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The concept of research and training simulator for testing car assistive devices for physically disabled drivers

Koncepcja badawczo-szkoleniowego symulatora samochodu osobowego do badania urządzeń wspomagających kierowców z niepełnosprawnością ruchową

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Presented are the assumptions and a description of the work carried out as part of the action on the development of a project to assist the prevention of social exclusion of people with disabilities. The developed research and training simulator for a car with a weight of up to 3.5 tons will allow the study of the suitability of various solutions enabling the driving of a motor vehicle for people with upper and lower limb dysfunctions. This simulator equipped with a driver's cockpit attached to the motion platform, platform, image projection system and application will be tested with the participation of 20 people.
KEYWORDS: driving simulator, disabled people, virtual reality

According to data from the "National Population and Housing Census" of 2011, the total number of people with disabilities (both legally and biologically) at the end of March 2011 was approx. 4.7 million (exactly: 4697 thousand) [1]. Thus, such persons accounted for 12.2% of the population of Poland.

People with physical disabilities account for almost 60% of people with disabilities in Poland. GUS data indicate that in 2011 a significant percentage of people with disabilities were economically inactive (79.7% of the total analyzed population). Only 16.4% worked. The unemployment rate among people with disabilities was as much as 19.2%.

The results of the Population Economic Activity Survey indicate that the share of people with disability among the total number of people registered in commune labor offices in December 2016 was 7%.

The presented data show that there is a need to minimize the effects of disability by helping to activate this group of society, e.g. in the form of removing barriers to free movement. Limited mobility translating into limited independence may contribute to the isolation of these people in society and reduce their self-esteem, which may lead to depression or a reduced mood. Barriers to the free movement of people with disabilities are minimized, for example, by removing architectural obstacles, but also by adjusting public transport vehicles to transport people from this group [2]. Persons with motor disabilities may also drive motor vehicles, however, both the driver and the vehicle must meet certain conditions [3].

The factors determining the possibility of driving a car by people with disabilities include the degree and type of disability, the ability to adapt the car to specific needs and the fear of driving a car with the use of special equipment. On the basis of GUS data, the most common cause of disability is the diseases of the circulatory system, motor organs and neurological diseases. According to the study presented on the website [4], it is possible to adapt the car to 12 configurations of upper and lower limb dysfunctions and for persons of short stature.

Customizing a car usually requires:

- assembly of the swivel seat,
- mounting a handle to facilitate entry into the car,
- pedal extensions,
- introduction of the left gas pedal,
- assembly of a device for manual gas and brake operation,
- the use of an automatic clutch,
- fastening the knobs on the steering wheel of the vehicle,
- use of the control panel to operate turn signals, car lights, wipers and an audible signal.

In Poland, there is a well-developed network of vehicle adaptation points to meet the needs of people with disabilities. The websites use products of foreign companies and Polish solutions (e.g. CEBRON companies). An important place for the disabled is the Automotive Service Center for the Disabled at the Motor Transport Institute - the first institution in Poland providing a comprehensive system of support for the mobility of people with mobility disabilities.

The degree and type of movement disability (acquired or congenital) directly affect the perception of themselves as drivers. It is estimated that there are approx. 200,000 in

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Poland. drivers with disabilities, which is a small percentage of all people with disabilities [5].

Driving simulators for people with disabilities can be useful in convincing such people to obtain a driving license or have an adapted car. Simulators help in testing the motor skills of a person in driving a customized car. The advantage of this type of simulators is that the participant in a safe way (for themselves, potential road users and equipment) tests specific solutions, while increasing experience in driving the vehicle, and the skills acquired during such simulation shorten training time in real conditions.

Driving simulators are used in the process of training truck and bus drivers. These devices must meet the requirements set out in Regulation [6] (defining high-end simulators [7]), which transposes into the legal order of the Republic of Poland the provisions of Directive 2003/59 EC of the European Parliament and of the Council of 15 July 2013. In the case of drivers of passenger vehicles there are no formal requirements, only recommendations on the use of driving simulators in the driver training process.

The latest, from the last three years, literature reports about driving simulators for people with disabilities are few. In Poland, such an example is a simulator developed at the Silesian University of Technology [8]. It uses a mobile Stewart platform on which a passenger car has been fitted with adjustments for people with lower limb dysfunctions. The image is displayed on three screens at the front and one mounted at the back of the car. A disabled person gets into the simulator using a hoist.

There is also a stationary simulator [9] available for analyzing the possibilities of targeting disabled people using the special Autoadapt equipment installed in cars.

A limited number of examples of the use of car driving simulators using a mobile platform for people with physical disabilities confirms the legitimacy of the Virtual Reality Technique Laboratory at the Central Institute for Labor Protection - National Research Institute. An attempt was made to develop a position for simulation of driving a car by disabled people with selected motor disabilities and hearing loss.

Methodology of research and applied tools

The activities related to the development of the simulator were divided into three stages. In the last stage, the simulator will be tested with 20 volunteers, including: 10 non-disabled people, five people with upper limb dysfunction and five people with lower limb dysfunction. It is assumed that persons participating in the study will have a type 05-R (musculoskeletal) condition.

