UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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HEAD-UP DISPLAY (HUD) INTERFACE DESIGN FOR AUTOMOTIVE APPLICATION

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Manufacturing Design)

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DECLARATION

I hereby, declared this report entitled “Head-Up Display (HUD) Interface Design for Automotive Application” is the results of my own research except as cited in references.

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APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Manufacturing Design) (Hons.). The member of the supervisory is as follow:

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(Muhammad Syafiq bin Syed Mohamed)

ABSTRACT

This work address the design and development aspect in the context of automotive head-up display interface. Head-up display (HUD) directly displays the driving information onto the windshield or combiner, and this would greatly reduce the frequency and duration of the driver's vision shifted away from the road. However, with HUD, distraction still occurs, where the driver subconsciously focused on the driving information presented on the HUD. Hence, to overcome this problem, the project had gone through the Kansei study, where the emotions of drivers that related to the HUD interfaces has been identified and its relation to the design elements has been analyzed through the Partial Least Square (PLS) regression. From the coefficient results of PLS regression, several design elements proven to have overall positive impact to the interface design, where it will improve the consumer acceptance of the technology and recognition of the driving information that presented on the HUD. Later, those design elements were adopted in the new interface development and through a similar eye glance test of NHTSA, most of the participants were able to identify the driving information presented on the new interface within 2 seconds duration.

ABSTRAK

Kerja ini merujuk kepada reka bentuk dan aspek pembangunan dalam konteks automotif “head-up display”. “Head-up display” (HUD) memaparkan maklumat memandu ke windshield atau combiner secara langsung, dengan ini ia akan mengurangkan kekerapan dan tempoh penglihatan pemandu beralih dari jalan raya. Walau bagaimanapun, dengan HUD, gangguan masih berlaku, di mana pemandu separa sedar dalam memberi tumpuan kepada maklumat memandu yang dibentangkan pada HUD. Oleh itu, bagi mengatasi masalah ini, projek ini telah melalui kajian Kansei, di mana emosi pemandu yang berkait dengan pengantaramukaan HUD telah dikenal pasti dan perhubungan dengan unsur-unsur reka bentuk telah dianalisis melalui regresi Partial Least Square (PLS). Daripada keputusan pekali regresi PLS, beberapa elemen reka bentuk terbukti mempunyai kesan positif kepada keseluruhan reka bentuk, di mana ia akan meningkatkan penerimaan pengguna dalam teknologi ini dan pengiktirafan maklumat memandu yang dibentangkan pada HUD. Kemudian, unsur-unsur reka bentuk akana digunakan dalam pembangunan pengataramukaan baru HUD dan melalui ujian yang sama dengan NHTSA, kebanyakan peserta dapat mengenal pasti maklumat memandu yang dibentangkan pada pengantaramukaan baru dalam tempoh 2 saat.

DEDICATION

To my beloved parents

To my respect supervisor and lecturers

To my generous and supportive friends

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LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

AR	-	Augmented Reality
CPA	-	Multimodal Critical Path Analysis
CTAM	-	Car Technology Acceptance Model
DALI	-	Driving Activity Load Index
DLP	-	Digital Light Processing
FOV	-	Field of View
GM	-	General Motor
GPS	-	Global Positioning System
HA	-	Heuristic Analysis
HCI	-	Human Computer Interaction
HDD	-	Head-down Display
HMI	-	Human Machine Interface
HTA	-	Hierarchical Task Analysis
HUD	-	Head-up Display
IVIS	-	In-Vehicle Information System
IVS	-	In-Vehicle System
LA	-	Layout Analysis
NHTSA	-	America National Highway Traffic Safety Administration

PGU	-	Picture Generation Unit
PLS	-	Partial Least Square
SHERPA	-	Systematic Human Error Reduction and Prediction Approach
SUS	-	System Usability Scale
TAM	-	Technology Accept Model
TI	-	Texas Instruments
UCD	-	User Centered Design
UTAUT	-	Unified Theories of Technology Acceptance Model

CHAPTER 1

INTRODUCTION

This work address the design and development aspect in the context of automotive head-up display interface. Head-up display (HUD) directly displays the driving information onto the windshield or combiner, and this would greatly reduce the frequency and duration of the driver's vision shifted away from the road (Kiefer, 1991; Kaptein, 1994). Driver able to acquire necessary information while remains focus on the road condition. Hence, the driving performance is improved and road safety is ensure. Nevertheless, some researches on head-up display has been carried out, Smith and Fu (2010) used Kansei Engineering to study the relationship between HUD interface and driver's emotions; Liu and Wen (2004) have studied the driving performance of conventional head-down display and head-up display. Besides, the literature have suggested the design of HUD interface should base on consumer viewpoint and satisfaction.

