THE DEVELOPMENT OF A HIGH FIDELITY 3D VISUAL INTERACTIVE SIMULATION ENVIRONMENT TO ENABLE HIGHLY REALISTIC DRIVER RESEARCH BASED ON A NEWLY DEVELOPED AND UNIQUE MULTI-DEGREE DRIVE SIMULATOR

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KEY WORDS

Drive Simulation, Hexapod, 3D Visual Interactive Simulation, Road Safety, Human Factors, 6 Degrees of Freedom, 6DOF, 3D VIS, Drive Simulator, 3D VR, Virtual Reality

ABSTRACT

This paper describes the development of a unique Driving Simulator (DS) system to be used in a range of highly detailed and complex driver and traffic safety research projects. The 3D Visual Interactive Simulation (3DVIS) software which forms the basis of the DS simulation technology is the award winning Japanese product ‘UC-win/Road’. Researchers will use this 3DVIS technology along with a specially designed and constructed DS hardware system to provide the virtual driver with a totally immersive and realistic driving experience, via a motion platform composed of an X table, a 6 degrees of freedom hexapod, a Y table and vibration system, plus a 360° field of view screen and 3D simulation software that can accurately reproduce every possible vehicle, road and environmental condition. The result is a totally realistic and unique driving experience that was previously not possible.
In addition, the DS system will have data collection capabilities that will enable the monitoring of human behaviour characteristics under a wide variety of traffic situations, emergencies and other potential driver distractions, with the overall objective of the project being the improvement of road safety in its widest sense.

INTRODUCTION

The development of simulation systems to reproduce the effects of driving cars, trucks and bikes has advanced significantly over the past years [1,2]. The availability of faster and lower cost computer processors and graphics cards, coupled with the development of highly interactive 3D Virtual Reality software such as UC-win/Road [3] and highly accurate vehicle dynamics packages such as CarSim [4] has led to the availability of many new and exciting DS systems.

In addition, a greater focus on driver safety with respect to car design, along with a similar focus on road safety from a driver behaviour perspective [5, 6, 7], has led to more demand for high quality drive simulation systems from both Universities, vehicle manufacturers, driving schools, emergency response and other professional driving organisations, as well as a growing number of government transport planning organisations.

DS systems that are based on the very best virtual reality technology make driver training and research fast, efficient, safe and low cost [3]. The ability to reproduce vehicle and driver conditions at will and in a realistic virtual environment make the best DS systems invaluable in both cognitive driver training and research as well as vehicle related research and design.

EXISTING RESEARCH SUMMARY

In September of 2010, the U.S. National Highway Traffic Safety Administration (NHTSA) released a report on distracted driving fatalities for 2009. The NHTSA considers distracted driving to include some of the following as distractions: other occupants in the car, eating, drinking, smoking, adjusting radio, adjusting environmental control, reaching for object in car, and cell phone use. In 2009 in the U.S. there was a reported 5,474 people killed by distracted drivers. Of those 995 were considered to be killed by drivers distracted by cell phones. The report doesn't state whether this under or over represents the level of cell phone use amongst drivers, and whether there is a causal relationship [5]

A 2003 study of U.S. crash data states that driver inattention is estimated to be a factor in between 20 to 50 percent of all police-reported crashes. Driver distraction, a sub-category of inattention, has been estimated to be a contributing factor in 8 to 13 percent of all crashes. Of distraction-related accidents, cell phone use may range from 1.5 to 5 percent of contributing factors [6]. However, large percentages of unknowns in each of those categories may cause inaccuracies in these estimations. A 2001 study sponsored by The American Automobile Association recorded "Unknown Driver Attention Status" for 41.5 percent of crashes, and

"Unknown Distraction" in 8.6 percent of all distraction related accidents [7]. According to NHTSA, "There is clearly inadequate reporting of crashes" [8].

Currently, "Outside person, object, event" (commonly known as rubbernecking) is the most reported cause of distraction-related accidents, followed by "Adjusting radio/cassette/CD". "Using/dialing cell phone" is eighth.

