

Automated system for assessing the structure of a dairy cattle herd

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Abstract. The article describes a model of an information system for assessing and forming the structure of a dairy cattle herd. Based on a brief description of this task, a logical model of a relational database is built using predefined SQL data types. Based on object-oriented modeling, a system behavior model is developed, presented in the form of a UML diagram of use cases and sequence diagrams. The option of using this model in the form of a local information system and the possibility of its integration with existing software systems is considered. The correctness of the model is confirmed by the developed local information system of the aforementioned assessment of the herd structure.

1 Introduction

Currently, much attention is paid to information technology in agricultural production. One of the most important areas in agriculture is animal husbandry, in particular the breeding of dairy cattle.

Now, for use in agricultural enterprises of the livestock sector, there are a number of software tools that solve the main typical tasks of operational accounting, breeding and animal feeding. Such software includes the "Selex" software package [1], developed by the LLC "Plinor", which is primarily focused on breeding work. The program "1C: Breeding in animal husbandry. Cattle" [2] (development of LLC "Matrix").

1C LLC offers a specialized configuration "1C: Enterprise 8. Digital animal husbandry. Operational accounting and production management. Cattle" [3], designed to maintain operational records in almost all major areas of activity related to the breeding of cattle.

There is also a software package "Korall. Animal Feeding and Herd Management Programs" (development of Russian Timiryazev State Agrarian University) [4], designed primarily to optimize animal feeding rations, as well as to accounting in the field of veterinary and herd movement.

However, along with the main areas of activity in animal husbandry, already automated in existing software products, there are a number of tasks that have not been implemented in existing programs.

One of these specific, but important tasks in dairy farming is the assessment of the herd structure, which consists in assigning each animal to one of the productive and technological

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groups (categories) [5]. Unfortunately, neither “Selex” nor other program provides such an assessment.

Assessment and formation of the dairy herd structure is carried out on the basis of the productive and technological indices, which take into account the exterior, productivity, constitutional features. They include the exterior parameters for each animal: height at the withers (hw), chest depth (cd), body length (bl), chest circumference (cc), on the basis of which the following indices are calculated: leg length index (li) and body index (bi) defined by expressions

$$li = \frac{hw - cd}{hw} \times 100 \quad (1)$$

$$bi = \frac{cc}{bl} \times 100 \quad (2)$$

In addition to the exterior parameters, the following indicators of each animal are also used in assessing the structure of the herd: milk yield (my), milk fat percentage (fp), milk protein percentage (pp), on the basis of which the amounts of milk fat (mf) and milk protein (mp) are calculated according to the expressions

$$mf = \frac{my \times fp}{100} \quad (3)$$

$$mp = \frac{my \times pp}{100} \quad (4)$$

The indices also include the weight of each animal (w). The main criterion for assigning each animal to a particular group is the value of the productive and technological index (pti), defined as

$$pti = \frac{my}{w} \times \left(\frac{hw - cd}{bl} \right) + \frac{\left(\frac{my \times fp + my \times pp}{100} \right)}{amf + amp} \quad (5)$$

where amf is the average amount of milk fat, amp is the average amount of milk protein, calculated as

$$amf = \frac{1}{N} \sum_{i=1}^N mf_i \quad (6)$$

$$amp = \frac{1}{N} \sum_{i=1}^N mp_i \quad (7)$$

where i is the animal number and N is the total number of animals in the herd.

Taking into account (1) - (4), formula (5) can be written in a compact form

$$pti = \frac{my}{w} \times \frac{li}{bi} + \frac{mf + mp}{amf + amp} \quad (8)$$

Based on the calculated pti , the group of each animal is determined (Table 1) [6].

Table 1. Criteria for group assignment.

pti	Group
$pti > 5$	Breeding
$4 < pti \leq 5$	First Production
$3,5 < pti \leq 4$	Second Production
$pti \leq 3,5$	Sale Preparation

Thus, today in the field of information technology in animal husbandry there is a need to automate the assessment of the structure of the dairy cattle herd.

2 Methodology and results

The purpose of this work is to develop models of information support for an automated system for assessing and forming the structure of a dairy cattle herd.

To achieve this goal, methods of designing relational databases [6, 7], object-oriented modeling of information systems [8, 9], and a structural approach to software design [10, 11] are used.