This study first conduct literature review on the head-up display. Next, it investigate the consumer acceptance of head-up display, as it is vital to the study, which to find out how the consumer able to accept new technology. Then, followed by the Kansei study, to further investigate the relation between the Kansei of the consumer and the design aspects of the interface. New interface is design and develop base on the findings and outcomes of earlier section and lastly, the evaluation of new interface, to validate the feasibility of the design.

1.1 Background

Generally, the head-up display was developed to assist pilots operate aircraft. In 1960s, the first operational HUD was used in Blackburn Buccaneer (Liu, 2003), an aircraft designed to carry a nuclear bomb below the radar coverage. Later on, in early 1970s, the first civilian use head-up display was used on McDonnell Douglas MD-80, to display guidance and flight information. For automotive, it is first introduced by General Motor (GM), an American company, in their Oldsmobile and Pontiac models. In recent years, automotive manufacturers have implemented HUD technology in their luxury car to attract buyers. For example, BMW, Cadillac, Toyota, Buick LaCrosse, Lexus, Kia, Hyundai, Mercedes and Peugeot are equipped with head-up display. Driving information such as speedometer, fuel level, engine speed, warning lights, gear position and navigation are presented on HUD. The image of HUD is presented either on the windshield or any transparent display, according on the preference of automotive manufacturers.

Figure 1.1: The head-up display of BMW.

1.2 Problem Statement

For many years, people have debated about the causes of car accident. And one of the causes would be the driver's distraction while on the road (French, 1990; Wierwille, 1995). According to David (2012) distraction is an act of inattention which the driver focus on other tasks while driving. Distractions may come from built-in devices in the vehicle, smartphone or from persons who on board. There are several kind of distractions, where the driver have to look away from the windshield and focus on a particular task, where the driver give away the control of steering wheel to perform certain task and where the driver is thinking on other matters while on road. Beside the impact is not only limited by type, but also the frequency and duration of the task. Although a task might be less distraction compared to the others, but with high frequency or long duration, it can increase the risk of car accident.

America National Highway Traffic Safety Administration (NHTSA) stated an estimated of 899,000 cases are involved distraction of driver in 2010 and out of 3 percent is related to built-in system of the vehicle. Therefore, NHTSA have conducted several studies to identify the relationship between distraction and driving safety. A guidelines have been developed to reduce the distraction and car accident.

As the in-vehicle technology advanced decades, the head-up display (HUD) have been implemented in automotive, to reduce the visual distraction when driving. Several studies on head-down display (HDD) and head-up display are conducted to increase the safety of driving. The conventional HDD require driver to look away from the windshield to acquire driving information which reduce the driving safety (Zwahlan, Adams and Debald, 1988). However, through HUD, the driving information is presented either on a transparent display in front of windshield or directly on the windshield, reduced the visual distraction (Ablassmeier et al., 2007). Therefore, the drive is more aware to the road environment (Sojourmer and Antin, 1990; Horrey and Wickens, 2004; Liu and Wen, 2004). Generally,

HUD improve the driving performance and reduce the collisions occurred (Burnett, 2003; Yung Ching, 2003; Liu and Wen, 2004; Charissis et al, 2008).

However, with HUD, distraction still occurs, where the driver subconsciously focused on the driving information presented on HUD (Gish and Staplin, 1995; Prinzel and Risser, 2004; Tufano, 1997). It is also caused by switching of vision between two sources, HUD and the road environment, especially in high traffic areas. Therefore, HUD should provide a simple and easily recognition design to reduce the attention and focus of driver on HUD. As an example, when a driver looking at the icons of HUD and hesitate for a seconds, it will cause the driver to focus at thinking and eventually loss concentration on the road event. Therefore, the purpose of this study is to design and develop a head-up display interface to resolve the distraction problem as well as identify needs and requirements of consumer. All the methods employ will based on consumer viewpoint to fulfill customer satisfaction and easier to adopt new technology.

1.3 Research Objectives

The purpose of this study is to design and develop an automotive head-up display interface. To develop an interface based on consumer perspective, the consumer needs and requirements must identified and understand clearly. Not only that, the consumer acceptance must identified as well to ensure the technology is applicable, especially in Malaysia. The aims of the study is to design and develop a new head-up display interface which is targeted to provide a simple and quick recognition to driver, which to minimize or eliminate distraction and increase driving safety by providing vital driving information. The objectives of study are stated as follow:

1. To identify the consumer usability requirements on the head-up display interface.
2. To translate the consumer emotions into the aspects of interface design.
3. To evaluate and verify the performance of new interface.

The detail explanation of objectives are as follow:

1. In order to makes head-up display applicable and accept by the consumer, the consumer emotion on the interface must be investigated. The purpose is to understand how consumer think and feels when using the interface and what they expected to have on the interface.

2. To translate the consumer emotions, the results that collected from first objective must carefully analyzed. With the result of the analysis, the preference of the consumer on the design features can be determined easily. Fulfilling the preference can makes the consumer to think that the new interface is specially designed for them.

