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A NOVEL VISUAL SISO AND MIMO COMPUTER INTERFACE FOR PROCESS PRODUCTION SYSTEM

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ABSTRACT

Computer based automation systems have found a wide range of applications in manufacturing and processing industries. To interface computer and control system, various standard industrial interfaces were used. Because of its complexity and high cost in some places, a custom model was built by a person having broad knowledge of computer and control system. Later on visual patterns based computer interfacing was introduced. This used less hardware when compared to the standard model. To further reduce its hardware complexity, in this paper, a modified vision based computer interfacing is introduced for single input single output (SISO) systems. This technique is further extended for multiple inputs and multiple output systems (MIMO). The working of the proposed interface modules were tested with the help of computer control based SISO conical liquid tank system and MIMO heat exchanger system.

KEYWORDS: Computer, Closed-Loop Control System, Computer Interface, SISO & MIMO

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Original Article

INTRODUCTION

Control systems found various applications in almost all industries and home appliances. Introduction of automation into control systems had become a revolutionary success in all its applications. Automation is widely implemented in manufacturing industries, processing industries, power supply stations, and construction fields. Its applications extend to electrical grid lines and household applications [1, 2]. This improves efficiency, time consumption and productivity. Automation system usually consists of various processors that perform several process and exchange signals using various interfaces. The industrial standard interfacing module like ADAM-5000 series requires large amount of hardware such as I-V(Current to Voltage) converter, ADC (Analog-to-Digital Converter), microprocessor, DAC (Digital to Analog Converter), V-I(Voltage to Current) converter, and UART protocols (Universal Asynchronous Receiver and Transmitter) to RS-232 protocols conversion for data acquisition and control [3]. A flexible, custom-made microcontroller-based data acquisition device was built in [4]. The custom model mentioned in [4] uses microcontroller with an integrated USB transceiver and ADC. Comparatively custom model requires fewer components than standard interface model. To further reduce the complexity a vision based computer interfacing is developed which replace processor and complex protocols with LED (Light Emitting Diode), inbuilt hardware, image processing software and LDRs (Light Dependent Resistor). Many applications namely automation in shipbuilding, monitoring of industrial flotation and angular measurement have been implemented with vision based computer interfacing [5-8]. A dynamic pattern based visual interfacing for automation using adaptive proportional−integral (PI) controller technique has been developed with low cost [9-11]. In complicated automatic control system such as chemical plant, constantly, more than one independent parameters need to be measured and controlled at the same time [12]. However most of these techniques require conversion circuits like ADC, DAC, I-V and V-I converters. The proposed interfacing technique eliminate all these complexity and utilizes only an intensity property of an LED to communicate physical data through the inbuilt camera of the computer and the control signal is received by LDR to manipulate the process. This technique reduces the design complexity of interfacing module resulting in simplicity and low cost for both SISO and MIMO computer based control system.

SYSTEM MODELS

In this section, proposed system model is structured as follows:

- **Visual SISO Interface**: A computer interfacing system for single input and single output scenario.
- **Visual MIMO Interface**: An extended version of computer interfacing for multiple inputs multiple output scenarios.

In order to design these interface an optical transceiver circuit was built with the help of LED, LDR and built in computer components such as camera and monitor.

Visual SISO Interface

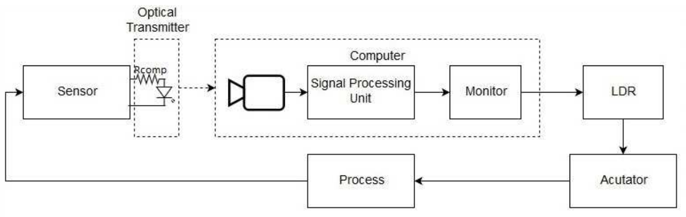

Figure 1: Block Diagram Representation of Computer Interfacing for SISO System

Visual SISO interface for SISO system is shown in Figure ure1 to measure the process system parameters. A Direct Current bias Voltage (VDC) is supplied to a sensor. It reads the system parameter and converts its reading in the form of a Direct Current (DC) varying from 4-20 mA. This DC is supplied to the LED through a resistor as shown in Figure 2. The sensor's internal resistance, LED internal resistance, wire resistance and the resistance in series with LED in the transmitter circuit are considered to maintain the DCloop of the circuit in the range of 4-20 mA.

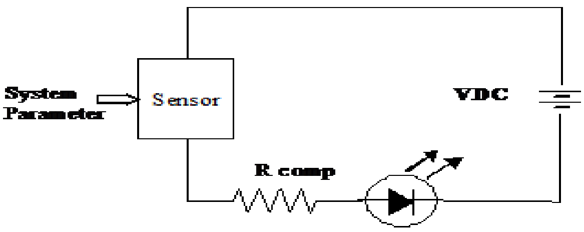

Figure 2: Circuit for Transmitter

LED converts DC into light intensity. The intensity variation is captured by an inbuilt camera of the computer. Therefore, this LED and camera setup is basically referred as an optical transceiver circuit. The output of the transceiver circuit is given to the adaptive PI controller. It generates a control signal. Then this generated control signal is converted into light intensity value with the help of LED projected on the monitor. Here LED is built with help of GUI (Graphical User Interface).

