Justification of parameters of automatic control system of robot feed distribution in cattle barn

S M Bakirov, O V Logachev and S V Shlyupikov

Saratov State Agricultural University n. a. N.I. Vavilov, 60, Sovetskaya St., Saratov, 410060, Russia

E-mail: s.m.bakirov@mail.ru

Abstract. The algorithm of operations of the automatic control system of the robot feed distribution in the cattle barn is proposed. The requirements for the workflow of a technological operation and of a robot are formulated. The main parameters of the control system are highlighted. The main parameters are data on orientation in space and time. An example of the length of time of technological operations in a typical cowshed with the type of feeding through the feed table is described. Orientation parameters in the barn space are set by control points and the distance between them. The main function of trimming the feed is described using the parameters of the distance of the feeder space.

1. Introduction

Modern livestock farming has long been industrialized to which the volume of products, processing technologies for primary and finished products, the level of automation, the level of process control, etc. indicate.

At the same time, in the “man – machine – biological link” system, the most vulnerable and unpredictable is the biological link, presented in the form of an animal or a plant. Therefore, complex automation of agricultural production is difficult to achieve. For example, in cowsheds, sensors are used to monitor animal health. They are attached to the neck of each cow and read the frequency of contractions of the masticatory muscles. With a reduced frequency of contractions, the signal with the cow number is sent directly to the veterinarian, who, upon visual inspection, gives an opinion on the state of the cow. Nevertheless, far from all processes in cowsheds are manually controlled [1].

In typical modern cowsheds, the feeding process is simple (Figure 1). In the technological corridor, which is the feed table, food is distributed on both sides.
When feed is consumed by cows, part of the feed remains in the “unreachable” zone. This is because the animal selects the tastiest part from the total feeding mass, moving aside a portion, about 30-40% of the feed, into an area that cannot be reached later [2].

2. Materials and methods

Various methods are used to distribute and trim the remaining feed [3,4]. The most promising is the use of a robot feed distributor (RFD), since this process does not require the presence of a person. This situation puts forward requirements for the automation of the process [5].

Automatic control system (ACS) of any robot is a complex algorithmic and multifunctional system. From the definition of «robot» [3,5], one can distinguish the main components of ACS: the performance of the main function of the device (robot); orientation in the space of the feed table; decision-making algorithms in specific working conditions; feedback elements, etc.

3. Feed trim process requirements

The determining conditions for the ACS robot are the parameters of the feed table of the barn and the requirements for the functionality of the robot [6]. The basic requirements for the process of trimming feed are as follows:

– trimming and distribution of feed, which is out of the access zone;
– distribution of feed throughout the feed table on both sides (Figure 2);
– determination of the beginning of the feed distribution after completion of the previous cycle after 100 min;
– the average speed of the robot is 5 m/s;
– trimming the feed should not coincide with the time of distribution of the feed (6:00 morning and 20:00 evening distribution can be adjusted depending on the technology of keeping cows);
– the technology of keeping animals should not be disturbed during the process of feed distribution;
– when the feed distribution process is arranged, the construction of buildings and structures must not be disturbed.

The parameters of the feed table are defined (Figure 2).
In order to perform automatic trimming, it is necessary to lay the overall dimensions of the barn’s premises, namely the feed table, in the system, as well as determine the control points for checking the functioning of the robot and its orientation in space. Together with the function of orientation in space, it is necessary to use an autonomous device of orientation in time [7].

4. ACS action algorithm

Furthermore, we consider the ACS of the robot as a general algorithm of actions in one cycle with above-mentioned conditions taken into account:

1 – when you turn on the RFD, the battery level and daily time are determined using a time sensor that has a separate power source and exit time with an accuracy of 1 min;

2 – spatial orientation according to control points 1–2–3–4 (Fig. 2);

3 – comparing the parameters of the space \( l_1, l_2 \) and making a decision about the direction of movement;

4 – location determination based on the width of the feed zone \( l_3 \);

5 – determination of the feeder space in the direction of movement in the sector of the sensor signal (correction \( l_3 + l \)) and departure to the route, taking into account the comparison of the parameter of the width of the feed zone of the cow \( l_3 \) and the feeder space \( l_3 + \Delta l \);

6 – determination of other obstacles and comparison of traffic safety conditions with predetermined regulatory values;

7 – movement execution – distribution of feed on the feed table, along the orientation of control points 1–2–3–4, taking into account the feeder space.

To quantify the parameters of each step of the ACS algorithm, it is necessary to specify the operations. At the first stage, it is necessary to enter data on the time of feed distribution to determine the beginning of the execution of cycles throughout the day up to a minute.

Figure 3 shows the time intervals of the functions of the robot feed distributor for 23 hours and 59 minutes.

The time of feed distribution can be adjusted taking into account the technology of keeping animals which leads to the adjustment of the time of related activities. Depending on the period of turning on the robot, ACS compares the real time of switching on with the embedded cycle of the daily operation mode [8, 9]. If the real time coincides with the distribution of food or the period of eating food, then the robot is in a “sleep” state to save battery power; if it does not match, then a decision is made to move on to the next stage.
Figure 3. Daily cycle from 0 to 23:59 of RFD operation ($t$ – the duration of the allowed execution time of the main trim function; $t_r$ – the duration of return to the nearest checkpoint 1–2–3–4; $t_d$ – feed distribution duration; $t_f$ – the duration of animal feed intake)

Figure 4. ACS of RFD (a simplified block diagram)

At the second stage, the actual battery charge level is compared with the minimum acceptable. In this case, the solution to this comparison has several results:
– when the charge level is below the permissible level, a decision is made on the battery charge;
– returning to the control point in real time in the interval $t_r$;
– performing the next stage of comparison.
Similarly, the work of the algorithm of the other stages is performed.

Figure 4 shows a simplified block diagram of the ACS algorithm of RFD. The RFD algorithm is tuned in a cycle from the moment it is turned on and until it returns to the control point 1. \( R \) and \( L \) denote the right and left sensors for determining the presence of feed, if \( R = 1 \) then the right part of the robot contains feed, if \( R = 0 \) then there is no feed.

5. Conclusion
Thus, according to this structure of the algorithm, the main parameters of the automatic control system for the robot feed distributor are distinguished. In this algorithm, the main parametric data is space-time data. Time is limited by the introduction of ranges of technological operations of feeding, and space – by the boundaries of control points and the distance of action. The remaining parameters: the charge level, the distance of the scattered feed, the signal value of the sensors on the right or left side, are consistent with the basic data of space and time.

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