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SIMULATOR OF A CAR FOR PEOPLE WITH DISABILITIES

Abstract. This paper presents the results of a project conducted by the authors, the purpose of which was to build a simulator for teaching disabled persons how to drive a car. This paper presents also the functional design requirements established for the project. The structure of the mechatronic system, on the basis of which the simulator was built, is presented. The details of each subsystem of the simulator and its capabilities and the method of its functioning are also described.

Keywords: robotics, driving simulator for people with disabilities, Stewart platform.

1. INTRODUCTION

Integration and mobilisation of disabled people is a very important social and cultural issue in the 21st century. People with locomotor dysfunctions, either congenital or acquired, who do not want to be excluded or marginalised, who want to live an active life, must be mobile. This is of particular importance in the case of vocational mobilisation of these people. It is very important for people with locomotor dysfunctions who want to be vocationally active to have an adequately adapted car and an appropriate licence to drive such car. For this reason the authors of this paper and their research team made an attempt to develop and construct a simulator for teaching how to drive a car adapted to be used by impaired people. This simulator was created as part of the implementation of a project titled "Mechatronic integrator of vehicle control procedures for disabled persons" which was financed by the National Centre for Research and Development (agreement no. NR03-0005-10/2010). The goal of the project was to develop a simulator enabling realistic simulation of driving a car so that disabled people could safely train various stages of driving a vehicle.

2. SIMULATOR CONCEPT

The first stage in the creation of the simulator stand was the development of the concept [2, 3, 4, 5, 7, 8]. The following subsystems were defined in the concept:

- vehicle control subsystem for controlling the real vehicle mock-up moving in a virtual world,
- visualisation and sound generation subsystem for generating and projecting virtual training routes on a system of four screens and for generating sound effects heard in a real moving car,

- car dynamics simulation subsystem for acting on the vehicle mock-up to simulate sensations experienced when driving a real car. For this purpose a Stewart platform with a car body fixed onto it was used,
- a safety subsystem ensuring safe use of the simulator,
- simulator control subsystem, based on Powerlink network, for integrating all subsystems and proper operation thereof.