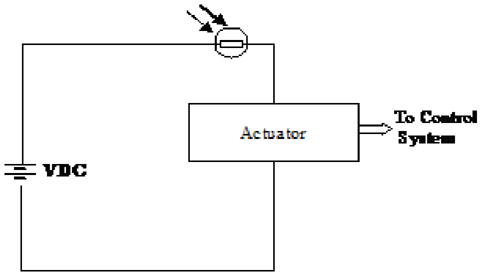

Figure 3: Circuits for Receiver

An LDR connected in series between VDC and actuator is placed exactly on the position of LED to detect the light signal as shown in Figure 3. The variable resistance of the LDR and the internal resistance of the actuator are considered to maintain the DC loop in the range of 4-20mA. LDR resistance dynamically varies with respect to the light intensity received from LED. As the result of this process DC supplied to the actuator varies from 4-20 mA. Then the Actuator automatically controls the control system based on variation in DC value.

Software Description

The color images obtained by the camera are converted into grayscale images and LED is selected as the region of interest (ROI). The intensity of the LED is calculated using average algorithm and the values are noted. The noted values are fed to the adaptive PI controller to generate the control signal. This control signal is fed to actuator to manipulate the process for the desired response. This control signal is converted into intensity value and is displayed on the monitor with the help of GUI.

Visual MIMO Interface

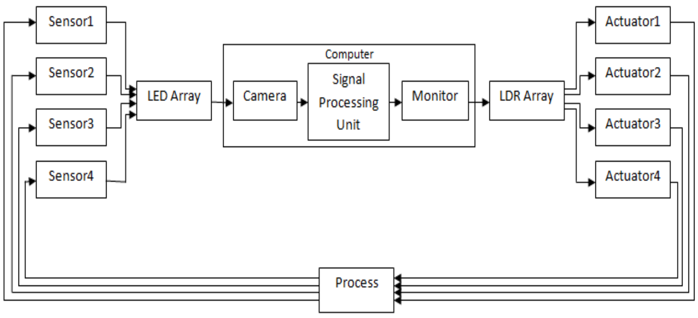

Figure 4: Block Diagram Representation of Computer Interfacing for MIMO System

An extension of the proposed SISO interface is shown in Figure 4. In this system, multiple parameters of the system are measured and controlled at the same time. Four different sensors are used to measure 4 different parameters such as pressure, temperature, flow and level of the process system. All the sensors are connected in parallel with each other to a power supply as shown in Figure.5 such that current in each loop of the circuit is maintained in the range of 4-20 mA based on the sensor output. These variations are converted into light intensity by 4 LEDs connected in series with 4 different sensors. On the other side, a single inbuilt camera to the computer captures the light intensities and passes these 4 independent light intensity values to the adaptive PI controller. It generates 4 control signals and these control signals are again converted into light intensity with help of 4 different LEDs built on the monitor using GUI.

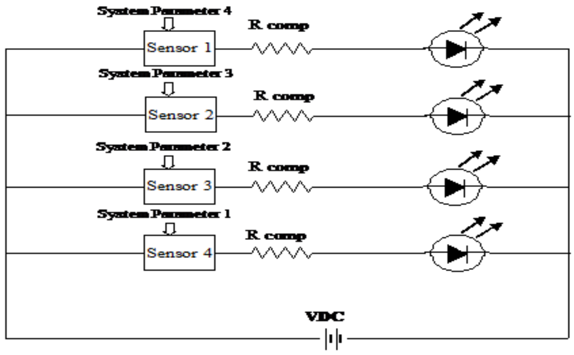

Figure 5: Transmitter Circuit for MIMO

On the other side, four independent LDRs connected in series with four actuators and parallel with power supply as shown in Figure 6 are placed exactly on the position of LEDs on the display such that each LDR receive light from only one LED, LDR's resistance dynamically varies with respect to the light intensity received from LEDs. As the result of this process DC supplied to the all four actuators varies from 4-20 mA. Then the Actuators automatically control 4 independent control systems in parallel.

