# GENERIC INTELLIGENT DRIVER SUPPORT

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## I WHAT IS GIDS ?

The acronym GIDS stands for Generic Intelligent Driver Support. The GIDS project is part of the DRIVE Programme which was initiated in 1988 by the Commission of the European Communities with the aim of stimulating and coordinating the introduction of modern Road Traffic Informatics in Europe. The purpose of the GIDS project is to develop an intelligent, electronic co-driver. Co-drivers are systems, human or artificial, which support vehicle operators during task performance, by providing them with information, for instance in the form of warning, advice, or intervention, under a range of circumstances, particularly in case of emergency.

In recent years various applications of advanced micro-electronic technology have become commercially available, including special navigation systems that assist drivers in finding suitable routes to preselected destinations. Unlike these dedicated monofunctional applications, however, a co-driver system as envisioned in the GIDS philosophy should be able to assist drivers to perform a variety of driving task easily, safely, and efficiently. More specifically intelligent co-drivers should be able to take into account the intentions, capabilities, and limitations of the human at the wheel. Drivers must cope with an increasing amount of information of an increasingly complicated nature. Reasons are the steadily growing volume and complexity of traffic, the growing number of on-board and roadside sources of information, and the popularity of additional equipment for filling our vehicles. The latter includes such items as telephones, fax machines, dictaphones, and electric shavers. The resulting avalanche of information is certain to affect almost every aspect of the driving task, from route planning and navigation to manoeuvring and elementary vehicle control operations. The situation will be further aggravated by the fact that, unless something systematic is done about it, all this information is going to be presented in a highly haphazard fashion, without much concern for its meaning or urgency level. At the same time the availability of microelectronics has, of course, also vastly increased the potential for sophisticated driver support. This allows us to provide a variety of support functions, each directed at containing or even reducing the information load. Note that these functions as listed in Table 1 show an increasing order of adaptive control by the co-driver.

Generally speaking a very important function of co-driver systems, such as GIDS, will be to counter the information pollution that is increasingly threatening the vehicle operator. GIDS will achieve this by filtering, interpreting, integrating, prioritizing, and presenting the information from any number of sensors and applications. The GIDS system is specifically capable of offering warnings, advice, explanation, and instruction, but it will, generally speaking, neither intervene nor take control. However, there is one important limiting condition that should be emphasized at this point. Some elementary control actions, such as steering and braking, frequently require a very rapid response from the driver. In such cases GIDS will indeed be able to provide a form of direct support that is close to intervention or cooperative driving.

Table 1.: Nine types of basic co-driver support functions, showing an increasing amount of adaptive control. Examples of each function are given in brackets.

- enhancing information (increasing visibility by retroflection)
- augmentation (special information about icy patches)
- warning (against speeding or other violations)
- advice (to take a less congested route)
- explanation (reason for delay, e.g., accident ahead)
- instruction (feedback about incorrect action)
- intervention (speed delimiter)
- substitute or secondary control (cooperative driving)
- autonomous or primary control (robot driving)

## 2 MODELING DRIVER BEHAVIOUR

In order to provide a driver with adaptive intelligent support, as is the case in GIDS, we must be able to characterize the driver's behaviour in formal terms to such an extent that it can be understood by an artificial intelligence. In other words, the development of a driver support system, we first of all need a genuine model of driver behaviour, a so-called computational theory (e.g., Boden, 1989; Posner, 1989). This raises the preliminary question whether models that qualify for this purpose are, perhaps, already available. The answer to this question is negative; for critical reviews the reader should see Michon (1985, 1989). The first serious formalized driver models date from the midsixties. These were the dynamic servo-control models that allow fairly precise predictions of lane keeping and car following performance under ideal conditions (e.g., Weir & McRuer). More or less simultaneously there were early attempts at information processing models (Kidd & Laughery). None of these models were adaptive. At the time some adaptiveness was displayed, however, by the so-called precognitive loop models (Young, 1969; Godthelp, 1985). A precognitive loop is essentially a conditional switch. It is sensitive to one or more specific external conditions such as, for instance, a change from a dry to an icy road surface. It may also be tuned to performance errors becoming larger than a preset acceptance threshold. Whenever one of its critical set of conditions is satisfied, the switch will operate, thereby resetting the parameters of the model so as to achieve an optimal performance of the model under the new condition. Although the precognitive loop goes back to the early days of dynamic control modelling, we may equally well look upon it as an early attempt at cognitive modelling. The function of a precognitive loop is formally equivalent to a conditional statement:

IF condition X prevails

THEN initiate parameter settings (Y1 Y2, ... Yn).