The scientific literature is mixed on the dangers of talking on a cell phone versus those of talking with a passenger. The common conception is that passengers are able to better regulate conversation based on the perceived level of danger, therefore the risk is negligible. A study by a University of South Carolina psychology researcher featured in the journal, Experimental Psychology, found that planning to speak and speaking put far more demands on the brain's resources than listening. Measurement of attention levels showed that subjects were four times more distracted while preparing to speak or speaking than when they were listening [9]. The Accident Research Unit at the University of Nottingham found that the number of utterances was usually higher for mobile calls when compared to blindfolded and non-blindfolded passengers across various driving conditions. The number of questions asked averaged slightly higher for mobile phone conversations, although results were not constant across road types and largely influenced by a large number of questions on the urban roads [10].

A 2004 University of Utah simulation study that compared passenger and cell-phone conversations concluded that the driver performs better when conversing with a passenger because the traffic and driving task become part of the conversation. Drivers holding conversations on cell phones were four times more likely to miss the highway exit than those with passengers, and drivers conversing with passengers showed no statistically significant difference from lone drivers in the simulator [11]. A study led by Andrew Parkes at the Transport Research Laboratory in the UK, also with a driving simulator, concluded that hands-free phone conversations impair driving performance more than other common in-vehicle distractions such as passenger conversations. However, some have criticized the use of simulation studies to measure the risk of cell-phone use while driving since the studies may be impacted by the Hawthorne effect [12].

A significant amount of human factors research has been conducted throughout the academic world non-more so than at the ITS centre within Leeds University in the UK. This research includes work on the effect of in-car ITS systems [13] as well as the evaluation of traffic signage to driver behaviour [14]. In addition modern DS systems have been used to assist in the physical design of new highway infrastructures [15].

PROJECT OBJECTIVES

To develop an experimental drive simulator system that enables researchers to collect driving data under as wide a range of controlled driving and environmental conditions as possible.

In particular:

- The accurate simulation of a wide variety of road surface conditions
- The reproduction of the vehicle's precise position on the road at any time based on the universally adopted 6 degrees of freedom
- A comprehensive and flexible data collection facility concerning the road surface, vehicle dynamics, position and other pertinent 'human factors' data. Plus a comprehensive analysis and display facility

PROJECT AIMS

The project aims to enable researchers to carry out the following activities

- Driver safety research in various road, weather and vehicle conditions / dynamics
- Traffic research into the effects of congestion, accidents and other emergencies
- Human factors research including driver position and posture and the effects of a variety of driving distractions
- The ability to change driving conditions quickly and easily including road textures, individual vehicle dynamics and other important parameters
- Reduced research costs

