Transportation Research Part C 42 (2014) 132–146

Contents lists available at ScienceDirect

Transportation Research Part C

journal homepage: www.elsevier.com/locate/trc

Overview Paper

A novel classification method for driving simulators based on existing flight simulator classification standards

Utkan Eryilmaz [a], Hatice Sancar Tokmak [b,*], Kursat Cagiltay [c], Veysi Isler [d], Neslihan Ozmen Eryilmaz [e]

[a] *TED University, Faculty of Economics and Administrative Sciences, Turkey*
[b] *Mersin University, Computer and Instructional Technology Department, Turkey*
[c] *Middle East Technical University, Computer and Instructional Technology Department, Turkey*
[d] *Middle East Technical University, Computer Engineering Department, Turkey*
[e] *Middle East Technical University, Institute of Applied Mathematics, Turkey*

ARTICLE INFO

Article history:
Received 27 June 2011
Received in revised form 17 February 2014
Accepted 17 February 2014

Keywords:
Driving simulators
Simulator classification
Training device

ABSTRACT

As technology has advanced and costs have fallen, the advantages of using simulators to train for safe, economical, and environmentally friendly driving have become more apparent. The need for a driving simulator classification arises from understanding and comparing simulator capabilities and options; however, only a limited number of studies have been conducted related to classification, calling for determination of methods and criteria. In this study, a classification method for driving simulators is proposed by adapting criteria for helicopter flight simulation training devices in which established methods of classification are defined by international and national regulators such as the Joint Aviation Authorities and Federal Aviation Administration. In the proposed method, the level of a simulator is determined by taking general characteristics under consideration, such as motion, visual, and sound systems. Through a case study, the method was applied to determine the class of a specific truck simulator.

1. Introduction

Currently, simulators are commonly employed in the academic research, government operations, space exploration, recreational computer markets, and driver training schools as well as by the military, medical sector, and automotive industry (Straus, 2005). For example, flight simulators play an indispensable role in pilot training and certification. Driving simulators are gaining interest due to developments in electronic and computer technologies and the reduction in cost of laboratory facilities (Janke and Eberhard, 1998). Moreover, Reed and Green (1995) note that the exploitation of the driving simulator is superior to in-vehicle testing for three reasons: safety, equipment cost, and experimental control.

The classification of simulators is extremely significant in training studies because it is crucial in determining the appropriate type of simulator to employ for the desired purpose (Galloway, 2001). The results of driving simulator studies are frequently transferred to the transportation field; however, for a more beneficial transfer of this information, the classifications of driving simulators should be, first, clearly defined (Sancar et al., 2009). While recent studies have provided approximate definitions for classification, they do not include detailed criteria. For example, Blana (1996b) has proposed a classification

* Corresponding author. Tel.: +90 5077418457.
E-mail addresses: utkaneryilmaz@gmail.com (U. Eryilmaz), haticesancarr@gmail.com (H. Sancar Tokmak).

http://dx.doi.org/10.1016/j.trc.2014.02.011

method for simulators based on their purpose, and Seropian et al. (2004), have defined a classification method according to fidelity level. Recently, the TRAIN-ALL research project (Lang et al., 2007) has proposed a method for classification by including dimensions related to training goals. There is still no standard classification method for driving simulators that is defined with detailed criteria.

The intention of this study is to provide a classification method for driving simulators by adapting classes and criteria of flight simulator classification as defined by the Federal Aviation Administration (FAA), the International Civil Aviation Organization (ICAO), and the Joint Aviation Authorities (JAA). For flight simulators, certification is performed by these organizations as well as local member aviation authorities (JAA, 2008). In the current study, an innovative classification method for truck driving simulators is proposed by adapting the classes and criteria defined for flight simulators (cabin, control panel, motion platform, visual system, and sound system). Although the classes have been defined and the criteria adapted based on the requirements of truck driving simulators, the method is also applicable for the classification of other driving simulators.