This IF-THEN format reveals that the precognitive loop is, at least in a trivial sense, a rule-based representation or production system. Altogether, neither the dynamic control models, nor the early information processing models, nor, for that matter, the simple precognitive loop systems could satisfy the requirements of a computational theory of driver behaviour. Only as late as 1984 a serious proposal was made for such a computational rule-based approach to the problem of formally describing the driver task (Michon, 1985). Even then it took another two years until the initiation of a research program aimed at a genuine cognitive approach to driver behaviour (Michon, 1987). The motivation for that program was ultimately based on two premises:

(a) the availability of a sufficiently detailed analysis of the driving task by McKnight and Adams (1970). This work represents a landmark in traffic science. It has, however, long been undervalued, despite the fact that it gives an indispensable, nearly complete overview of the driving task in some 1700 elementary subtasks. It is possible to develop this task analysis further into a general description of driver behaviour;
(b) the availability of sufficiently well-tested 'intelligent architectures' based on the production system concept, in particular ACT* (Anderson, 1983), Soar (Laird, Newell, Rosenbloom, 1987), ABSTRIPS, and several other scheduling or planning formalisms (Georgeff & Lansky, 1987; Allen, Hendler, & Tate 1990).

In short, the intelligence of cognitive architectures had, by 1985, become sufficient to support an effective formalization of the driving task. This culminated in a proposal for developing the intelligence required for a robot driver capable of passing its driver's license examination in the year 2000 (Michon, 1987). This was, and still is by any standard, a somewhat exalted and farfetched undertaking, and it will not come as a surprise that the idea met with a good deal of disbelief from experts in the field of driver behaviour. When the Commission of the European Communities launched its DRIVE programme a consortium of thirteen partners from six European countries joined forces and submitted a proposal to the DRIVE Commission promising to develop:
*"the functional requirements and design specification for a class of intelligent co-driver systems which will be maximally consistent with the information requirements and performance capabilities of the human driver".*

## 3 THE DESIGN OF GIDS

In this section an summary overview is presented of the design approach adopted by the GIDS consortium. It covers the functionality (3.1), the architecture (3.2), and the intelligence (3.3) of the GIDS prototype system as it is presently under construction. In 3.4 an additional development, the GIDS simulation, is reviewed. GIDS is a generic system. This means that, despite initial limitations to be discussed in the next sections, this design will guarantee that at a later stage in the evolution of GIDS the range and scope of GIDS can be increased step by step. This will allow extensions of the architecture, when new information systems become available. It will also permit additions to the repertoire of situations that GIDS can handle, to the extent that additional elements of the driving task can be successfully formalized.

### 3.1 The functionality

In order to retain the GIDS project within manageable boundaries of computational complexity, a number of limiting constraints have been imposed on each of the following four major aspects under consideration in GIDS, in addition to those imposed by the system's architecture: driving environment, driving task, support functions and Man-Machine-Interface.

#### 3.1.1 Driving environment

The first generation GIDS system is required to offer driver assistance in a subset of real world situations. This subset has become known as the Small World. Although the Small World contains most relevant real world situations, it has some restrictions to reduce the complexity. It consists of straight road sections, curves with differing radii, T-junctions and X-junctions, and roundabouts. All roads are standard dual-lane undivided roads allowing two-way traffic. The Small World allows buildings, traffic signs and road markings to be present. Driving in the Small World may lead to encounters with other traffic, at present, cars only. Physical obstacles may occur on road sections and in curves. Standard rules of the road and priority regulations apply in all situations. This World is also configured in a computer simulation.

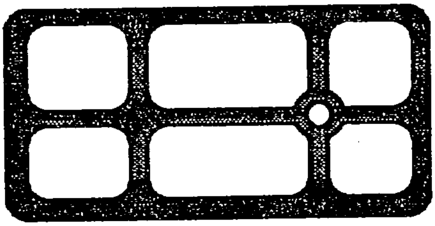

Figure 1: The Small World topography.

Altogether the Small World provides a set of well-defined environmental conditions for the formal representation of the driving task and for empirical tests of the GIDS prototype. In the course of the project the Small World concept has provided a highly satisfactory degree of methodological focus to a number of project activities.