3. To evaluate and verify the performance of new interface, a suitable evaluation method must be discovered or developed. The evaluation method helps to benchmarks the performance of new interface and verify the feasibility.

1.4 Scope and Limitations

This study is conducted to identify the consumer acceptance factors and requirements, and use the result to design and develop an interface that embeds consumer emotion. The aims of such interface is to create a consumer based interface and thus improve the feasibility

and usability of the technology. Besides that, this study focus on designing the virtual interface of head-up display, hence actual head-up display device is not employed.

In term of participants, it is focus on university or college student who acquired driving license at least 1 year. The age group of the participants would be limit within age 19 to 30. It is to avoid the excessive variation of participant behavior. Therefore, the data interpretation later would be easier to conduct, with focus on particular group of young people.

In term of evaluation methods, all the evaluation of the interface design will based on desktop evaluation methods, where the new interface will be evaluate by one of those methods. Experimental evaluation methods will not conducted in this study due to the limitation of resources and time. Therefore, the study is conduct without any driving simulation or test, which was used by other researchers in evaluating the head-up display interface design and efficiency.

CHAPTER 2

LITERATURE REVIEW

The research on automobile head-up display has discussed how head-up display performs compare to convention head-down display (Liu and Wen, 2004), Kansei Engineering in head-up display (Smith and Fu, 2010), effects of using head-up display (Liu, 2003) and others. This especially makes sense in the context of using head-up display in automobile, where the head-up display may improve the driving performance but also cause additional distraction to the driver. This happen when the driver focus on the head-up display and less awareness to the road events ahead. According to Tufano (1997), head-up display possess two potential issues on driving safety. The focal distance of display and its effect on the cognition of actual objects when driving, and how the design of head-up display affect visual attention. This is where interface design comes in and play an important role in the efficiency and effectiveness of head-up display, which improve the driving performance as well as increase the road safety to all road users.

The chapter continues with providing additional backgrounds of HUD. It is necessary to understand the meaning of HUD before proceed any further. Then, the chapter reviews the methods, techniques, guidelines and principles used to design HUD or automotive user interface. It is critical and useful to the designer in conceptual design stage, to reduce or eliminate rework or redesign of the interface. Not only that, the chapter also reviews user

and design in Human-Computer interaction (HCI), includes the issues concerning automotive user interface, to further improve the design and usability.

Next, the chapter reviews technique that used to acquire the consumer information, example like Kansei study. These techniques capable to extract important information regarded head-up display from the consumer. In addition, the chapter reviews existing method in evaluating the usability of user interface. It is to explore and investigate their suitability in evaluate the In-Vehicle Systems (IVSs). Lastly, the chapter reviews previous studies on HUD to understand the findings of other researchers and their purpose of the studies. However, those studies did not target the interface design and the relation between interface design and overall performance. Thus, this study focus on the interface design in the aspect of usability to fill in the gap that have missed by other researchers.

2.1 Head-up Display

As mentioned in previous chapter, head-up display originally is used in military aircraft to assist the pilot in sighting weapons and provide an artificial horizon for navigation (Weed, 2011). In contrast to conventional head-down display, HUD collect the driving information and present it on the view of external world (Swift and Freeman, 1986). Therefore, the driver can view the information directly from the windshield without move away the eyesight from the road. As a result, the driver has a quicker response time than using conventional head-down display and the speed control of automobile are more consistent (V. Charissis, S. Papanastasiou, 2010; V. Charissis, S. Arafat, W. Chan, C. Christomanos, 2006; Y. C. Liu, M. H. Wen, 2004). Hence, the driving safety is improved along with the head-up display.

In some HUDs design, the presented information was fixed by the automobile manufacturer, where there are some HUDs are able to choose or select the driving

information by the preference of driver. The driving information presented by HUD includes speedometer, rpm meter, navigation directions, warning signals, fuel level, speed limit and estimated destination time. The speedometer works as conventional speedometer, which present the current speed of the automobile, so that the driver can easily keep track of their speed without risking their life. With the navigation directions feature of HUD, the driver no longer need extra navigation device or holding their smartphone as navigation device. The built-in navigation system of the automobile or by connecting to the smartphone, the HUD present the navigation directions right in front of the driver, which improve the ease of use, efficiency and the driving safety.

Some HUDs come with new features called “Pedestrian in the road”, lane departure warning and adaptive cruise control. “Pedestrian in the road” is to detect pedestrian and reduces the driver reaction time, further ensure the driving safety on road. For lane departure warning, it helps to keep the vehicle in the lane by warning the driver if departure happens. Lastly will be the adaptive cruise control, which able detect the speed of the vehicle or object ahead and adjust the vehicle speed accordingly.

2.2 Working Mechanism of Head-Up Display

In the early HUD of aircraft, the information is projected through a large collimating lens system on a cathode ray tube which located in the focal plane. The pilot sees the information through the reflection in a partially reflecting plate, called the combiner, which located in front of him (Swift and Freeman, 1986).