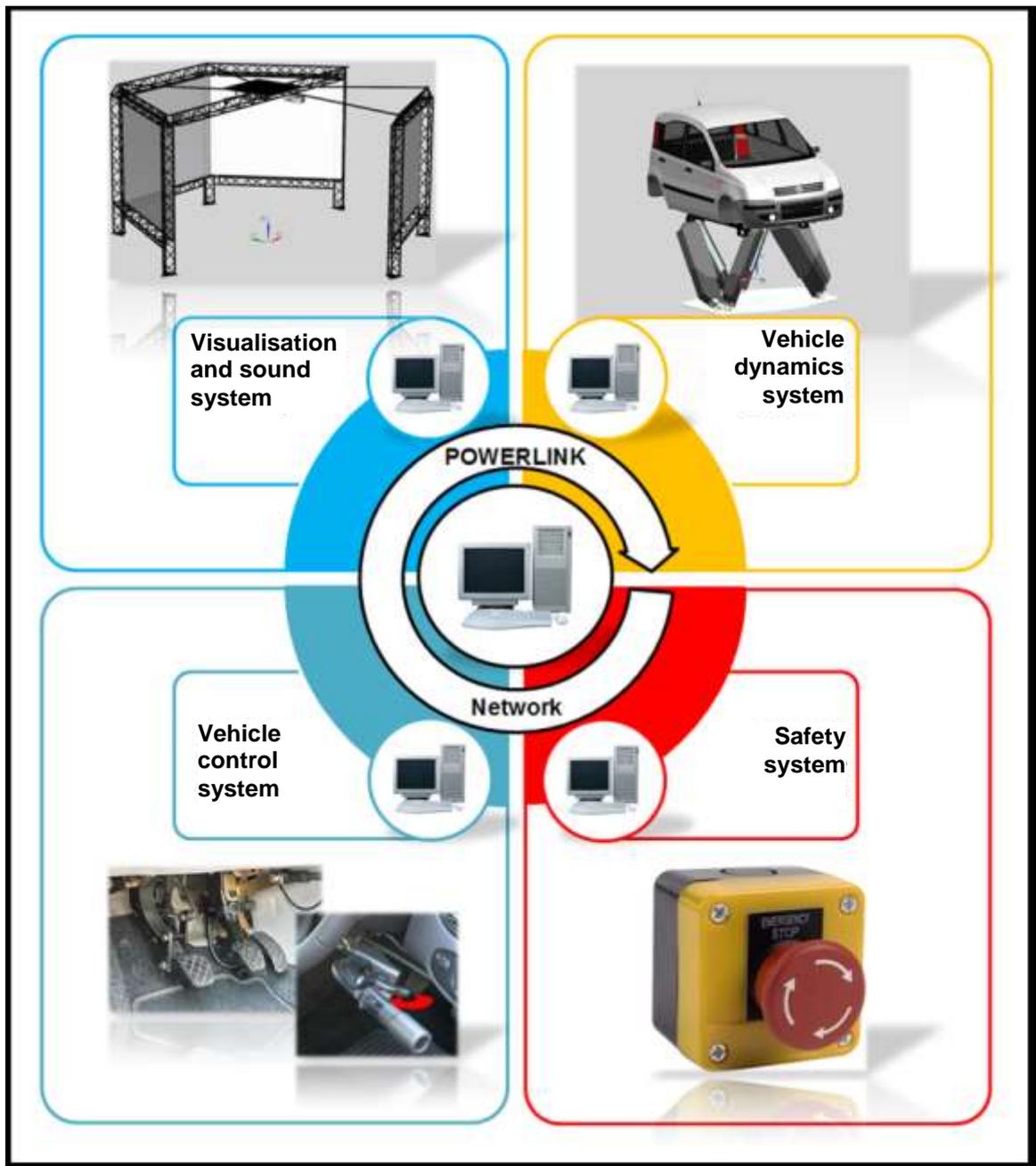


Fig. 1. Simulator operation concept

Basic components were determined and configured and approximate dimensions of the simulator stand were determined in the course of conceptual work. Figure 2 shows a model of the simulator stand positioned within a model of a room with all major components labelled.