Detailed information is presented in the second section regarding several driving simulators and the Heavy Vehicle Driving Simulator (HVDS) incorporated in the case study. In the third section, simulator classes identified in the literature are discussed and the proposed method for classification is described. In the fourth and fifth sections, the aim and details of the classification method are explained: it was formulated considering categories, classes, and criteria defined by the JAA for helicopter flight simulation training devices (JAA, 2008). The classification of the HVDS is determined by utilizing the proposed method. In the conclusion, the method is discussed and further research topics are listed.

2. Driving simulators

Driving simulators are instruments employed for training, entertainment, and research (Blana, 1996a). Widespread commercial utilization of driving simulators is relatively recent compared to flight simulators that have been used for pilot training since the early days of simulations (Blana, 1996b; Slob, 2008) dating back to the 1910 when simple mock up cabins and panels were used for training purposes (Page, 2000). In the United States, the first driving simulators were exploited for analyzing vehicle safety in an attempt to decrease the rate of accidents. A focal point of research in the late seventies and early eighties was human factor issues such as the exploration of performance differences between young and old drivers (Case et al., 1970).

A typical proponent of research simulators in the United States at the early eighties was the HYSIM (Highway Driving Simulator), which was used for research purposes—initially for highway signing and traffic control device research, and later for intelligent vehicle/highway system evaluation and age-based driver performance investigations. The Federal Highway Administration (FHWA) Human Factors Laboratory has operated the HYSIM beginning in the early 1980s (Alicandri, 1994). The first generation HYSIM was a fixed-based, interactive driving simulator that applied computer-generated imagery for its visual display. It was comprised of 9 modules, including a graphics computer, a scenario computer, cinematic roadway projection, sign generation, sound generation, a psycho-physiological component, and an operator control center. Over time, additional modules were added, the size of the screen changed, and the projection equipment was relocated to provide greater quality rear-projection images. Although these changes increased the utility and realism of the HYSIM, the basic system remained unchanged until the second version was released in 1994 with a polygon based graphic generation engine.

Several technological developments have contributed to the advancement of driving simulator development. The Six Degrees of Freedom (6DOF) motion platforms were first introduced by Stewart (1965). By utilizing the Stewart motion platforms, motion cues in all three axes can be produced by simulators. Following the 1980s, the image quality and resolutions of projectors continuously improved, and techniques such as edge blending became available. Finally, computation hardware and software advancements enabled the development of realistic motion and traffic models and the generation of high resolution images. Innovative technologies for advanced representation of motion and visual cues, cabin and control equipment, vehicle motion and environmental factors were adapted for driving simulators. The motion and visual technologies exploited by certain simulators developed after 1980s are exhibited in Table 1, organized by date of development. This table shows developments of simulator technologies in an illustrative, non-exhaustive depiction drawn from the available literature. More detailed and comprehensive reviews of existing driving simulators can be found in Blana (1996b) and Lang et al. (2007).

During the 1980s, several simulators were developed in Europe for vehicle systems and human factors research. The Swedish Road and Transport Research Institute (VTI) simulator (Nilsson, 1989) was one of the first advanced simulators with a motion platform developed primarily for research. The Daimler Benz simulator (Drosdol et al., 1985) was a state of the art driving simulator at the time of development, featuring a full car body, a 6DOF motion platform, a wide front field of view (180 degrees), and a rear view. It was designed primarily as a test bed for actual vehicle development. In the Netherlands, driving simulators were employed extensively for evaluating and analyzing a driver's visual attention (Ponds et al., 1988). The TNO simulator, a medium cost simulator in the 1980s, included a cabin and computer-based image generation but lacked a motion platform (Blana, 1996b). The Leeds University Advanced Driving simulator was also developed for research and had the capability to simulate both urban and rural environments.

During the late 1990s, the adaption of motion platforms, mock up cabins, and projectors with high resolutions increased. Medium cost simulators such as the Transportation Research Laboratory (TRL) Simulator and the Pennsylvania Truck Driving