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THE USE OF LED-BASED DIGITAL OPTICAL MINISTICKS AS MULTI-FUNCTIONAL CONTROLS OF UNIFIED HUMAN-MACHINE INTERFACES

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ABSTRACT

The active development of robotics requires increasingly complex remote control devices. The remote control devices are increasingly large, complex, and expensive. They decrease economic efficiency of robotics and increase their price.

The scientific task is the research into possibility of applying optical mini-sticks on the basis of light emitting diodes as the new type basic multi-functional controls of unified human-machine interfaces allowing us to control commonly known robotic equipment types using identical devices.

During the research original ergonomic methods of purposeful combination of two mini-sticks on two actuating levers were used so that to provide convenience of tactile control of various robots without visual contact with controls.

As a result of the research**,** new controls were created and patented. They became known as "poly-joysticks" (patent of Russian Federation No. 2497177) and allow controlling engineering facilities having up to 20 degrees of freedom which exceeds the similar parameters of known controls by factor of 3 to 5. Due to combined use of optical mini-sticks, two poly-joysticks and a video mask, a new general-purpose generation human-machine interface was created. It allows controlling various robots and vehicles, from tractor to aircraft.

The discussion of the obtained results was carried out by comparing them with parameters of control panels of different robotics systems. The analysis of the comparison results has shown that the controls based on poly-joysticks and digital optical mini-sticks on the basis of light emitting diodes have the best indices in terms of implemented among known control devices, in terms of ratio of functionality to weight and volume of the devices. New interfaces have already been applied for developing multi-agent robotic system control system for fire forest extinguishing.

Keywords: optical mini-stick, LED, photo diode, optical system, poly-joystick, control system, unified human-machine interface

1. INTRODUCTION

Nowadays complex robotics is being developed for fire extinguishing, emergency and rescue activities, carrying out dangerous operations in mining industry, etc. The robotic systems are increasingly complex and multi-purpose. The existing control panels created using traditional joysticks and buttons are increasingly large and expensive, but their functionality is still insufficient and they are inconvenient. Therefore, the developer companies often have to copy the whole cab of a vehicle to be robotized. For instance, this is the way they followed in Komatzu and BELAZ companies for controlling robotic dump trucks [1, 2]. Such solutions, in which the cost of control facilities is comparable with the cost of robots, decrease economic efficiency of robotics. It is possible to solve this problem by developing cheap and ergonomic human-machine interfaces on the basis of new multi-purpose controls. Such controls were invented in Research, Develop-

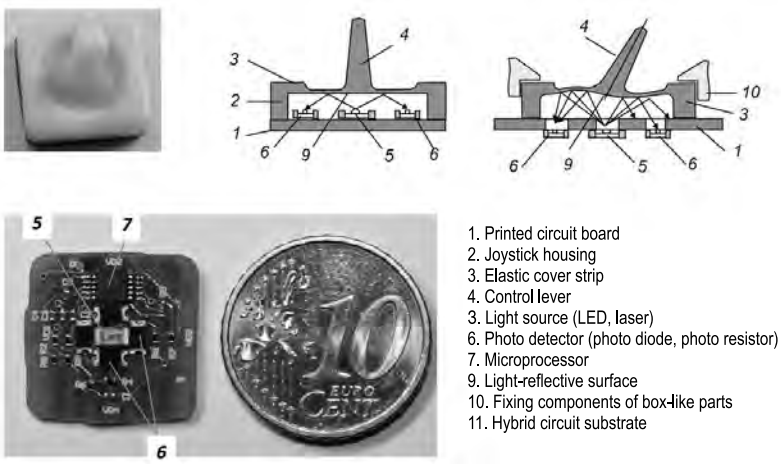

Fig. 1. Optical mini-stick DMR4I–Ch developed by Research, Development and Manufacturing enterprise "TENSOSENSOR"

ment and Manufacturing enterprise "TENSOSENSOR" and patented in Russia (patents of the Russian Federation Nos. 2596576 and 2594992).

The scientific task of this paper is the research into possibility of applying digital optical mini-sticks on the basis of LEDs as the basic controls of unified human-machine interfaces.

2. PROPOSED METHODOLOGY AND DISCUSSION

The optical system of a digital mini-stick is shown in Fig. 1. The mini-stick contains LEDs and a photo diode above which an elastic deformation element is located. It is made of an elastic polymer with a control lever. It is an optical modulator changing the intensity of the reflected light flux impinging on the photo diode as the handle is tilted. The mini-stick processor calculates the mini-stick angle and inclination direction and transmits the information to the control system.