Innosim iDrive

SimCraft DS

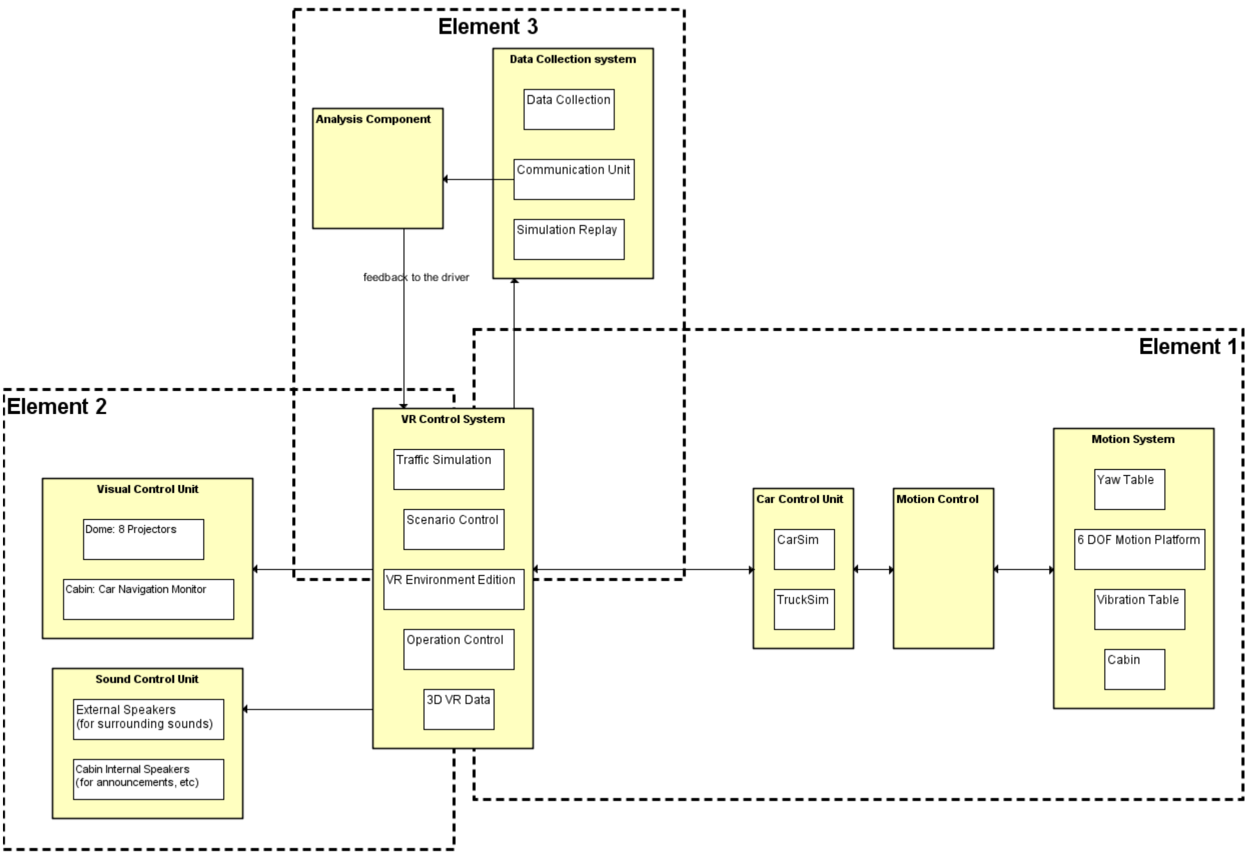
METHODOLOGY

There are three elements to this project:

1. The development of a multi-degree hexapod based mobile platform system, with 360° wrap-round vision, controlled by the 3D VIS simulation software which also allows high fidelity reproduction of a range of real vehicle dynamics through the use of the industry standard software CarSim and TruckSim [4]

2. The second is the enhancement of the existing 3D VIS technology (UC-win/Road) [3] to enable realistic reproduction of any conceivable environmental factor or road condition. Including advanced car and traffic sounds, improved graphics and lighting with an comprehensive and flexible environmental weather system

3. The third is based on the further development of the 3D VIS simulation software that allows driver behaviour to be analysed under the widest possible range of conditions through the development of a comprehensive data collection system. In addition, this software also allows the driver experience to be replayed for further analysis.



DS Hexapod 8DOF Hardware System Configuration

The 6 DOF hexapod undergoing final factory testing at Bosch Rexroth

Images of the proposed final system configuration

RESEARCH PROJECT

The overall research project is composed of three sub-projects A, B & C

PROJECT A. DATA MONITORING & CAPTURE

Function and Action

The main function of the DS multi-degree platform system is to check the driver's decentralized attention capacity under different driving conditions and thereby to examine ways to improve overall road safety.

- This is made possible due to the chosen 3D VIS software's ability to reproduce highly immersive and realistic traffic conditions, including speed and congestion
- The 3D VIS software (UC-win/Road) also enables the researchers to reproduce almost any conceivable environmental condition that a real road user would have to contend with. These conditions include rain, wind, snow, fog with the ability to control the intensity of each of these weather factors dynamically
- The 3DVIS software also enables the researchers to build 3D environments quickly and easily using a combination of digital terrain models and aerial ortho imagery. Plus these environments can be quickly and easily populated by other 3D digital models from a number of industry sources, including 3D Studio Max, Google Building Maker, SketchUP as well as from its own inbuilt modeling system. In addition the 3D VIS software UC-win/Road has a database of over 4000 3D digital models for the researchers to use. This database includes a wide range of street furniture and street signage from around the world, as well as vegetation, vehicles and people
- UC-win/Road also has an open database and a Software Development Kit (SDK) for future project customization, a key requirement of the system specification

DS System Features

To examine the driver's attention capabilities, the 3D VIS DS system software also had to have the following particular capabilities:

Driver Behaviour. The reproduction of the real human driving experience, within the driving space and the ability to test and monitor a range of functions of the drivers' behaviour.