### 3.1.2 Driving task

Driving, especially in the presence of other vehicles, requires the performance of a non-trivial set of subtasks of the driving task. Given the aim of implementing the GIDS concept for a limited but realistic set of driving tasks, the following activities were selected. If the driver is on a straight road section, the manoeuvres are stopping, moving off, avoiding an obstacle and overtaking. Manoeuvres in a curve are decelerating and avoiding an obstacle. On junctions and roundabout the manoeuvres are decelerating, using indicators, turning and yielding for traffic (and changing lane on a roundabout). This implies that the required tasks that are handled by the GIDS system are:
- lane following
- car following
- overtaking
- negotiating an intersection
- negotiating a roundabout
- merging

The initial criteria for inclusion into this set were (a) the possibility to generate a sufficiently detailed formal description of the task, the associated support requirements, and the required communication structure (message vocabulary and semantics); (b) the possibility to study the task in sufficient behavioural detail; and (c) the relevance of each subtask for more than one of the support functions discussed in the next paragraph. It should be emphasized that the present set of tasks, although meeting these criteria, is not limitative. Depending on future work, it will be modified or extended.

### 3.1.3 Support functions

The driving task is conventionally divided into three major task levels, planning and navigation, manoeuvring, and vehicle control. The conceptualization of GIDS (Smiley & Michon, 1989) involves exemplary instantiations of all three task levels, more specifically a navigation system, a collision avoidance system, and two control functions, namely speed and heading control. Each task level requires separate behavioural strategies of the driver and, consequently, different support functions. The support functions of GIDS are, however, not restricted to adaptation to the momentary needs of the driver on the basis of observations of the prevailing circumstances. The system is also capable of acting on its past experiences with a particular driver. More specifically, it is capable of providing tutorial information (instructional feedback), and to phase out such information gradually when the driver is becoming more and more experienced. Finally GIDS will also offer support under circumstances that are not strictly related to the driving task as such, but that are increasingly becoming a part of normal driving habits, such as carrying on a telephone conversation while driving. All this requires a complicated architecture with a tight set of structural and functional constraints, which are presently under investigation in the GIDS project.

3.1.4 Man/Machine Interface

The driver will interact with the GIDS system by means of a variety of displays and controls. At present the rationale for the actual choice of modalities is largely pragmatic, being based on readily available, well developed equipment. The interface components that are presently studied in the context of the GIDS project include a voice generator, a speech input recognizer, an LCD video screen, a retractable keyboard (disallowing operation while driving), several conventional switches (such as the blinker switch), a diskette drive (simulating a smart card reader), and two 'intelligent' controls (gas pedal and steering wheel). These components are essentially used in a multifunctional way. Rather than rigidly restricting the output of the GIDS system to specific output channels, pertinent messages may be presented through selected channels.

### 3.2 The architecture

The Analyst/Planner supports the driving task. From the available sensory and navigational information it computes whether any rules for acceptable driving necessitate a support message. Second, it will time the navigation messages, i.e. it will determine the message relevance and preferred timing to be passed on to the Dialogue Controller. Finally it anticipates driver actions for the sake of the Workload Estimator. The Dialogue Controller receives messages to be presented to the driver from Analyst/Planner along with expected incurred workload, preferred presentation time and relevance interval, and message importance. The Dialogue Controller advances, postpones or suppressed messages if workload requires that. Suppression may be prevented by sufficient importance, e.g. life-saving. The Car Body Interface connects to the car control sensors on the one hand, the active controls on the other. In the simulator this is implemented on basis of the IRIS VME bus and integrated with the driving simulator.

The actual hardware largely consists of components that are already commercially available and that can readily be adapted to the GIDS specifications (see figure 2). Furthermore a special bus architecture has been adopted with the Dialogue Controller as 'server.' Rather than completely centralizing all communication on the bus, it appears to be advantageous to the efficiency of the system to allow certain functions to actually bypass the Dialogue Controller temporarily or permanently. This is required, for instance, in the case of extremely urgent messages, or in the case of a particular interaction between the driver and one of the support functions.