The use of an optical circuit and a microprocessor allowed creating a digital optical mini-stick DMR4I–Ch [3]. The mini-stick has high output signal linearity (Fig. 2), convenient digital signal output, compact size (16 x 19 x 13.5 mm), about 2.3 g weight, long service life – about 1.5 million presses. The control lever deviation range is 5 mm in any direction. The optical mini-stick characteristics research results are provided on articles [4–8].

The most important advantage of the created mini-stick is its polymorphy, i.e. its applicability as a multi-purpose device capable of performing several functions simultaneously, for example, as a button, toggle switch, multi-position switch, regulator and a joystick. The functionality can be changed immediately during operation that is on-line. The digital mini-stick is "intelligent", it is capable of distinguishing long-time and short-time pushes, single and double pushes, circular rotational movements, which is beyond the functionality of other types of switches.

During the research original ergonomic methods of purposeful combination of two mini-sticks on two robot actuating levers were used so that to provide convenience of tactile control of various robots without visual contact with controls. As a result of multiple screening of combinations of mini-stick positions and ergonomic tests of different control lever designs involving experienced experts the unique controls were created and patented. They were called "poly-joysticks" (patent of the Russian Federation No. 2497177).

Fig. 3 illustrates a poly-joystick with optimum layout of mini-sticks. Two mini-sticks (M1 and M2) are located under the thumb. Mini-stick M1 is very convenient for controlling the vehicle direction movement (turns, U-turns). Mini-stick M2 is convenient to be used for controlling the rotation of the direction video camera along the direction. It

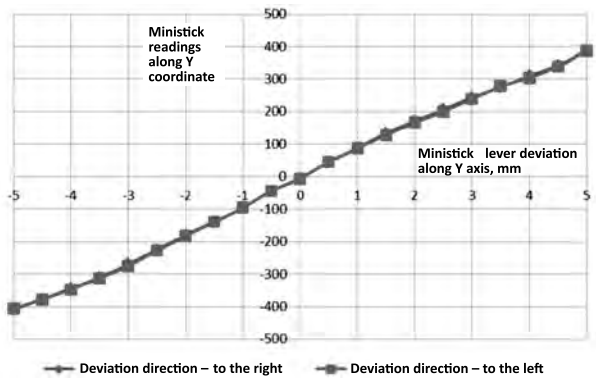

Fig. 2. Mini-stick output signal as a function of control lever deviation value

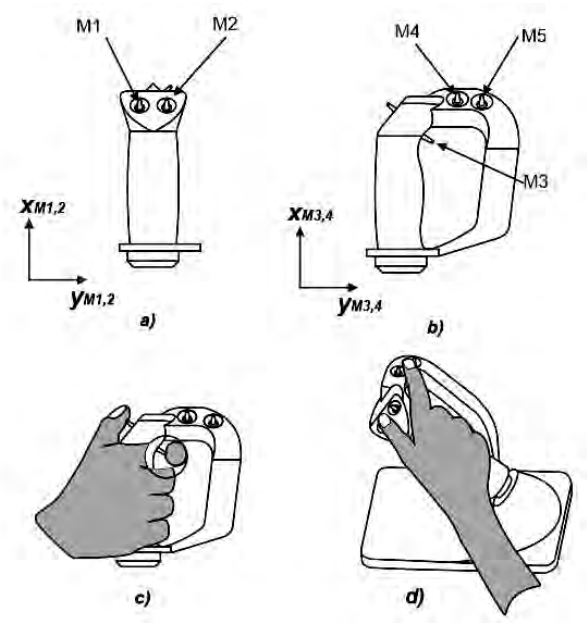

Fig. 3. The final version of mini-stick combination in the design of a poly-joystick with 5 mini-sticks (the mini-sticks are designated as M1, M2, M3, M4 и M5)

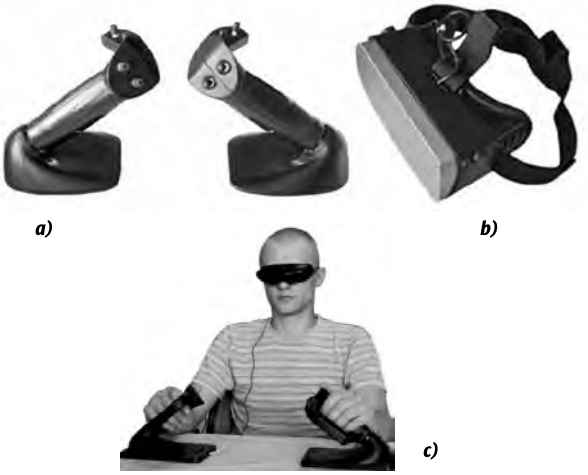

Fig. 4. – Unified human-machine interface
a) – poly-joysticks PD-002, b) video-mask, c) operator with a new unified human-machine interface

suits for air drones and ground robots. The third mini-stick M3 is located just like a pistol trigger, it is very convenient for emergency situations – abrupt deceleration, taking photos, shutter release, etc. The pointer finger reaction is very fast. Two more mini-sticks are located in the upper part of the poly-joystick (M4 and M5). These mini-sticks can be used for long-term special equipment control operations, effector guidance, switching over of operation modes or navigation.