For example:

- The measurement and analysis of physiological and psychological characteristics of drivers in different traffic conditions

- The ability to critically examine the influence on a driver's concentration level during a variety of different distractions, e.g. mobile phones, radio, passengers, road signage, advertising hoardings etc.
- To research the effect on traffic safety due to tiredness

Road & Traffic Safety Research Functions. The DS system also had to provide for the following road traffic safety research functions:

- A facility to enable detailed research into driving safety under changing road conditions including lighting, visibility, surface water etc.
- The ability to examine the effects on driver safety of changing road landscapes and other visual changes within the built environment such as new signage

Road Safety in Special Environmental Circumstances. The DS system also had to facilitate research into a wide range of environmental effects on traffic safety. In particular, the system research into traffic safety in bad weather conditions such as snow, strong wind and high or low temperatures etc.

General System Requirements

To satisfy the requirements of the system specification the DS has to be able to:

- Reproduce complex traffic space, whilst providing the researchers with total control of all the various environmental and other extraneous parameters
- Be highly flexible and easily controlled, thereby making the actual research work more efficient and more comfortable for the individual researchers
- Designed to minimise cost by incorporating industry standard, state-of-the-art personal computer 3D VR simulation technology

PROJECT B. SYSTEM CONFIGURATION

The DS system used in this project, on which drivers' attention / deviation capabilities are to be tested and the various preventive solutions and technologies examined, is composed of the following five units: Multi projection system, Projection screen, Projection control unit (including image brightness, screen processor), Visual generation unit and the sub assembly components (pedestrian support and platform, etc.)

PROJECT C. DS DESIGN SPECIFICATION

DS Functionality

- The ability to faithfully reproduce the individual vehicle's kinematics and kinetic features (turns, acceleration etc) under a wide range of driving conditions
- A software system able to reproduce the built environment and infrastructure, road networks, traffic volumes, sounds and all weather and road surface conditions
- Comprehensive data collection and analysis capabilities
- An open interface for future developments using an in-built SDK

Research Requirements

Driver Behaviour Research. The DS system must be able to reproduce the driver's driving 'sense' faithfully and must have the ability to log and analyse the driver's driving behaviour.

For example:

- The ability to measure and analyse driver psychologies and characteristics under various driving environments (road changes, acceleration, deceleration, breaking and changes in direction etc)
- Research the driving characteristics of various age groups (young/ old/ juvenile)
- The influence on the driver of mobile phone and radio use, etc.
- The influence of tiredness
- The influence of alcohol, disease and drugs (prescription medicine and social)

Road Safety Research. The DS system must also enable research into particular safety issues concerning a wide variety of individual road conditions.

For example:

- The ability to reproduce all road conditions, sizes and types (long descending slopes, tunnels, bridges, doglegs, complex intersections, etc.)
- The DS system should also have the ability to assist in security and emergency planning and research
- Facilitate research into various roadway lighting, guiding and changes in visibility
- The DS VR software must enable the easy yet comprehensive design and production of 3D roads, associated infrastructure and landscape
- A road safety evaluation function for management and maintenance personnel

Road Safety Research under Special Environmental Conditions. Another DS system requirement is the ability to accurately reflect every conceivable environmental condition that the road user would have to contend with. These include: fog, ice and snow, high or low temperature, snowstorm, wind and etc. In addition these environmental effects need to be able to be controlled dynamically by the researcher to show the effect of rapid or slow changes to the weather**.** The researcher needs to be able to switch on or off special events, such as traffic accidents, fires, smoke and other abnormal situations as well as being able to reproduce a range of potential security and emergency events

CONCLUSION

The result of these 3 projects is the production of a unique multi-degree road safety driving simulator using the very latest hydraulic, electronic and 3D virtual reality technology. It has been designed to meet all the requirements of the agreed system specification, including:

- The faithful reproduction of the driving experience through easily to use parametric controls

The multi-degree road safety DS system has the same driving interface as a real vehicle it simulates real road traffic conditions and reproduces the individual driver's driving capability.