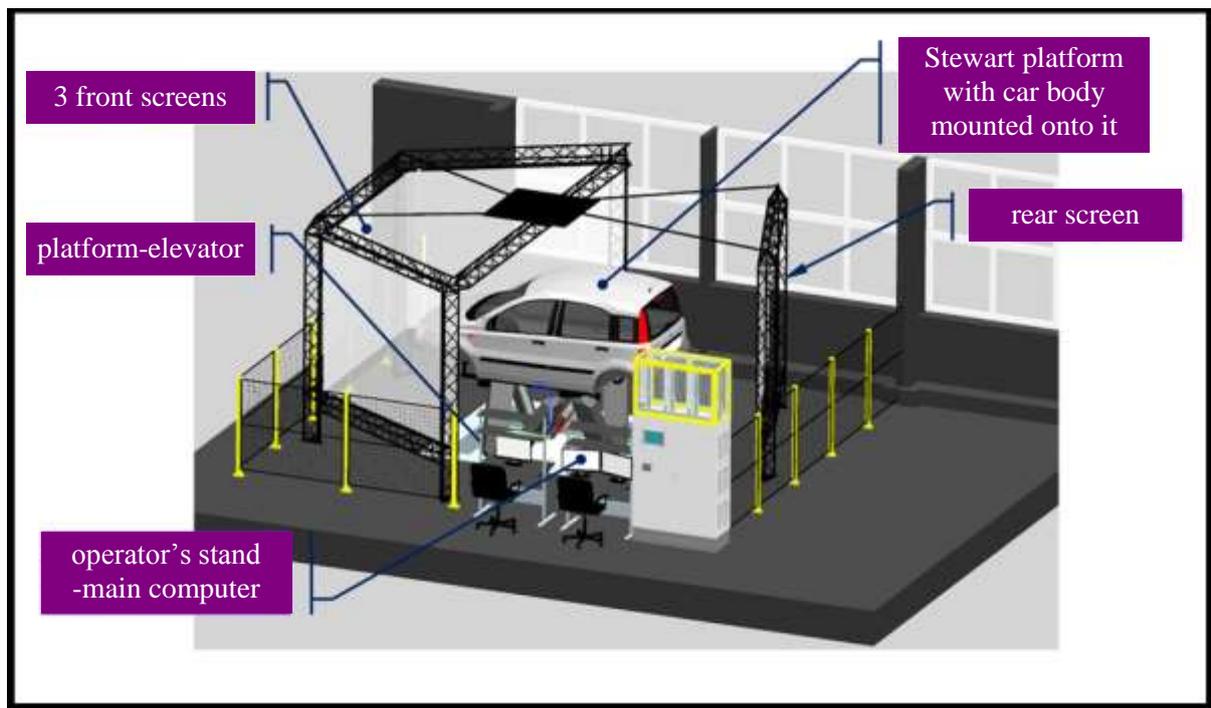


Fig. 2. Model of the simulator stand

The developed simulator stand comprises the following components:

- four screens for displaying virtual routes. The screen at the back of the simulator enables seeing the right-hand mirror view, seeing the rear mirror view and looking back over one's shoulder,
- a Stewart platform, with a car body fixed onto it,
- platform for lifting a person getting into the car to the "ground" level, that is to the level from which a person would normally step into a real car,
- operator stand with three computers responsible for the operation of the simulator. The operator on this stand can initialise the various stages of simulator operation (getting in, getting out, driving, route selection, printing reports). In addition the displays show images from cameras placed in the car. This enables observation of the behaviour of the disabled person driving the simulator,
- control cabinet, which houses automatic control elements and an industrial computer for controlling the simulator components.

3. IDENTIFICATION OF INTERACTIONS OCCURRING WHEN DRIVING A CAR

The next step was the identification of interactions and sensations experienced when driving a real car [6, 9]. To this end measurements were conducted of accelerations occurring when typical manoeuvres are made when driving a real car. Various traffic situations were analysed to be able to determine how the platform should react when simulating driving.

Measurements were made using USB X6-2 accelerometers arranged in various points of the car (among them: on the driver's head, on the seat, on car body).

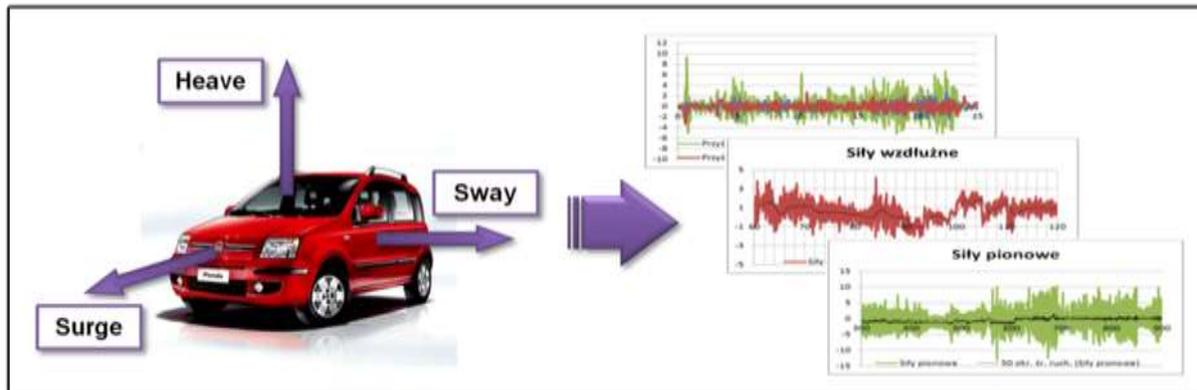


Fig. 3. Identification of interactions occurring when driving a car

The tests carried out and the analyses of the results obtained led to the determination of geometric, kinematic and dynamic parameters of the platform necessary to generate realistic sensations experienced in a real car. These parameters of the platform are given in Table 1. The measurements made provided input data for constructing the Stewart platform.