To increase functionality, it is expedient to use two poly-joysticks with non-symmetrical function distribution simultaneously, i.e. to control one set of functions with the left poly-joystick and to control the other one with the right poly-joystick. In this case it is possible to switch over the functionality symmetry using special control software. For right-handers one functionality order can be set, and for left-handers the mirror order can be used.

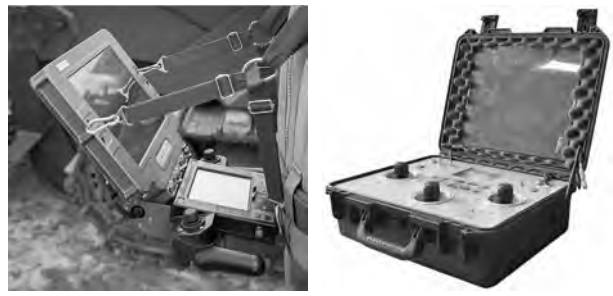

Fig. 5. Specialized panels for robot control

Poly-joysticks PD-002 type were created on the basis of the conducted research. Their specifications are posted on the TENSOSENSOR company web site [7].

3. RESULTS OF THE EXPERIMENTS

The experimental research into functionality of poly-joysticks have shown that they allow controlling both aerospace (shuttles, aircraft, helicopters, drones), and various ground and aquatic facilities – motor vehicles, tractors, excavators, harvesters, reaper threshers, skimming boats, etc. 10 two-coordinate mini-sticks operating in joystick mode allow controlling robots requiring control of 20 degrees of freedom. It is a very high functionality index.

The unified human-machine interface includes two control poly-joysticks, a video-mask and a unit interfacing with the control system. The video cameras image, tactical environment and different control instruments and switches are displayed in the video-mask display. Multi-functional controls – digital optical mini-sticks are located on poly-joysticks. The use of polyjoysticks allows carrying out the reliable visual contact with handling devices.

A demonstration video with examples of various equipment controlling is available on the web site of the company (see http://www.tenzosensor.ru/images/TenzosensorPJ.mp4).

An experimental research has shown that poly-joysticks of the unified human-machine interface ensure high ergonomic standards and con-

Fig. 6. PonsseComfort interface

venience of operation for both right-handers and left-handers.

The use of video-mask of the original design allowed doing without bulky displays sensitive to flare, vibration and jerks.

4. COMPARING PARAMETERS OF DIFFERENT ROBOTIC SYSTEMS' CONTROL PANELS

The HOTAS (hands on throttle-and-stick) concept used by the authors for creation of the new interface is fairly popular. Its development follows the trend of increasing the quantity and nomenclature of operational aircraft controls on the aircraft actuating levers for both left and right hands of the pilot.

However, such an approach to HOTAS concept implementation has serious drawbacks. Essentially, only one fixed-functionality operational control can be located on the grip. Off-the-shelf items and original solutions are used to control robotic systems.

From the off-the-shelf products the mobile platform developers usually select various joysticks, game pads, control panels, etc. The advantages of such products are absence of costs of their development and guaranteed operating life. The drawbacks are the fixed functionality of devices and ergonomic solutions which are not always in line with the developer's wishes.

The original solutions of control facilities in the form of specialized control panels are generally used by major developers, Fig. 5..

The advantages of specialized control panels are expanded functionality. Low ergonomic properties are drawbacks of such systems.

The interface of harvester produced by *Ponsse* – *PonsseComfort* company [8] (Fig 6) can be considered to be a close equivalent of poly-joysticks manufactured by Research Development and Manufacturing enterprise "TENSOSENSOR". It contains joysticks, armrests and a side instrument panel.

Analogical mini-joysticks are located on side surfaces of huge basic joystick levers under operator's thumbs. There are many programmable buttons for execution of different operations in range of thumbs access zone. Despite high functionality, the use of standard component parts demanded a high cost; the interface *PonsseComfort* has significant drawbacks: large overall dimensions and weight, and high price.

Table 1 contains specifications of known robot control systems.