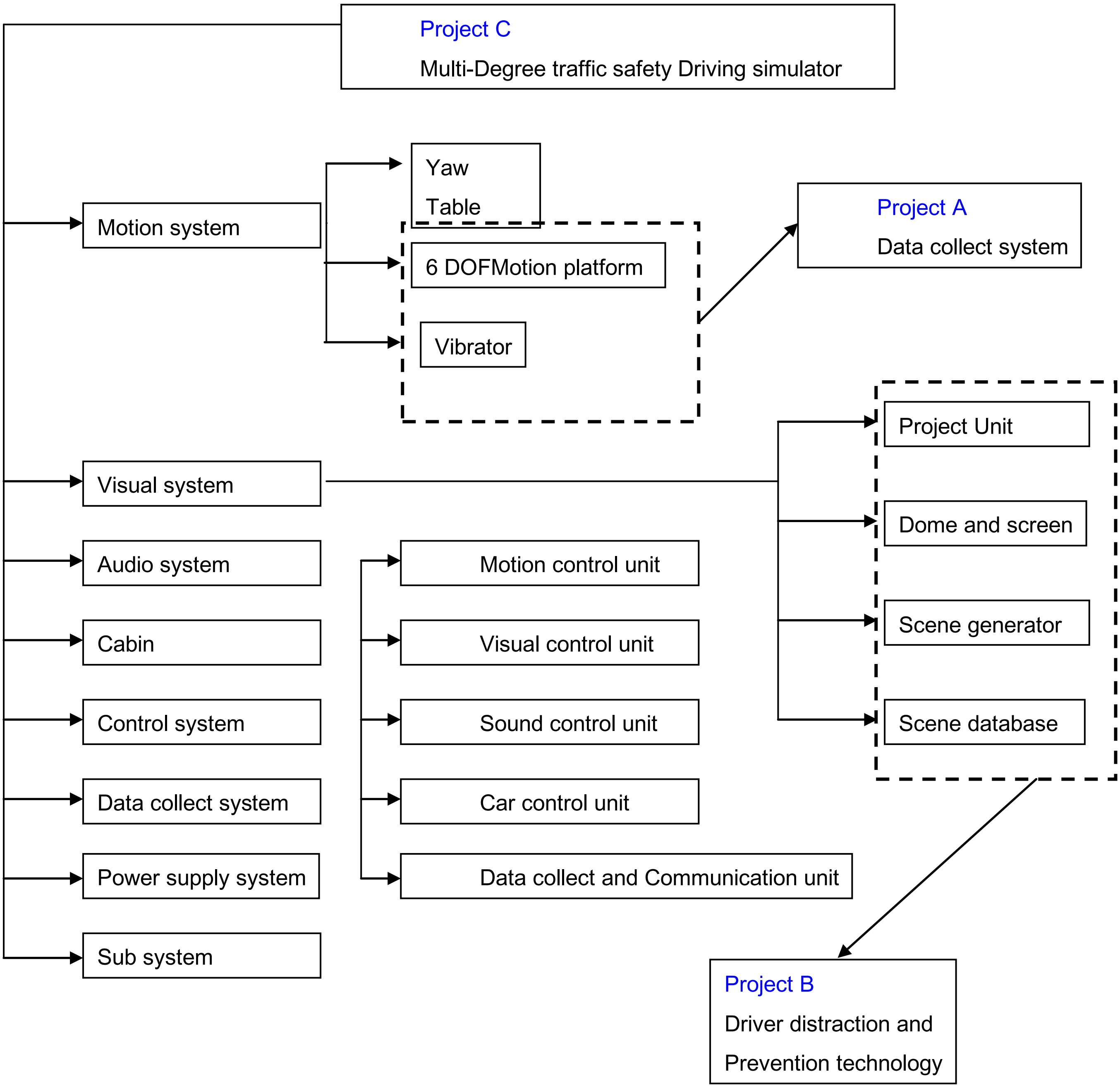
The system will improve the level of road safety research significantly by allowing the researchers to use the single or the multi-dimensional parametric control system, as well as having a data capture and analysis system which is both versatile and accurate.