Table 1. Parameters set for the Stewart platform

Coordinate system	Surge	Sway	Heave
Maximum displacement	$\pm 0.30m$	$\pm 0.30m$	$\pm 0.30m$
Maximum speed	$\pm 0.5m/s$	$\pm 0.5m/s$	$\pm 0.5m/s$
Maximum acceleration	$\pm 5m/s^2$	$\pm 5m/s^2$	$\pm 5m/s^2$
Maximum angular displacement	Roll	Pitch	Yaw
	$\pm 25^\circ$	$\pm 25^\circ$	$\pm 20^\circ$

3. CONSTRUCTION OF THE SIMULATOR STAND

Design of the simulator stand was made with the help of CAD software. The stand and all of its components were modelled using Siemens PLM NX software. This enabled the verification of simulator operation at an early stage of development [1]. A number of analyses, calculations and simulations led to the creation of the final structure of the simulator. Figure 4

shows a CAD model of the platform along with a frame onto which car body is mounted, and Figure 5 shows a model of the "leg" of the platform.

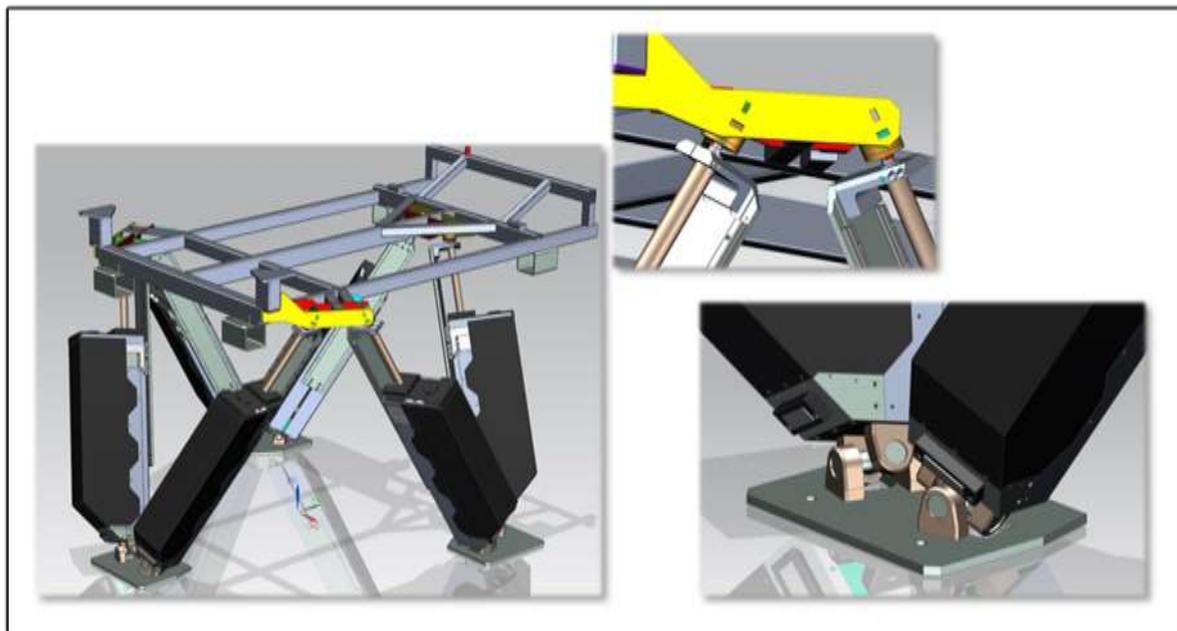


Fig. 4. CAD model of the Stewart platform

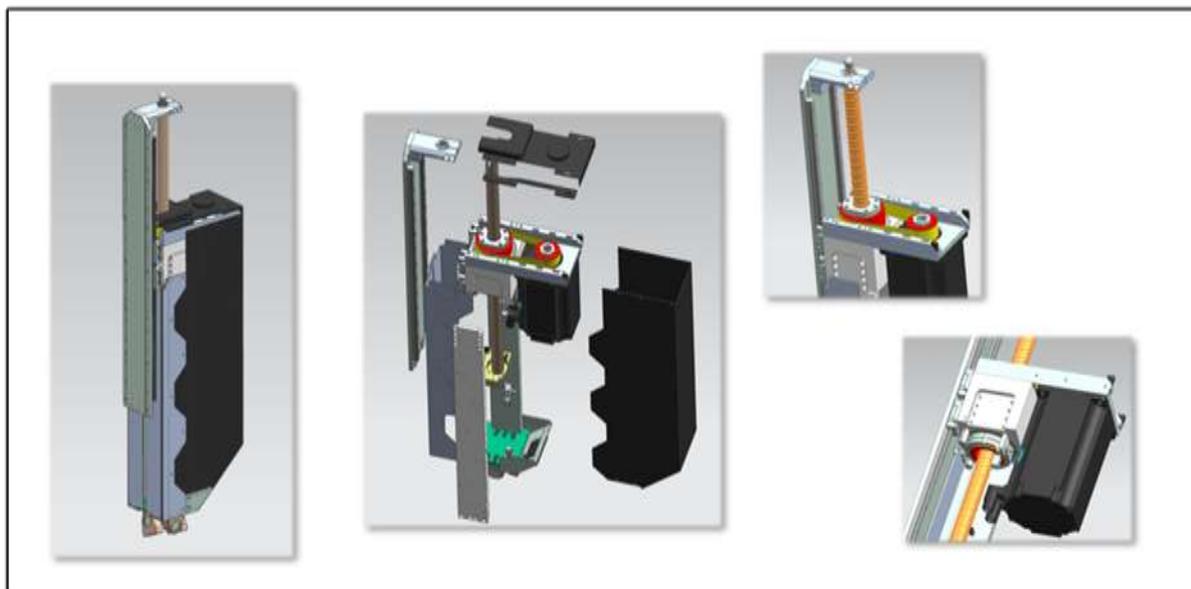


Fig. 5. CAD model of the "leg" of the Stewart platform

Based on the created CAD models, design documentation was developed, which in turn formed basis for constructing the simulator stand.

A Fiat Panda car was mounted onto the platform designed and constructed by the authors. Components of the car not required in the simulator (engine, transmission, wheels, etc.) were removed in order to reduce the weight of the car. All elements associated with the "driving of the car" (pedals and associated fittings, steering system, hand brake, etc.) were retained. The interior of the car was also left unchanged, including the dashboard, so that the

person "driving" the car could experience the same ergonomic conditions and the sensation of moving as in a real car. All sensors used for collecting data associated with the displacement of car control actuators were connected to the standard pieces of car equipment. This enables modifying the instrumentation of the car to adapt it to the needs of people with various degrees of impairment, provided that these modifications do not alter the standard car controls. The current version of the simulator is equipped with a brake control, a mechanical accelerator control and with a steering wheel ball. Other configuration is also possible.

The virtual environment of the simulator is based on a MAXELKA 4M (EduCar) driving training simulator provided with additional procedures for controlling the platform. This environment enables the generation of routes and initialising various traffic situations. Routes created for the project enable training to deal with most traffic situations:

- driving in the training yard,
- driving in the town,
- crossings and roundabouts,
- driving on expressways,
- other routes routinely included in the MAXELKA 4M simulator.

