

CONTROL DEVICE FOR CYBER-PHYSICAL SYSTEMS

This invention relates to the field of computer technology and automated control systems, primarily in the field of mobile robot management and unmanned aircraft that provide motion control based on the processed data received from the devices connected to the unit, such as cameras, microphones, sensors measuring various physical parameters of the unit itself and its environment.

The closest analogue of this invention is the device for controlling movement of a robot described in patent US 2006279246 A1, published on Dec. 14, 2006. The device described in US 2006279246 A1 includes a central processing unit (hereinafter referred to as a 'CPU'), which is connected to a random access memory and processor's controller; the processor's controller is connected to servo motor controller, a communication control device, a peripherals control device, and a serial access memory unit. The known device can obviously be used to control almost any cyber-physical systems comprising a number of individual devices, or to control the single cyber-physical object. This single node of the controller which determines the control algorithms is the CPU and all other units included in the controller provide data processing and interaction with peripheral devices via predetermined (unchanged) protocols. The obvious drawback of this device is its lack of speed and limited quality of objects control in conditions requiring the analysis of large volumes of data received by the sensors, combined with the high speed and dynamics of mobile objects, such as unmanned aircraft and mobile robots moving in different environments and other system integrated cyber-physical objects.

The proposed invention will eliminate these disadvantages and provide higher reliability, performance and robust object control in cyber-physical systems using high computational complexity algorithms including adaptive adjustment algorithms, through CPU resources release and distribution of control functions among multiple computing subsystems. The technical result described above is achieved by using the proposed control device in cyber-physical systems or the management of individual cyber-physical systems such as mobile robots and / or unmanned aircraft. The proposed device includes a central processor unit, which is connected to a storage device; a triple-axis accelerometer and/or triple-axis gyroscope; an interface for external devices and a user interface. Unlike known solutions, the device contains the peripheral processing unit connected to

the CPU and an interface for peripheral devices control connected to the peripheral processing unit, wherein the user interface is connected to the CPU and to the peripheral processor unit. The interface for peripheral devices control includes a number of the following (but is not limited to): an electric motors control unit; a servo motors control unit, an angular velocity control unit (encoders); an electromagnetic sensors control unit; a thermodynamic sensors control unit; a location sensors control unit. The external devices interface includes those selected from the list (but not limited to): means of connectivity and control of peripheral devices; means of connectivity and control of sensors; means of controllers connectivity; means of PC connectivity; means of video signal receiving; means of audio signal receiving. The user interface includes the means selected from the list (but not limited to): a display; light and/or sound indication equipment; WiFi/Bluetooth. The peripheral processing unit comprises a means of control of electrical energy consumption by the controlled objects.

The proposed device includes:

- 1) a CPU with a memory unit (RAM, flash memory, SD card), which is connected (that is, electrically connected) to the following:
- 2) the peripheral processing unit
- 3) a triple-axis accelerometer
- 4) a triple-axis gyro
- 5) an external device interface and
- 6) a user interface.

The peripheral processing unit, 2) above, is connected to:

- 7) the interface for the management of the equipment of the controlled object.

The user interface, 6) is connected to 1) the CPU and 2) the peripheral processing unit. The accelerometer, 3) and triple-axis gyro, 4), make it possible for the processing unit, 1) to determine the position and trajectory of the device's motion in space without connecting external devices. DC sources and batteries may be used for the electrical supply of the device.

The means of external device interface 5) may include different hardware which provides connectivity and control of peripheral devices (timers, pulse-width modulation sig-

nal ports, signal ports, extension slots, USB ports, etc.); connectivity and control of sensors (encoders, etc.); connectivity of external controllers; PC or other programmable terminals connectivity (UART port, etc.); receiving the video and audio signal from external devices.

User interface, 6) may include a display; light and/or sound indication equipment; WiFi/Bluetooth, keyboard, etc. The specific choice of equipment of the external devices interface, 5) and user devices will be determined by features of purpose and design of a particular cyber-physical object. The operator (user) can remotely control the device from a computer or mobile device interface via BlueTooth as well as via an Ethernet network using a WiFi wireless interface. It is possible to control the device locally by keys and a touch screen, because the keys are user-programmable.

The dedicated peripheral processing unit, 2) provides control of the various means of control interface, 7), i.e. it allows both the release of the CPU, 1), resources to perform resource-intensive algorithms to analyze the whole volume of the data aggregated by the controller, as well as providing a high dynamic of operational control of objects based on the instantaneous measurements by sensors of values of physical quantities. In addition, the peripheral processing unit includes the means for monitoring the consumption of electric power by the controlled objects and protection of the controlled objects from exceeding the allowable electric current levels. The distribution of control functions between the two processing units will enable the use of sufficiently complex control algorithms to control cyber-physical objects without degrading the response time to external events and changes in environmental parameters. The tools of the interface of the controlled object equipment control, 7) may include various hardware / individual blocks and / or memory blocks that provides control of electric motors and / or actuators (power drivers of electric motors, current limiters); controls of angular velocity sensors (encoders); controls of electromagnetic sensor values (direction and intensity of the electromagnetic field, etc.); controls of sensors of the thermodynamic quantities (temperature, pressure, etc.); controls of location sensors (the rotation angle and the like). A specific set of control interface 7) tools will be determined by the peculiarities of purpose and design of an unmanned aircraft, robot, or any other cyber-physical object.

The operation of the proposed device for the control of cyber-physical systems and objects can be explained through the description of the individual subsystems forming the device. These subsystems represent areas of 1), the CPU and 2) the peripheral processing unit memory and various purpose peripheral devices.