Fig. 7 illustrates the quantity of freedom degrees for joysticks used in control devices shown

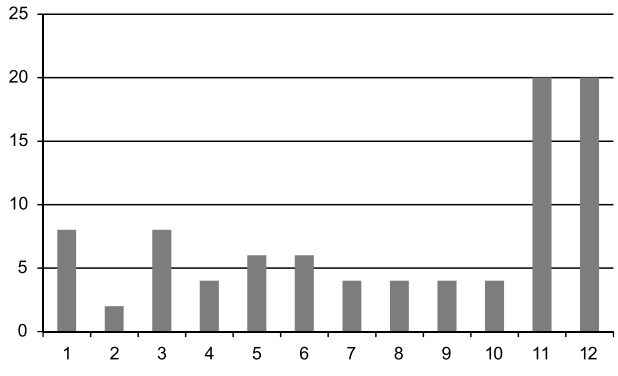

Fig. 7. Quantity of freedom degrees for joysticks (Device numbers correspond to the order in Table 1)

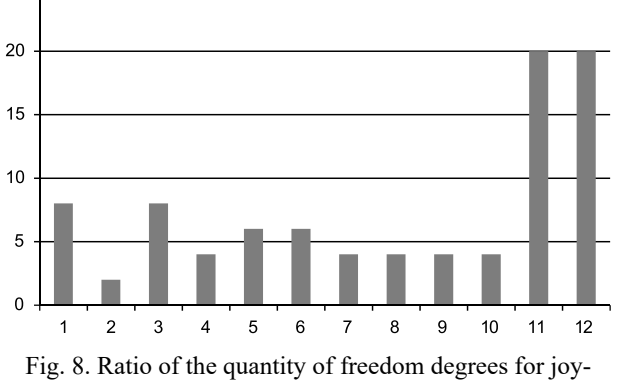

Fig. 8. Ratio of the quantity of freedom degrees for joysticks to the volume of control devices (the device numbers correspond to the order in Table 1)

Table 1. Specifications of Known Robot Control Systems

Item No.	Manufacturer or product name	Quantity of joysticks, pcs	Quantity of switches, pcs	Length/ width/ height, dm	Volume/ Weight, l/kg
1	Platform TALON/SWORDS robot	4	23	4/4/1.5	24/12
2	Robotic board SWAT-Bot	1	5	0.8/0.5/1.2	0.48/0.8
3	Panel HBC Radiomatic Palfinger	4	1	4/2/1.5	12/3
4	Panels of Russian State Scientific Center for Robotics and technical Cybernetics	2	20	4/4/1.5	24/8
5	Control panel for robot “VARAN” – Scientific and Training Center of Bauman Moscow State Technical University	3	22	4/4.5	24/8
6	Control panel for robots “Varyag” – Scientific and Training Centre of Bauman Moscow State Technical University	3	24	4/4/1.5	24/8
7	Control panel for multi-purpose robotic system “Metallist” (Kovrov)	2	24	3.5/3.5/0.7	8.58/4
8	Control panel for “Tigr” vehicle, OJSC Elins	2	12	4/2/2.5	5/12
9	Control panel for robot manufactured by OJSC Spetstekhnika pozharotusheniya	2	25	4/4/1.5	24/12
10	Control panel for robot “Tral-Patrul”:	2	6	3.5/1.5/1.5	7.88/3
11	Poly-joysticks manufactured by Research, Development and Manufacturing enterprise “TENSOSENSOR”	**10**	-	**0.2/1.8/1.2**	0.86/1.2
12	Hand-wheels based on poly-joysticks	**10**	-	**3/1.8/1.8**	9.72/2.5

in Table 1. Fig. 8 illustrates the ratio of quantity of freedom degrees for joysticks to the volume of the devices shown in Table 1.

The discussion of the obtained results was carried out by comparing them with parameters of control panels of different robotics systems. The analysis of the comparison results has shown that the controls based on poly-joysticks and digital optical mini-sticks on the basis of light emitting diodes have the best indices in terms of implemented among researched robot control devices, in terms of ratio of functionality to weight and volume of the devices.

5. CONCLUSIONS AND RECOMMENDATION

The results of the conducted research allow concluding that the use of LED-based digital optical mini-sticks as multi-functional controls enables creating up-to-date ergonomic human-machine interfaces with expanded functionality.

The comparison of the up-to-date robot control systems and advanced developments in the field of human-machine interfaces shows expediency of use of unified human-machine interfaces developed by Research, Development and Manufacturing enterprise “TENSOSENSOR” on the basis of digital optical mini-sticks in control systems of robotic systems of various applications. On the basis of the conducted research it was decided to use the developed interface in the control system of the multi-agent robotic system for forest fire extinguishing [9].

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