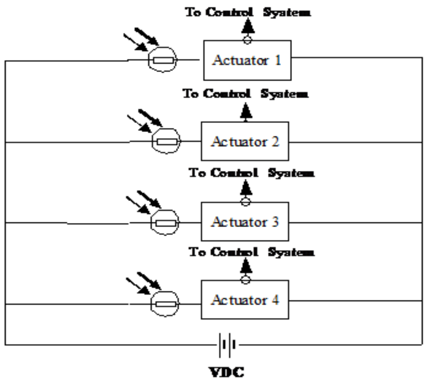

Figure 6: Receiver Circuit for MIMO

Software Description

In this system, Unlike SISO system, color image obtained by the camera contains four LEDs. These LEDs are spatially separated from each other. So, the obtained image is segmented into four parts such that each part contains only one LED. Each LED is set as ROI and intensity of each LED is calculated. These four different intensity values are given to the adaptive PI controller to generate four different control signals. These control signals are fed into four different actuators to manipulate parameters of the control system. These control signals are converted into intensity values and are displayed with four LEDs on the monitor with the help of GUI.

RESULTS AND DISCUSSIONS

The proposed SISO interface technique is implemented and tested for a level control of a conical tank system as shown in Figure 7. The level of the tank is measured using a Differential Pressure Transmitter (DPT) and is acquired by the computer using the proposed Analog interface (AI) technique. The error between the desired and the actual level is calculated and used to generate the control action by an adaptive PI controller [1]. Then the control action is translated into the corresponding intensity with the help of GUI shown in Figure 9. The proposed Analog Output (AO) interface is used to control the valve position which in turn regulates the inflow to the conical tank. Thus, the desired level is achieved.

Further, the proposed vision based MIMO interface techniques is implemented and tested with the MIMO Heat exchange system as shown in Figure 8. Four Resistance Temperature Detector (RTD) sensors are interfaced with the computer which can give information about the heat exchange process. Using this information, Adaptive PI controller generates corresponding control variables in terms of intensity using GUI shown in Figure 10 such that, hot and cold water inflow has been regulated to achieve the desired temperature in the cold water. Additionally, the temperature of the hot water resent into the reservoir is also controlled.

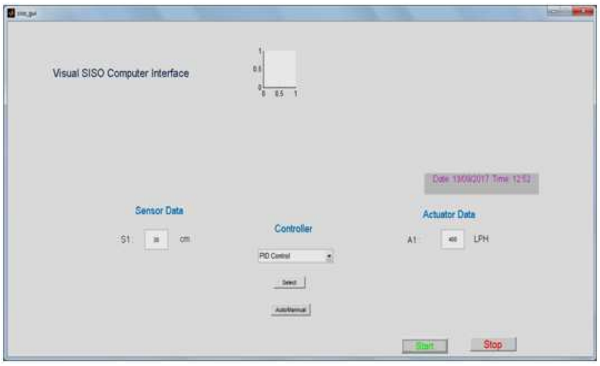

Figure 7: GUI for Computer SISO Interface

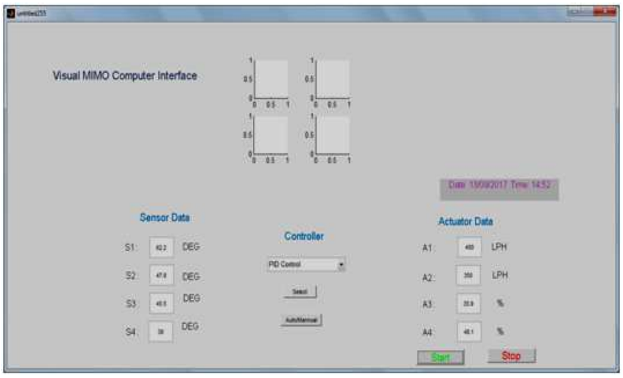

Figure 8: GUI for Computer MIMO Interface

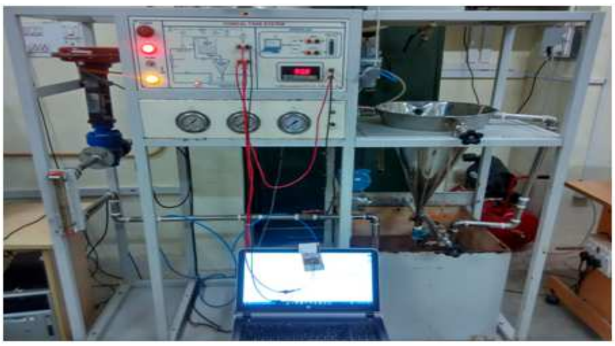

Figure 9: Real Time Implementation and Testing of Computer SISO Interface for Conical Tank System

Figure 10: Real Time Implementation and Testing of Computer MIMO Interface for Heat Exchanger System

CONCLUSIONS

We observed that the proposed SISO interfacing model uses very less hardware components like LED, inbuilt camera, monitor and LDR by eliminating I-V converter, ADC, processor, DAC and V-I converter used in most of the standard and custom based interfacing modules. It also eliminated the complex protocols used for data acquisition and control. When compared with existing vision based model, our proposed vision based model does not require I-V converter, ADC, DAC and V-I converter and Hence, with all these comparisons, we conclude our proposed interface module as less complex and low cost. Further, the proposed interfacing model was tested with MIMO system where the speed and efficiency of the control system was considered to be important.

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