During the tests, the simulator will be evaluated using the questionnaires and the analysis of objective indicators. The tests will be conducted based on the user testing method [10], assuming the participation of people who are not experts in the field of driving simulators.

During the research, objective information will be collected about the mistakes made and the time taken to complete the tasks (passing through the obstacle course and special tasks, e.g. starting uphill, crossing the curve on a corked street, parallel parking, passing near low obstacles). The subjective assessment of the simulator will refer to the utility, the level of generated symptoms of the simulator disease, the usefulness and realism of the simulation.

During testing, the following research tools will be used:

- Kennedy SSQ questionnaire,
- questionnaire on the technology acceptance model,
- short version of the spatial presence questionnaire,
- system usability scale (system usability scale).

Assumptions regarding the construction and use of the driving simulator

Work began with developing assumptions regarding the simulator and its components. It is assumed that the driver's seat will be equipped with: an armchair with a modification facilitating the entry of a disabled person, seat belts, a simplified passenger car (traffic light switch, sound signaling, clutch pedal, brake and acceleration, gear stick, hand brake, panel with indicators).

The controls will be adapted to the needs of people with disabilities (for selected disabilities of lower and upper limbs). The driver's cockpit will be attached to a movable platform with six degrees of freedom, with which the angular position of the virtual car's body will be mapped to simulate the sensations related to braking, acceleration or twisting.

Simulation of driving based on platform operation will be carried out with at least three degrees of freedom. The main method of image presentation will use stereoscopic projection glasses, and the triple projection method is optional. The simulator application and car model will be created in the Unity 3D environment, which provides full support in creating virtual reality applications.

The virtual environment of the simulator will contain various types of roads, intersections and obstacles, roads in the built-up and undeveloped zone, with variable landscape, traffic lights, selected vertical and horizontal road signs. The whole virtual environment will enable driving a virtual car in accordance with the traffic code. In addition, the environment will be equipped with a maneuvering area.

The application will enable maneuvers: starting, braking, turning, reversing, accelerating and releasing with the use of steering devices, including gear shift lever.

The simulator is not meant to simulate driving in extreme/special conditions, but only moderate driving while controlling the car, using auxiliary equipment.

Test stand - a mobile driving simulator platform

Using the experience of the research team [11], a mobile platform with six degrees of freedom was developed. The platform will have a lifting capacity of 2000 N and will ensure the effector's translation in all axes, at least ±15 cm, and a change in its angular position by at least ±15°. The platform effector will achieve instantaneous translational speeds ≤ ±0.3 m/s and instantaneous angular velocity ≤ ±30°/s, and instantaneous angular accelerations ≤ 200°/s^2.

Test stand - driving simulator equipment

The simulator's equipment includes the driver's cockpit, platform and image presentation system.

The simulator cockpit was designed using a computer model of a man whose dimensions are compatible with anthropometric 50 centile dimensions. The whole will be built of aluminum profiles and equipped with the original driver's seat, steering wheel and dashboard, pedals, handbrake, switches and switches for lights, wipers and direction indicators. Mounting the chair will allow its free extension and half-turn (two degrees of freedom). The key controls (modules) that will be instrumented will be mounted in a way that allows quick replacement for an optional solution.

Another element of the driving simulator equipment adapted to the needs of people with disabilities is a platform that will enable people moving on a wheelchair to conveniently reach the car seat placed on the platform's platform. The structural elements have been designed using modular aluminum profiles. The dimensions of the platform were developed in accordance with the guidelines included in the literature [12].

The last element of equipment is the image projection system. The simulator assumes the use of two forms of image presentation - using stereoscopic projection glasses (HMD - head mounted display) and three sets of projector-screen (monoscopic image).

The basic form of the presentation are projection glasses, while the option is a three-screen solution, possible in a situation where the simulator user will refuse to put on the glasses.

3D projection glasses - a consumer version of the HTC VIVE model were selected.

An optional version of the image presentation required the design of a suitable construction, on which the screens joined together and set at an angle of 120°, separated from the participant by approx. 2 m.

Conclusions

The simulator will allow virtual prototyping and testing of solutions enabling persons with selected motor disabilities to drive a mechanical vehicle, such as: manual gas and brake (e.g. horizontal brake with motorcycle gas handle, brake and vertical pull-push gas or vertical brake with a knob gas), additional pedals (e.g. gas pedal from the left side), manual clutch or handles for drivers with partially inoperative upper limbs. The simulator will be adapted to the possibilities of installing typical, mentioned devices supporting people with disabilities and will allow the study of more advanced devices supporting drivers with hearing loss, using techniques of enriched reality and presenting additional information on traffic in the form of appropriately crafted visual data.

The simulator will be able to be used to train people with disabilities in the field of driving vehicles. It will be adapted to the needs of people with disabilities through a construction that facilitates the entry into the cockpit of the simulator and the installation of devices supporting the driving of the vehicle.

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