a single display field, e.g. navigation information.

Acoustic output

Acoustic signals can be used in order to draw attention, announce messages, and to offer information of a more general type, e.g. "danger". Speech is used for precise information, e.g. – navigation information.

Tactile displays

Dynamic tactile displays are suitable for information which is closely linked to a driver's action, e.g., "haptic accelerator". Static tactile displays serve for tactile recognition and for information concerning spatial allocation to other objects, i.e., the allocation of input elements.

Redundant coding

For all information being relevant for the driver a certain degree of redundancy is appropriate. This can be achieved via a multi-modal presentation, i.e., a combination of acoustic and optic signals. This is also advantageous for drivers without visual or acoustic deficiencies and will improve the driver's capacity of perception.

4. Design concept of an reconfigurable instrument

The idea of reconfigurable instruments (RCI) is based upon a large display replacing the instrument cluster. The instruments are displayed by a computer and a powerful graphics hardware and for safety reasons they will appear similar to the traditional pointer instruments. The customer will have the choice between tens or hundreds of different styles but due to safety reasons he will not be able to reconfigure the functionality of necessary instruments on his own. Obviously, this goal can only be achieved with the help of a powerful hardware, a sophisticated and flexible software concept, and after carefully conducted studies on ergonomy and acceptance of the device.

The layout of a common instrument cluster undergoes a long evolution process in close cooperation with the developer of the actual car. The layout must match the overal appearance of the car, must comply with safety requirements and governmental regulations. On the other hand, it should act like a fingerprint of the philosophy of the car, as it is the most visible part of the car for the driver.

The flexibility of the display contents allows to filter and provide information when necessary. Depending on the current situation, additionally to the simulated classical pointer instruments and few safety relevant data, components related to the driving situation, e.g. technical information, driving statistics, navigational hints, parking aids, and video images (e.g., from a rear view camera), even important for elderly and handicapped people, may be displayed. Several data can be enhanced when exceeding critical values, for example by increasing the size of the fuel gauge or the coolant thermometer. Smooth and fluent animation of moved pointers is an absolute demand from users who are accustomed to mechanical instruments. A sophisticated co-operation of software and hardware is necessary to avoid jerky motions on the screen. This includes a picture compression technology. An example of a prestudy is shown in Fig. 2.

Advantages for various driver groups are for instance:

- reduction of unnecessary information,
- quicker readability (reduced eyes-off-road time),
- sublimated suggestion (e.g., background colour used to signal freezing road),
- support of the average driver by fading in information when relevant, e.g. from a navigation or traffic information system, or a cruise control system,
- support of business drivers (truck drivers, police, fire guard) by providing additional information, e.g. route planning, navigation, tachograph,
- flexible configuration by the manufacturer, ideally at the customers end so that the instrumentation can be tailored individually to the single customers needs, or even changed by customer's request.

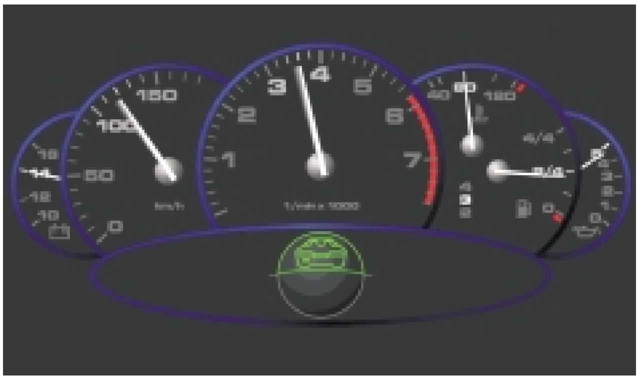

Fig. 2. Prestudy of the appearance of a Reconfigurable Instrument Cluster. The free spaces may be used to provide additional non permanent information.

Car instrumentation is one of the most important tools of passive safety. Absolutely mandatory information must be readily available on the start of the vehicle (velocity, oil/coolant/battery tests, fuel gauge). Warnings (e.g. increasing the size of the fuel gauge or the coolant temperature display) or alert situations (e.g. brake failure, drop of oil pressure) must trigger an emphasised signal. Sublimated suggestion (e.g. slow change of the background colour) may signal environmental changes, e.g. freezing road, exceeded speed limit.

A major objection against the reconfigurable instrument is the question of acceptance. Therefore, acceptance studies must be performed to convince car-makers of the ergonomical advantages of this kind of instrumentation.

5. Conclusions

Electro-optical displays and flat screens incorporating liquid-crystal technology will be used to an increasing extent in future vehicles. Their use will expand from the instrument cluster through the centre console to the rear passenger compartment area. The classic instrument cluster will be enhanced with graphics-capable display modules displaying information relevant to the driver from the vehicle and from navigation systems (route guidance symbols), and it will be replaced in the future by full colour, full graphic LC-screens.

The centre console is the obvious choice for display of information relevant to driver and passenger from various information components, displayed on a screen with a size of between 5 and 6" and operated by means of a few controls with menu prompting.

Owing to the availability of appropriate transmission methods to the moving vehicle, smaller monitors for entertainment and multimedia purposes will be found in the future in the rear passenger compartment area. Flat PC monitors, integrated in the passenger seat's backrest, will, in the future, make possible the mobile office with all usual components of the office workstation, in conjunction with the familiar mobile services.

A broad range of suitable displays is available for all these applications. Various LCD technologies, from the simple TN-LCD to the actively addressed flat screen, will allow effective adaptation of the display performance to the relevant application.

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