The proposed device for the control of cyber-physical systems / management of individual cyber-physical objects includes the following subsystems: a central general control subsystem; a video capture and processing subsystem (computer vision subsystem); an audio capture and processing subsystem as well as audio output; a subsystem for capturing and processing data from analogue and digital sensors, a local wireless subsystem; a local management subsystem; a subsystem of navigation devices control, a long-distance wireless communications and radar subsystem; a data storage subsystem; a subsystem for motors and servos control; an autonomous power subsystem.

The central general management subsystem provides centralized control of all the subsystems of the controller and performs intellectual algorithms, processing data captured from the input subsystems as well as performing adaptive control adjustment based on this analysis. The central subsystem provides stabilization in space for mobile robots and unmanned aircraft, as well as for moving objects that do not have static steadiness (classical helicopters with a single main rotor, walking robots, two-wheeled self-propelled platforms (segways), etc.

The video capture and processing subsystem (computer vision subsystem) provides device orientation in its surrounding space, in conjunction with information obtained from other input channels and data analysis or independently. The object is reliably identified by given visual patterns and is identified by its relative position in its surrounding space through the use of two parallel video stream inputs and algorithms of their parallel processing. Filtering and video compression is performed for further transmission over the wireless channel and/or saving in the internal storage.

The subsystem for capture, processing and the subsequent output of audio data provides the reliable identification of objects based on a set of sound patterns using two parallel channels of audio input, in conjunction with information obtained from other input channels and data analysis or independently. It also provides sound output in ac-

cordance with a given program, including the exchange of information with the identified object.

The subsystem for capturing and processing data from analogue and digital sensors collects and analyzes navigation and telemetry data from the built-in 3-axis accelerometer, a gyroscope, external navigation systems and sensors.

The local wireless communications subsystem provides user interaction within range of the wireless WiFi and/or BlueTooth access points, including via the Internet. The local control subsystem provides interaction with the user, including access networks outside the local wireless networks, using the buttons on the front panel and a touch screen.

The subsystem of navigation devices control, distance wireless communication and radar subsystems provides location orientation of the device, in conjunction with information obtained from other input channels and data analysis or independently. It also enables remote interaction with the user via external cellular and long-distance wireless communication devices (if available as part of the carrier device).

The data storage and registration subsystem provides storage for the device control program, including the executable binary code of all on-board subsystems. At the same time, the given program provides capture of audiovisual and telemetric data obtained in the course of autonomous work to a removable non-volatile memory unit.

The motor and servo control subsystem provides autonomous control of electric servos and motors based on commands and control parameters produced by the central general management subsystem. In addition, the servo and motor control subsystem performs step-by-step delivery of the unit or the payload to the target object, overcoming some parts of the route as the unmanned aircraft and other parts of the route as a mobile robot (wheeled, tracked or walking). The benefits of a step-by-step delivery are in weakening restrictions on working time in autonomous mode, as well as an increase in the possibility of delivery of the machine to the remote hard-to-reach objects.

The autonomous electric power subsystem provides power to all of the subsystems of the controller from a low-voltage DC battery, the parameters of which can vary depending on the design and technical requirements to the controlled device.

These subsystems and the hardware described above working together are used to input user programs that control the device via the connected computer or locally, including in-the-field conditions without any input devices and communication channels. An autonomous execution of the carrier device relocation task to the given destination point may be performed together with its subsequent return. A search of still or moving objects by a set of features is performed in the given area within a given range from a still or moving object, providing a safe landing of an unmanned aircraft based on its technical characteristics, and the control of its landing. The reliable identification of a given object is performed based on feature sets determined by a video channel, an audio channel, additional channels of measurements provided by sensors and other external devices. Physical or informational interaction with a given object is performed after its identification, along with the live transfer of the audiovisual and telemetric information via the radio and its registration in a built-in non-volatile memory unit.

The above description defines the control device for cyber-physical systems/control of individual cyber-physical objects, which provides reliable control and high-speed performance, as well as allowing the use of algorithms of high computational complexity.

CLAIMS

1. The unit is for the control of objects with the distribution of control functions and adaptive adjustment between a central processing unit (CPU) and peripheral processing units in cyber-physical systems, characterized by inclusion of a CPU connected to a memory unit, 3-axis accelerometer and / or 3-axis gyroscope, external devices interfaces, the user interface and peripheral processing units, and the selected peripheral processing units that are able to manage the control facilities, including the facilities controlling the energy consumption by the controlled objects and protecting the controlled objects from exceeding the permissible electric current levels, and the peripheral processing units are additionally connected to the user interface and the equipment control interface.

2. The apparatus in claim 1 is characterized by inclusion in the interface for controlling equipment of the types listed below (but is not limited to these):

controls of electric motors;

controls of electric actuators;

controls of speed sensors (encoders);

controls of electromagnetic values sensors;

controls of thermodynamic values sensors;

controls of location sensors.

3. The apparatus in claim 1 is characterized by inclusion in the external device interface of the means listed below, (but is not limited to these):

means of peripherals connectivity and control;

means of sensors connectivity and control;

means of controllers connectivity;

means of PC connectivity;

means of receiving the video signal;

means of receiving an audio signal.

4. The apparatus in claim 1 is characterized by inclusion in the user interface of the means or types listed below, (but is not limited to these):

display;

light and/or sound indication equipment;
means for wireless connections.

5. The apparatus in claim 1 is characterized by inclusion in the peripheral processing units of the means for the control of permissible operation modes of devices and connected equipment of a control object.

6. The apparatus in claim 1 is characterized by connection of the user interface and / or external devices interface to the CPU and peripheral processing units.

7. The apparatus of claim. 1 is characterized by comprising several peripheral processors connected to the CPU and equipment control interface of control objects connected to the peripheral processors.

8. A device in any one of the preceding claims is characterized by its purpose of controlling mobile robots and/or unmanned aircraft.