Analysis of the subject area showed that the following entities are involved in it: animal, group, measurement, breed, location. For implementation, the relational data model was chosen as the most commonly used at the present time [12]. After normalization to the Boyce-Codd normal form [13], it was shown that entities are characterized by the attributes given in Table. 2

Table 2. Entities and attributes

Name	Comment	Type	Constraints
Animal			
Animal_id	Primary key	Integer	Not null, unique
Animal_name	Animal name	String	Not null, less than 200 chars
Inventory_number	Inventory number	String	Less than 50 chars
Breed_id	Breed (code)	Integer	Foreign key
Group			
Group_id	Primary key	Integer	Not null, unique
Min_pti	Lower bound <i>pti</i> for group	Real number	Not null, non-negative
Max_pti	Upper bound <i>pti</i> for group	Real number	Not null, non-negative
Group_name	Group name	String	Less than 100 chars
Measurement			
Measurement_id	Primary key	Integer	Not null, unique
Measurement_date	Date of measurement	Date	Not null
Hw	Measured height at withers	Real number	Not null, non-negative
Cd	Measured chest depth	Real number	Not null, non-negative
Bl	Measured body length	Real number	Not null, non-negative
Cc	Measured chest circumference	Real number	Not null, non-negative
My	Measured milk yield for the period	Real number	Not null, non-negative
Fp	Measured milk fat percentage for the period	Real number	Not null, non-negative
Pp	Measured milk protein percentage for the period	Real number	Not null, non-negative
Lw	Measured weight of animal	Real number	Not null, non-negative
Animal_id	Animal (code)	Integer	Foreign key
Group_id	Group (code)	Integer	Foreign key
Location_id	Location (code)	Integer	Foreign key
Breed			
Breed_id	Primary key	Integer	Not null, unique
Breed_name	Breed name	String	Not null, less than 200 chars

Location			
Location_id	Primary key	Integer	Not null, unique
Location_name	Location name	String	Not null, less than 200 chars

The logical (relational) data model developed in Oracle SQL Developer Data Modeler [14] using predefined SQL data types is shown in Figure 1.

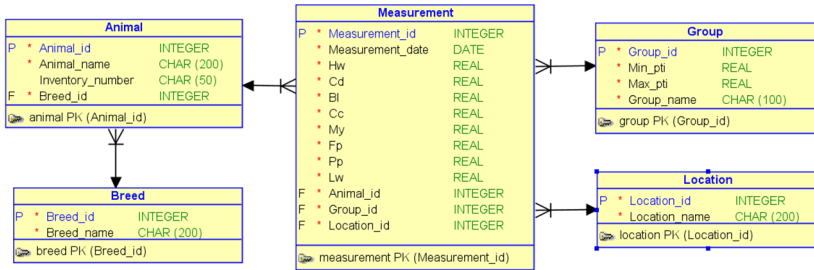


Fig. 1. Logical data model.

From the user's point of view, the system should provide the functionality defined in object-oriented modeling. The results of such modeling in Enterprise Architect (from Sparx Systems) [15] are presented in the UML use case diagram in Figure 2.

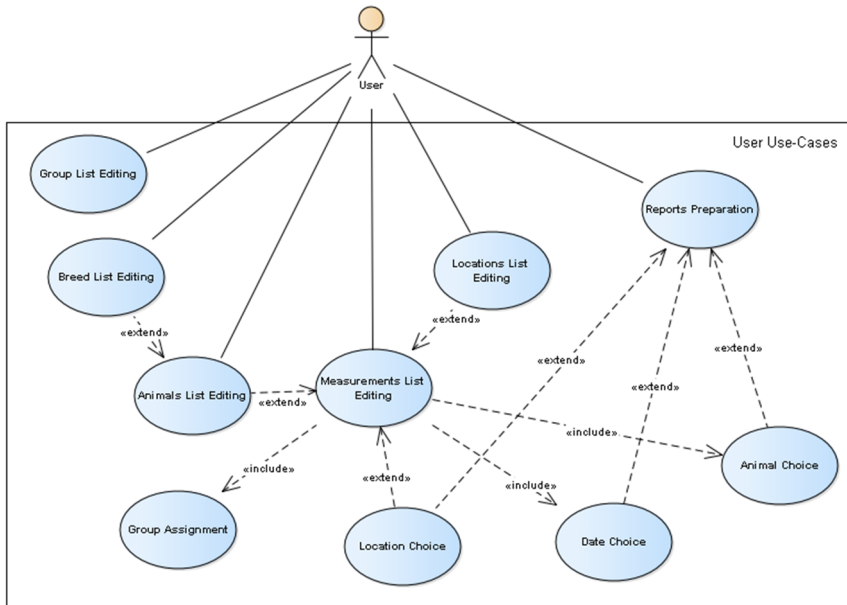


Fig. 2. An enlarged diagram of use cases.