- The ability to reproduce extremely dangerous road situations to enable researchers to expand the potential scope of their driver safety research
- The research objectives can be altered at will due to the flexible 3D VR driving environment which can be changed easily and efficiently leading to an improved research capability
- The DS system utilizes industry standard computer simulation technology and hence reduces research costs

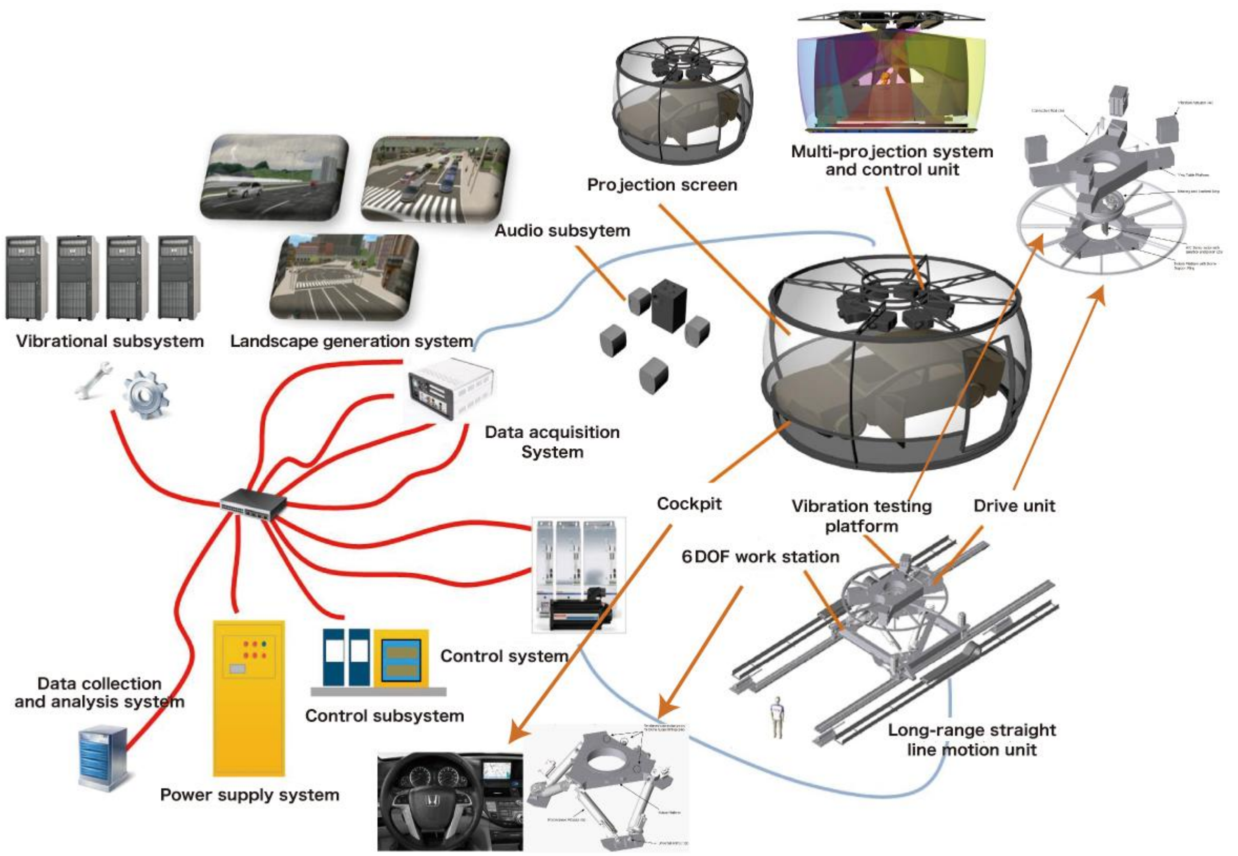
Typical research objectives tend to be focused on traffic accidents and other road incidents. Field experiments and collision tests using real vehicles is very expensive. However a multi-degree road safety DS system can reduce these research costs significantly whilst at the same time allowing the researcher to evaluate a whole host of ‘human factors’ through the application of the latest IT technology.

FINAL DS SYSTEM CONFIGURATION

The integration of Projects A & B with C results in the overall research system…



Explosion of the Component Parts of the multi-degree 3D DS



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