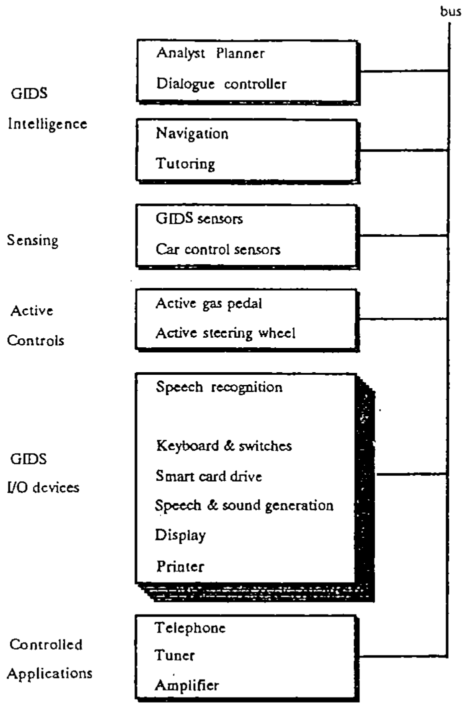


Figure 2: The GIDS architecture

### 3.3 The intelligence

The most important and innovative aspect of GIDS is its intelligence, its potential of taking into account the intentions, the capabilities, and the limitations of the individual driver. For this purpose one may conceive of GIDS as a database containing detailed scenarios for driving manoeuvres such as overtaking, negotiating intersections, or merging into a traffic stream. GIDS has stored a representation of every Small World situation and of every type of event that may occur within this world. Each representation consists of a vector of variables (numerical and binary truth values) that unambiguously identify each event. These are actually the variables that GIDS will sample through its sensors and applications. Associated with each vector element a range of acceptable values. As long as the driver's behaviour remains within this range jointly for all variables, there will be no output and the driver will be left to him- or herself. An exception to this general pattern occurs whenever the driver is actively requesting information from GIDS. In that case the system will generally try to respond to the request immediately. As soon as one or more observed variables fall outside the range of acceptable values, GIDS should recognize this discrepancy. Every such critical discrepancy is associated with one or more messages. Here the term message is used in a generic way: it may refer to a system-induced change in gas pedal response, a torque shift on the steering wheel, a beep, a spoken phrase or a pictogram or a written message.

When a message has been generated, it must be exchanged with the driver. This implies several potential problems that are tackled by the Dialogue Controller. The first problem is the possibility that several critical events occur simultaneously or so close in time that a priority conflict does arise. The second, related problem pertains to the driver workload created by the situation and by the message structure. And finally there is the problem of allocation of messages to the various interfaces to avoid drivers becoming confused or overloaded simply as a result of their interaction with the system as such. Once a message has been passed on to the driver, the GIDS system will continue functioning according to its overall way of operating: if the driver recovers from the critical situation - or if the problem goes away as, fortunately, happens frequently in traffic - the system will stop delivering messages until the next critical situation emerges (see Piersma, 1990).

### 3.4 The Small World Simulation

Despite the constraints imposed on the overall system design by the Small World it is a major task to compile a sufficiently detailed inventory of driver performance data, to implement the various event representations, and to analyze the dialogue structure of the GIDS system. All this, nevertheless, constitutes the necessary knowledge base for a driver support system that we may indeed call intelligent. Part of this substantial knowledge base can be derived from the available literature, another part has been collected in the context of the GIDS project (Janssen, 1989; Janssen & Nilsson,1990; Van Winsum et al.,1990; Kuiken & Groeger (eds.),1990; Verwey,1990; Farber et al,1990). This leads to the problem of creating and testing a sufficiently large set of event sequences, among other things to rule out the possibility of inappropriate warnings or instructions.

Rather than making this complicated generate-and-test procedure a an armchair exercise, or a costly real world experimental program, a Small World simulation has been developed. This has made it possible to identify relevant event sequences and critical manoeuvres within the constraints of the topography and the dynamics of the Small World. It allows the testing of all conceivable event representations, message structures, and dialogue scheduling, that arise when driving through this simulated environment. A version of this simulation program is now operational (Van Winsum, 1990). Thus it greatly expedites the process of implementing and extending the GIDS knowledge base as this depends in large measure on our ability to identify an appropriate set of constraints on what otherwise would be an infinite set of possible but largely dangerous, unacceptable actions. By selecting the proper constraints, the most absurd consequences can be ruled out on an a priori basis. At the same time the Small World simulation will allow an evaluation of the GIDS system prototype under simulated driving conditions.

## 4 EVALUATION OF THE GIDS CONCEPT AND CONCLUSIONS

The perspective adopted in the GIDS project is meant to be generic. Ideally, therefore, it should cover all of driver behaviour and all of the driver support functional domains, under all conceivable circumstances, and using all conceivable applications and MMI equipment. This being far beyond reasonable bounds, the GIDS consortium decided at an early stage to deal only with a limited set of conditions, without giving up the intended level of generality of the approach. This resulted in the Small World paradigm. This has proved to be a very important achievement for two reasons. In the first place it greatly facilitates the rapid prototyping and evaluation of the various real world circumstances under which the GIDS prototype will have to operate. In the second place it provides an excellent opportunity for extending and speeding up the task analysis required for the knowledge base of GIDS.

GIDS aims at a definition of standard rules, a protocol, for the filtering, prioritization, integration, and presentation of the various sources of information. It evaluates these rules with an eye on safety, effectiveness, impact on driver behaviour and workload, and (individual) acceptance. Much of the evaluations will be based on empirical results based on advanced simulator and on-the-road experiments.

