Wireless control system for two-axis linear oscillating motion applying CBR technology

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Abstract. The paper presents the aspects of elaborating a movement control system. The system is to implement determination of movement characteristics of the object controlled, which performs an oscillating linear motion in a two-axis direction. The system has an electronic-optical principle of action: light receivers are attached to a controlled object, and a laser light emitter is attached to a static construction. While the object performs movement along the construction, the light emitter signal is registered by light receivers, based on which determination of the object position and characteristic of its movement are performed. An algorithm of system implementation is elaborated. Signal processing is performed on the basis of the case-based reasoning method. The system is to be used in machine-building industry in controlling relative displacement of the dynamic object or its assembly.

1. Introduction
A relevant task in machine-building industry is controlling relative displacement of a dynamic object or its assembly. A three-dimensional movement control system is known [1]. It consists of a multi-point light emitter and a light receiver matrix. A three-dimensional position of the studied object is identified by a combination of responded light receivers. Such method allows controlling object displacement in time.

For a machine, which assembly performs a linear oscillating motion, the system described is difficult in construction and functioning. The issue is to elaborate a system, which controls linear oscillating motion of the studied object, based on the system described.

A new principle of structuring a movement control system is presented in the paper. The system is to perform two-axis movement control applying the electronic-optical method.

A schematic view of the system is given in figure 1 (plan view). Detail D is moving in the direction of an arrow along construction C. Light receivers VD₁, VD₂ and VD₃ are attached to the detail. Laser emitter LE is attached to the construction. Light receivers and the laser emitter are attached at an equal height. Thus, the light receivers condition (illuminated – on, or not illuminated – off) determines the location of the detail, and further processing allows determining movement characteristics of the detail.

The principle of the system action includes the following. While the object (assembly) is moving along the x- (translatory movement) and y-axis (perpendicular diversion from the set direction), the light receivers, attached to it, respond if illuminated by the laser emitter. At this point, the advantage of the elaborated system in comparison with previously described one is a lower number of light emitters and light receivers. This is a result of changing locations of light emitters (shift from the...
measuring device hull to the surface of the studied object) and light receivers (shift from the studied object to the measuring device hull).

2. Methods

A group of light receivers is presented in figure 2. The group includes a number of light receivers on the \( x \)-axis (horizontal row) and one light receiver on the \( y \)-axis (vertical rows). Response time of neighboring light receivers \( VD_i \), \( VD_{i+1} \), etc. is defined by relative movement velocity of the detail and the sensibility value and speed of response of light receivers.

According to figure 2, the movement velocity of the detail is defined as:

\[
V_{\text{mov}} = \frac{h}{t_{\text{act} i+1} - t_{\text{act} i}},
\]

where \( h \) is a distance value between neighboring light receivers, \( t_{\text{act} i} \) and \( t_{\text{act} i+1} \) is response time of \( VD_i \) and \( VD_{i+1} \) light receivers respectively.

The wireless interface allow devices to eliminate interface cables, which is significant for small-size peripherals, which size and weight is comparable to wireline (cable) [2-4]. Thus, the system elaborated uses wireless data transmission. Based on the data analysis of modern wireless technologies, which use infrared and radio signals, it was considered to use Wi-Fi technology (for instance, WiMAX) for data transmission.

Nowadays Wi-Fi technology is widely implemented in distant or hazardous production processes. It is especially relevant in situations when operational staff attendance is connected to high risks or problematic: in telemetry tasks in oil and gas industries, control tasks of operational staff and vehicles in mining industry, tasks of identifying staff location in emergency situations, control tasks of construction components displacement in complicated machine-building industry.

A limited number of suppliers offer Wi-Fi technologies support for industrial use. Thus, Siemens Automation & Driver offers Wi-Fi-solutions for SIMATIC controllers in accordance to IEEE 802.11g standard in idle ISM-band 2.4 GHz, which provides with data transmission speed up to 54 Mbits/sec. The technologies are applied in controlling dynamical objects and warehousing logistics and in
situations when there is no possibility to use epy wire-connected Ethernet network. Wi-Fi technology is characterized by high resistance to interference, which allows using it in industries with many metal constructions. For its part, Wi-Fi devices do not interfere narrowband signals.

3. Results and discussion

Considering the foregoing, the system has a structure presented in figure 3.

![Diagram of system elaborated structure](image)

**Figure 3. Diagram of system elaborated structure**

The movement control system is based on a microprocessor (MP) as a base element of signal processing and control. It includes the following components:

- optical signal emitter block (EB), which contains a laser emitter;
- light receiver response noting block (NB), which contains active light receivers with a set response level;
- previous processing block (PPB), which contains signal value transforming devices and parallel to serial signal flow transforming devices;
- backing storage block (BSB), which contains the program of system performance according to the algorithm set, a list of reserved constants and case base [5-7];
- wireless communication block (WCB), performing data transmission using Wi-Fi technology;
- data transfer and data receiving blocks (DTB and DRB), which perform coding and decoding data for transmission purposes.

The system implementation algorithm is presented in figure 4. During the initialization stage, the laser emitter is turned on and light receivers values are reset.

After that, light emitters scanning is performed. Responding light receivers (illuminated by the laser emitter) are identified, after which signals of these light receivers are boosted and transformed to format demanded for wireless transmission.
After data are received by DRB, it flows to MP, where it is processed. In accordance to the case base (CB), movement characteristics are defined: current location of the object, displacement in the perpendicular direction, movement velocity, etc. After that the procedures described are repeated.

It is noteworthy that at the last stage of the algorithm, case-based solution forming is implemented. The method [8-14] uses solution of the previously known task, but with adjustment to the current situation if demanded. Meanwhile, a parametric form of the solution is given:

\[ \text{CASE} \left(x_1, x_2, \ldots, x_n, R \right), \]

where \( x_1, x_2, \ldots, x_n \) are situation parameters considering \( x_i \in X_i, \ldots, x_n \in X_n \). \( X_1, \ldots, X_n \) are acceptable regions of respective parameters; \( R \) is recommendation, result description, extra information.

It is offered to use a modified CBR-cycle in conformity to the method of the nearest neighbor [12]. Defining similarity, degree \( S(\mathcal{C}, \mathcal{T}) \) in this way, according to Hamming, is given:

\[ S(\mathcal{C}, \mathcal{T}) = \frac{n_{ct}}{n}, \]

where \( n_{ct} \) is a number of similar traits for precedent \( \mathcal{C} \) and situation \( \mathcal{T} \).

Thus, a precedent mostly similar to the current situation is identified and saved into CB. Information of movement characteristics of the object is obtained as well.

4. Conclusion

Thus, a new principle of structuring the two-axis movement control system, applying an electronic-projecting method, is given. The system performs movement control for a machine, which assembly performs the linear oscillating motion, according to the algorithm elaborated.

The advantages of the system are a lower number of light emitters and light receivers (in comparison to the previously elaborated system), obtained by changing the principle of the system.
structure and functioning. Usage of Wi-Fi data transmission allows one to eliminate wires in the system elaborated, which is significant for such system, without distortion transmission impairment. A case-based reasoning method is applied to define movement characteristics of the studied object.

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