Based on the model above (Figure 2), the functionality of the system can be formulated as follows:

- the system should allow adding, changing, deleting information about groups, breeds, animals, locations, measurement results,
- perform calculations according to (1) - (8) to assign each animal to a specific group and fix this assignment when entering or changing each set of measured animal parameters,
- generate reports on animals assignment to groups for an arbitrary date

- for herd,
- for each location,
- for each animal.

To describe the implementation (scenarios) of these precedents, UML sequence diagrams were used [16]. The scenario of one of the main precedents “Add Measurement Results”, which is included in the “Measurements List Editing” precedent, is shown in Figure 3.

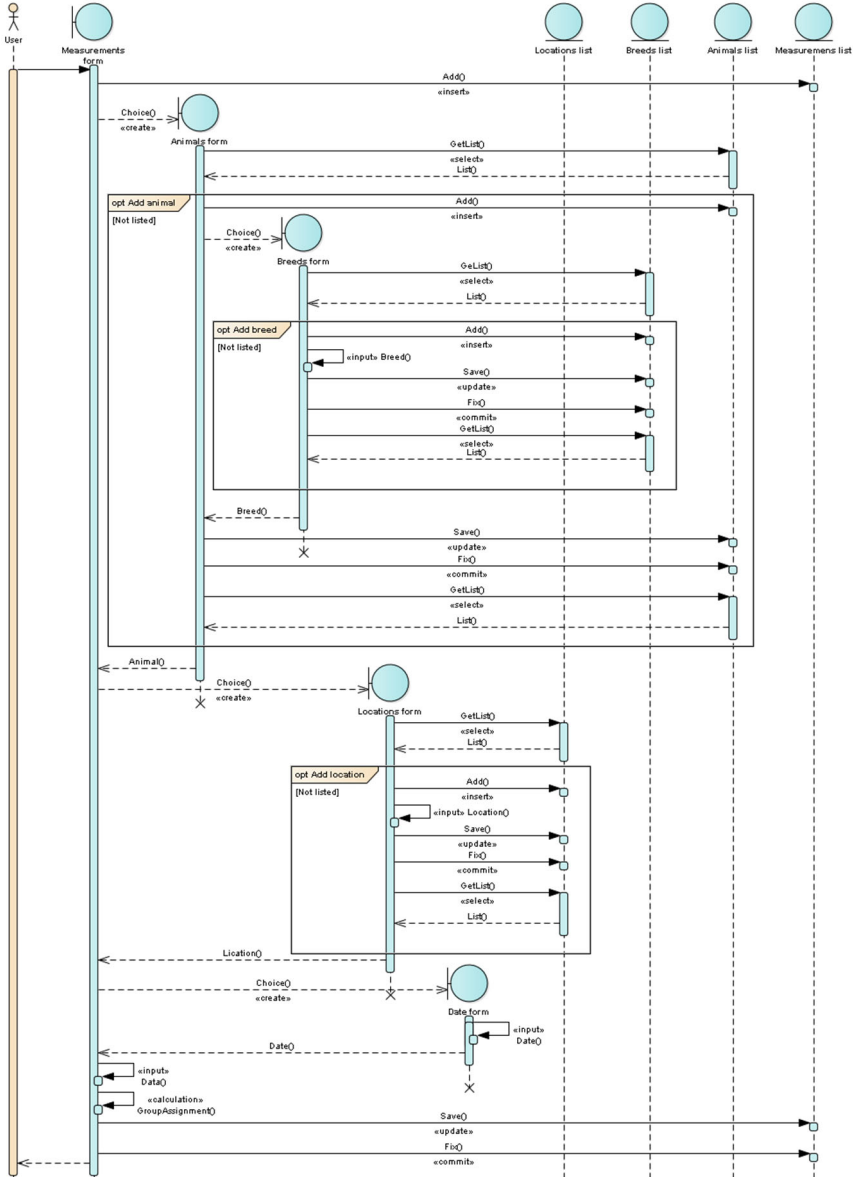


Fig. 3. Sequence diagram of the "Add Measurement Results" use case.