4. CONFIGURATION OF THE MASTER CONTROL SYSTEM OF THE SIMULATOR

The next key stage in the construction of the simulator stand was the development of the control system. The guidelines adopted for designing the master control system of the platform apply to:

- controlling the platform in accordance with the requirements defined by forward and inverse kinematics of the platform,
- integration of the mechanical system and VR (virtual reality) simulating the traffic conditions,
- safe operation of the stand, particularly the safety of people engaged in simulating the traffic,
- operator's supervision over the simulator provided with appropriate priority,
- diagnostic capability for the entire system and provision of communication between the drive components with tracking capability of changes in drive operation parameters,
- digital transmission of control signals (Ethernet Powerlink).

Figures 6 and 7 show a simplified schematic diagram of the structure of the designed distributed control system of the simulator.

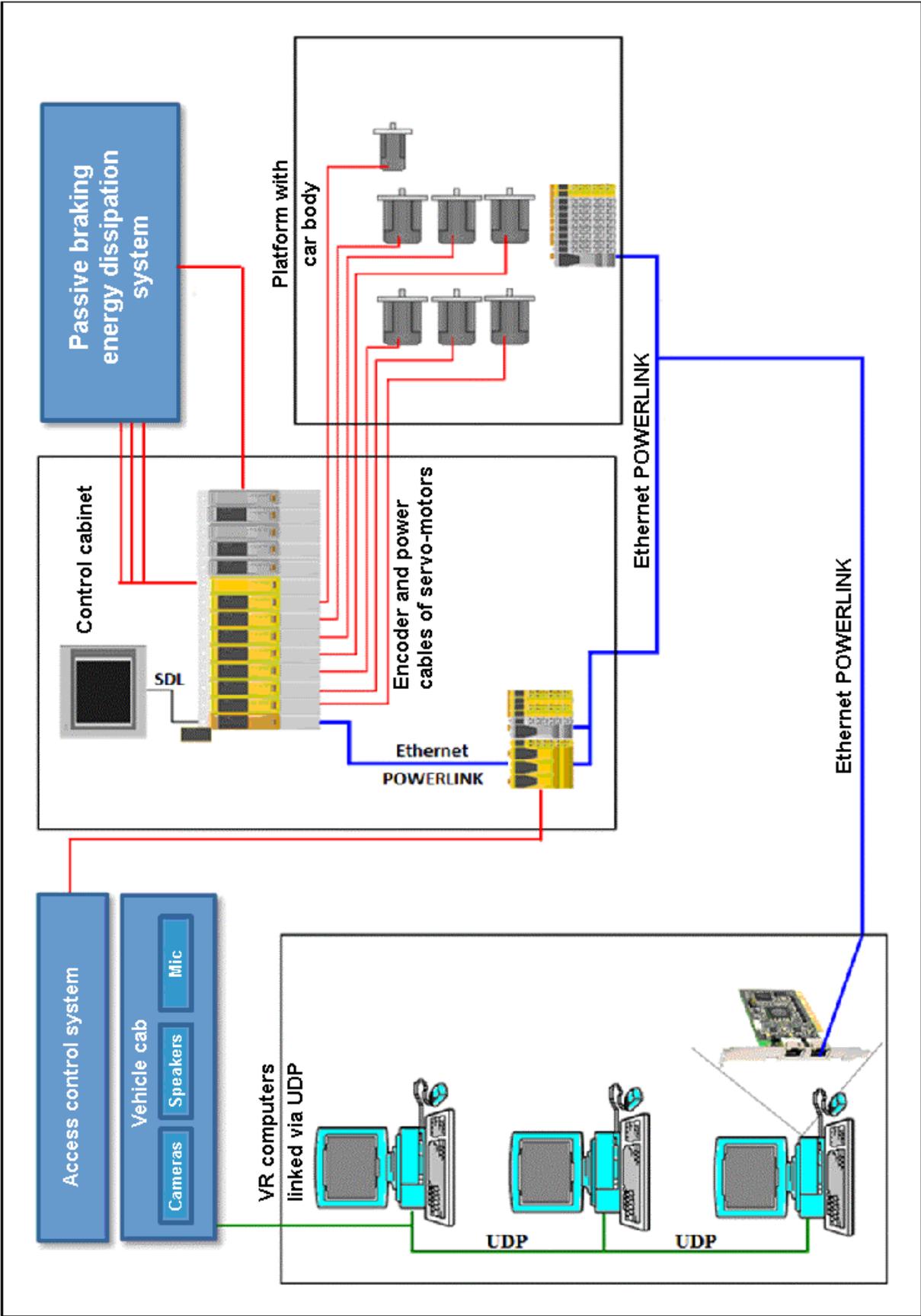


Fig. 6. Schematic diagram of the control system

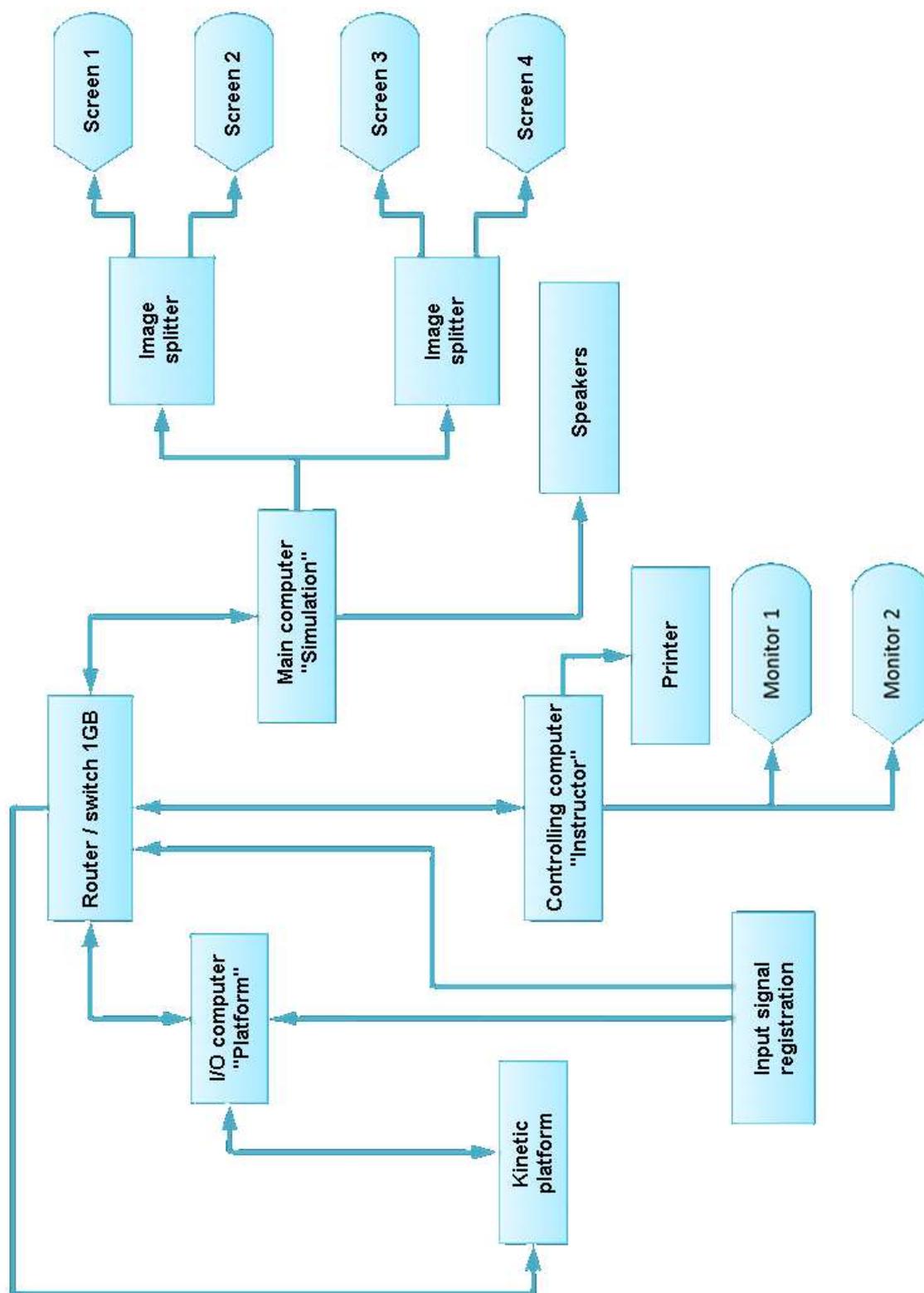


Fig. 7. Connection diagram of the distributed control system of the simulator

5. CONCLUSIONS

The design and construction efforts enabled the creation of a simulator shown in Fig. 8. The working simulator can be seen in the film accessible at <http://www.youtube.com/watch?v=D9yFqFPpWi4>.

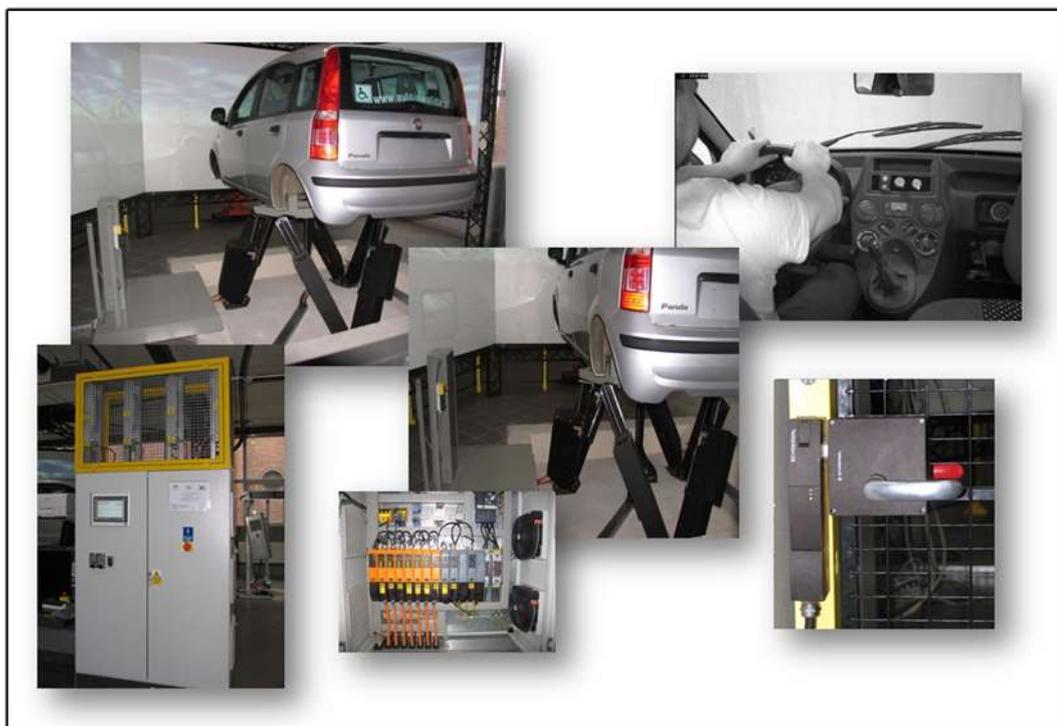


Fig. 8. Photographs of the constructed simulator

The created simulator enables disabled persons to practice driving in a stress-free manner on a vehicle adapted to their particular dysfunctions. Observation and analysis of driver's behaviour when driving the simulator may form part of initial verification of the skills and abilities to drive a car, which is paramount to deciding whether a given person is eligible for applying for a licence and whether she or he will not pose a threat for the real-world traffic. The virtual routes make it possible to check the reactions of these persons to various traffic incidents and to check their behaviour during unexpected traffic situations. The set of four cameras allows to observe closely and record the vehicle driver's behaviour. The usefulness and suitability of the assisting devices can be verified. The simulator also helps in testing new driving assisting devices and in adapting and tuning of instrumentation to meet individual needs of a disabled person.

6. REFERENCES

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