It is easy to conceive of a variety of task domains for offering electronic driver support, each of which would certainly add to the knowledge of a driver about specific driving conditions, and each of which might also contribute to the driver's confusion and workload. The GIDS project will result in a set of recommendations that would help to avoid confusion and overload. GIDS being a generic concept, these recommendations should be quite independent of specific applications and consequently they should be useful as overall guidelines for the design and architecture of GIDS-compatible applications.

GIDS is deliberately focusing on non-intervening driving support (see Table 1). An exception to this principle is low level vehicle control (steering and acceleration). The reason is that in this case the time constants involved in taking appropriate action are really too short to allow warnings or advice by means of displays. The question might be raised why we should restrict ourselves to just the control level, instead of making a more principled step in the direction of the robot driver (Michon, 1987). The answer is that, in order to introduce completely automatic (primary control) or advanced cooperative driving (secondary control) requires a traffic environment that is totally different from the present, comparatively unconstrained, environment which admits vehicles, road technology, and drivers, with vastly different performance characteristics. The technology-push toward automation should not make us close our eyes for the fact that for a very long time to come only human drivers will be capable of dealing with incomplete, ambiguous, or even contradictory information, and yet make correct decisions under most, and even very extreme, conditions. Unless major steps towards a constrained road environment are within view it would seem advisable to maintain and even increase the effort devoted to the kind of driver support envisioned in GIDS and to adopt a cautious, conservative attitude towards cooperative or automated driving.

Another important issue concerns the acceptance of various GIDS functions and of the GIDS system as a whole by drivers. Presently experience and age are the major driver-related factors studied with respect to impact on behaviour and user acceptance. It is comparatively easy, however, given the generic character of the GIDS concept, to extend this concept still further, for instance in the direction of other road user categories (motorcyclists, truck drivers). At this point it should be emphasized that the GIDS concept is eminently suited for support to disabled road users. The GIDS system should be able to incorporate special applications for drivers with sensory or motor handicaps, as well as for those who suffer from some forms of cognitive handicap.

As already pointed out before, the rapid increase in the number and variety of signals informing the driver of some state of affairs in the vehicle or in the outside world, the development of a consistent protocol for an "information refinery" such as GIDS is of great importance for a smooth and responsible introduction of user-oriented RTI. In this context it should be pointed out that the exploitation of GIDS will proceed, generally speaking, in two directions: (a) interactions with roadside information sources or so-called 'intelligent roads,' and (b) interactions with on-board information sources, in the context of the 'intelligent vehicle' concept. Apart from these general considerations regarding the exploitation of GIDS, a number of more specific aspects and features of the project appear to be open to further exploration and, eventually, exploitation. These aspects and features include both knowledge and technology and are specified in the following points. (a) Basic knowledge about the performance of various categories of drivers who are operating under a variety of circumstances (including their performance when using GIDS). This knowledge may be implemented in a sophisticated database, accessible for Research and Development purposes in the RTI domain, legislation, vehicle design, etc.

(b) A formal (algorithmic and perhaps partly heuristic) description of the driving task which

is extendible to other complex behaviours, to be applied in the construction of expert systems and adaptive monitoring systems, both in traffic and elsewhere.
(c) Basic insight in knowledge acquisition of trainee and novice drivers, and in the role of instructional feedback to be applied in adaptive tutorial systems (driver training programs).
(d) Principles of real time dialogue management and real time action scheduling for use in interactive and adaptive MMI-systems, both in traffic and elsewhere.
(e) Information exchange protocols for modelling interactive behaviour in driving, to be applied in construction and advice regarding various RTI applications; such applications, when developed according to these protocols, would be compatible with the GIDS architecture.
(f) Rapid prototyping technique (simulation) for testing and evaluating various aspects of the items mentioned under the points (a) through (e) above.
(g) Technical protocols for implementing sensors and dedicated applications into GIDS systems; such applications, when realized according to these protocols, would be compatible with the GIDS architecture and, thereby, with each other as well.
(h) Integral GIDS-system prototype. The generic, evolutionary character inherent in the GIDS concept will allow its early application as an operational prototype system, whilst extensions can still be added as soon as they become available.
(i) Special purpose GIDS systems for unusual categories of road users, including elderly, handicapped, and professional drivers.

The GIDS concept constitutes an important, innovative step towards the development, implementation, and acceptance of advanced RTI systems, in particular of those that should help road users to cope with the information load to which other applications may be expected to contribute.

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