3 Discussion

Agriculture in general, and animal husbandry in particular, is currently an area in which modern information technologies are being intensively introduced, both software and specialized hardware, from microprocessor tools [17] to IoT [18]. Basically, the developers are aimed at automating the main processes of operational accounting, breeding, veterinary medicine and animal feeding [19]. However, animal husbandry covers a very wide area of activity, including many relatively small tasks not yet solved in information systems, but which must be solved in the future. The first solution to one of these particular tasks is the model presented in this article.

The advantage of this model is its universality, since it does not contain any specific elements, and, therefore, it can be implemented using any relational DBMS and most modern programming environments.

To confirm the reliability of the decisions made and to test the performance of the model, an information system was developed and put into trial operation. The main window of the program is shown in Figure 4.

The screenshot shows a window titled 'Animals Data' with a menu bar containing 'Tables' and 'Reports'. Below the menu bar are three icons: a green plus sign, a document icon, and a trash can icon. The main area contains two tables. The first table has columns 'Inventory number', 'Name', and 'Breed'. The second table has columns 'Inventory number', 'Yield', 'Fat', 'Protein', and 'Group'. A 'More' button is located between the two tables.

Inventory number	Name	Breed
11140	Lama	Black-motley
12876	Gita	Black-motley
25432	Judy	Red-motley
23487	Ada	Red-motley
12437	Lada	Red-motley
32486	Puma	Black-motley
15683	Shahinya	Black-motley

Inventory number	Yield	Fat	Protein	Group
11140	4584	4,23	3,19	Second Production
11140	5233	4,15	3,13	First Production
11140	7059	4,2	3,1	Breeding

Fig. 4. The main window of the program.

As a DBMS, it uses MS Access, which is one of the ten most popular database management systems (Figure 5) (According to the DB-Engines Ranking website, URL: <https://db-engines.com/en/ranking> (last accessed 03/10/2023)).

The main reason for choosing this DBMS was the insufficient level of computer systems administration in small agricultural enterprises (many simply do not have qualified system administrators) [20]. At the same time, MS Access is included in the MS Office package installed on the vast majority of computers, and there is no need to install additional software.

The developed system is delivered in the form of a folder (directory) containing the MS Access database file and the executable file of the client (interface) database application, which are simply copied by the user to their computer to any convenient place and do not need further configuration.

410 systems in ranking, February 2023

Rank			DBMS	Database Model	Score		
Feb 2023	Jan 2023	Feb 2022			Feb 2023	Jan 2023	Feb 2022
1.	1.	1.	Oracle	Relational, Multi-model	1247.52	+2.35	-9.31
2.	2.	2.	MySQL	Relational, Multi-model	1195.45	-16.51	-19.23
3.	3.	3.	Microsoft SQL Server	Relational, Multi-model	929.09	+9.70	-19.96
4.	4.	4.	PostgreSQL	Relational, Multi-model	616.50	+1.65	+7.12
5.	5.	5.	MongoDB	Document, Multi-model	452.77	-2.42	-35.88
6.	6.	6.	Redis	Key-value, Multi-model	173.83	-3.72	-1.96
7.	7.	7.	IBM Db2	Relational, Multi-model	142.97	-0.60	-19.91
8.	8.	8.	Elasticsearch	Search engine, Multi-model	138.60	-2.56	-23.70
9.	10.	10.	SQLite	Relational	132.67	+1.17	+4.30
10.	9.	9.	Microsoft Access	Relational	131.03	-2.33	-0.23

Fig. 5. DBMS rating.

The proposed model and its implementation, as it is described in this article, looks isolated, since it is a solution to a limited particular task. The best solution today is its integration into existing software systems listed in the introduction to this article. Such integration should not cause difficulties, because in most of these systems there are already tables containing all the necessary data on animals, their breeds and their locations, listed in Figure 1.

The precedents "Breed List Editing", "Animals List Editing" and "Locations List Editing" (Figure 2) are also already implemented in the developed software systems. Therefore, to include the proposed model in existing systems, it is necessary to add tables for the "Measurement" and "Group" entities (Figure 1) and implement scenarios for use cases "Measurements List Editing" and "Reports Preparation" (Figure 2) with included and optional use cases.

4 Conclusions

In this paper, for the first time, a model of an information system for assessing and forming the structure of a dairy cattle herd is proposed. The developed model includes a relational database containing five tables (entities), as well as a description of the system behavior in the form of UML - use case diagrams and sequences for these use cases.

The model is quite simply integrated into existing software systems of livestock enterprises and can be considered as their extension.

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