Urbas, L. & Leuchter, S. (2008). Usability Engineering of „In Vehicle Information Systems“ With Multi-Tasking GOMS.
In: *Proceedings Dachkongress Patientensicherheit und Medizintechnik. APS 2008 – 3. Jahrestagung des Aktionsbündnis Patientensicherheit e.V. und MEK 2008 – 5. Medizintechnik und Ergonomie Kongress.* VDE [CD-ROM].

Usability Engineering of “In Vehicle Information Systems” With Multi-Tasking GOMS

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Abstract

The developments in vehicle electronics and new services are supposed to promise more convenience in driving. The offers and ideas range from vehicle-related installations, such as accident alert, petrol station assistance, dynamic navigation and travel guide, to communication and entertainment services. There is one central design problem that is essential for achieving the main objective “safe motor vehicle driving”, i.e. the use of the new service must not unduly distract the driver. In the following, we present a newly developed procedure to calculate the interference between main and additional tasks based on user models, which can already be applied in the early phases of system design. Thus, the driving tasks are described as ideal-typical resource profiles. There is only required a formative-quantitative task analysis in order to assess the secondary task using the well known and commonly approved method GOMS with some new extensions for multi-tasking.

1 Introduction

Usability engineering is typically conducted with user tests of system prototypes. User tests are laborious and also cost noteworthy development time. Thus they are typically only executed to implement some quality gates in a development process. Instead it is possible to virtualise user testing procedures with simulations of user interaction and system behaviour. A model of prospective users’ behaviour and performance characteristics is needed to achieve this.

The major advantage of such model based analytical methods compared to “real” user tests lies in the shorter time that is necessary to evaluate and compare design alternatives in the development process. Thus the development process can incorporate many repetitive (virtual) tests that support later “real” user tests implementing quality gates.

The precondition for the success of this method is the adequate mathematical-algorithmic formulation of the regularities or legalities of the systems under study and human performance that both can be derived from empirical results. In this paper we describe a new method and algorithm for model based user testing of interaction with “In Vehicle Information Systems” (IVIS) in the automotive domain.

2 Materials and Methods

The family of the GOMS methods represents an early approach of model based performance simulations [1]. This group of analytical methods is based on the summary of empirical results creating a model with a human processor and a set of modelling constructs for the description of interaction sequences with a technical interaction system. This method is suitable for predicting error rates and time periods necessary for the execution of well studied procedures. In order to have an appropriate correspondence of model prediction and observation, it has to be provided that the realisation of the described tasks is essentially influenced by reactive and automated behaviour and requires, in comparison, only a small part of “higher” cognitive efforts, such as planning, reasoning etc. This is given, on a large scale, for the application area “In Vehicle Information Systems” (IVIS). Therefore, GOMS has been investigated several times in respect of its eligibility as evaluation tool [e.g. 2, 3]. However, because of the restriction of the method, these approaches are limited to the analysis of the equipments while the vehicle is standing. For the driving context, the methods of the GOMS family are widely inappropriate in their original form, as the standard systems allow only the modelling of the task operation in undisturbed surroundings.

3 Results

The newly developed modelling approach Multi-Tasking GOMS described in this section builds upon the GOMS methodology. It is inspired by the complexity reduction strategies of current empirical analysis methods for driver distraction evaluation. The algorithm is comprised of three main components.

1. The primary task is represented by a *resource profile*, which is a typical but minimal sequence of cognitive, visual, auditive and manual resources to ensure safe driving. Typically there is a predefined and fixed set of profiles for relevant driving situations like city, highway or stop-and-go traffic.
2. The secondary task (using an IVIS) is the *task model* to be analyzed. This task is formalized in a GOMS-like notation with multi-tasking specific extensions.

3. The central and third part of the algorithm is the *interference engine* that takes both the task descriptions of primary and secondary task and generates an integrated multi-tasking model that can be used in performance simulations.

Parameters of single task performance and multi-task performance are used to derive key performance indicators like time-on-task expansion, that help to judge the driver distraction potential of the interaction with the specified IVIS. We call this patented approach that includes resource profile, GOMS notation extension and interference rules “Multi-Tasking GOMS”. A demonstrator has been implemented to show the feasibility of this innovative modelling approach. To distinguish the implementation from the theory, the demonstrator is called mtGOMS

Resource profiles are deliberately simplified representations of the work load of the driver in typical traffic situations. It describes the timely sequence of allocation requests of cognitive, auditive, visual and motor resources of the driver and is comprised of the following elements:

- beginning and end of the resource allocation
- coverage of resource allocation in percent,
- nature of resource allocation (cyclic or sporadic),
- frequency of resource allocation,
- distribution of resource allocation parameters.

Task model: While the driving model is reduced as much as possible, the secondary task is described at the rather detailed level of interaction with the specified IVIS. This task description is based of on the well known method GOMS with newly introduced extensions to capture interruptability and resumption of the task flow. This allows building upon established tools for task modelling in GOMS-like languages for the first step, the single task model. Then the task model has to be annotated with the multi-tasking extensions. This new elements describe which resources are allocated to which extend by operators and methods, mark them as interruptible and define what is necessary to resume after an interruption.

Interference engine: The central part of Multi-Tasking GOMS is a theory of the management of conflicting resource requests stemming from two tasks with different priorities that are executed in parallel. This theory is implemented in the mtGOMS demonstrator as an algorithm that calculates a combination of the primary task resource profile and the secondary task model. Because the set of rules that is evaluated by the algorithm describes the interference between competing tasks it is called interference engine. The interference engine reformulates the combination problem as a scheduling problem – which one of the potentially conflicting resource requests from each task should be satisfied next, which resource request have to be delayed until the requested resource is available again.

4 Discussion

The availability of qualitatively and quantitatively representative resource profiles is a vital prerequisite for the application of Multi-Tasking GOMS. For an initial set of profiles published empirical results, e.g. maximal off-road gaze time [4], were analyzed and transferred into analytical resource profiles for some basic manoeuvres.

These analytical profiles and the methodology itself were tested and evaluated in a driving simulator study using a concrete IVIS [5]. It revealed that IVIS interaction task models, which already predict single task performance well, do also make a valid prognosis of the extension of the task duration under multi-task conditions.

This shows that Multi-Tasking GOMS and the implementation mtGOMS are valid and useful to improve the usability engineering processes in IVIS development. Results of related research demonstrate that model based engineering can also be applied in other safety critical domains.

5 References

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