Information and search space for monitoring the machine and tractor fleet

V. D. Chervenchuk¹, G. V. Redreev¹, I. V. Chervenchuk², A.V. Shimokhin¹, A. A. Luchinovich¹

¹Omsk State Agrarian University named after P. A. Stolypin, Omsk, Russia
²Omsk State Technical University, Omsk, Russia
E-mail: gv.redreev@omgau.org

Abstract. The machine and tractor fleet of agricultural enterprises is a set of objects of agricultural machinery linked in technological chains, spread over the area of agricultural land. For effective use of the park, it is necessary to monitor it in order to maintain or restore its working condition in a timely manner through the implementation of repair and maintenance actions. The applied means of maintenance and repair are spread among various objects of the repair and maintenance base, being an integral part of it. However, for monitoring purposes, it is convenient to separate maintenance and repair facilities from the objects of the repair and maintenance base. This technique, which expands the theoretical possibilities of representing the monitoring process, allows you to get practically significant consequences. First, the degree of optimal equipment placement on the objects of the repair and maintenance base is revealed and it becomes possible to solve the problem of improving this placement. Secondly, the formation of a system of element interaction of «park – equipment – base objects» sets creates prerequisites for the development of a computer monitoring system.

1. Introduction
Under the monitoring of the machine and tractor fleet (MMTF), we will understand the system of constant monitoring of the operation, maintenance and repair of the entire set of machines necessary for the work mechanization on the cultivation of crops [1].

As part of this monitoring system, the statistical data is processed to evaluate, control and justify management decisions to ensure the economic efficiency of the machine and tractor fleet (MTF), the reliability and safety of equipment, and the safety of service personnel [2].

One of the most important tasks of creating the MMTF is to develop a data storage model that reflects the specific features of technical information and allows further statistical research. First of all, the specific features of the information that MMTF operates with are:

1) the data structure is based on a system of indicators that have an accepted classification;
2) the data is linked to an object;
3) the data is time-bound.

2. Research methods
The information core of the statistical information processing system is a hierarchical database. The hierarchy of objects and classification of indicators underlying the proposed model implies the use of a hierarchical structure.

The scientific concept of hierarchical structuring of this information system is based on some ideas of information algebra, which was developed by the CODASYL committee group [3–4].

The information algebra at its core contains two fundamental concepts: the essence and the property of the entity. The entity is physically existing objects, elements of a real system that has a complex hierarchical structure, and the properties of an entity are its logical and numerical characteristics that this entity possesses. For the proposed MMTF, as a system of continuous monitoring, the entity is transformed into the concept of object and property into the indicator concept. This terminology is more typical for monitoring. It was also used in environmental monitoring in Omsk [5-6]. Here the world of objects is a special case of the world of entities, and the world of indicators is a specific feature of the world of properties.

The object will be called the characteristic carrier (logical or numeric). For example, an object can be a machine and tractor fleet as a set of machines necessary for the work mechanization on cultivation of agricultural crops. Such an object consists of the following groups of objects:

- tractors as a universal energy tool;
- agricultural machines connected to it in a common unit (plows, seeders, harrows, cultivators, mowers, various harvesting machines, non-self-propelled, and others);
- self-operating harvesting machines;
- stationary machines with individual or group drive of working bodies;
- transport vehicles, etc.

The agricultural machines included in the MTF are combined into complexes (in accordance with the requirements of complex mechanization), taking into account the production peculiarities. The structure of these machine complexes depends on the farm specialization, production technology, weather, soil and other factors that affect the choice of machines.

3. Results

The aggregates and complexes of machines form a set of objects of technical support for the cultivation of agricultural crops. Let’s introduce a notation for this set. It has a hierarchical structure in the form of a root tree (Fig. 1).

![Figure 1. MTF technical support tree](image)

**Figure 1.** MTF technical support tree

- **X** - tree root; **X_{A1}, X_{A2}, ..., X_{An}** – aggregates for cultivation of various crops; **X_{tr}** – tractors;
- **X_{av}** – agricultural vehicles (**X_{pl}** – plough, **X_{se}** – seeder, **X_{hr}** – harrow, **X_{cul}** – cultivator, **X_{mo}** – mower, **X_{nshm}** – various non-self-propelled harvesting machines); **X_{sm}** – stationary machines with
individual or group drive; $X_{hm}$ – self-operating harvesting machines; $X_{tm}$ – transport machine; $X_{rb}$ – rechargeable battery; $X_{ice}$ – internal combustion engine; $X_{pto}$ – PTO; $X_{g}$ – generator.

Another group of objects is a tool for technical maintenance and repair of objects of the first group. This set of objects $Y$ includes machines, test benches, diagnostic scanners, various tools and measuring devices. The structure $Y$ is the same as in $X$ (Fig. 2).

![Figure 2. MMTF tool tree](image)

$Y$ – tree root; $Y_{tse}$ – technical service equipment; $Y_{de}$ – diagnostic equipment; $Y_{ht}$ – hand tools; $Y_{mi}$ – measurement instrumentation; $Y_{st}$ – stands; $Y_{sc}$ – scanners and testers; $Y_{erm}$ – equipment for repairing tractors and agricultural machinery; $Y_{etr}$ – equipment for repair of trucks; $Y_{ce}$ – compressor equipment; $Y_{w}$ – washings; ($Y_{wp}$ – washing of parts, $Y_{wa}$ – washing of aggregates); $Y_{we}$ – welding equipment; $Y_{rm}$ – riveting machine for brake pads; $Y_{cl}$ – car lifts; $X_{tfe}$ – tire fitting equipment; $Y_{ge}$ – garage equipment; $Y_{sc}$ – start-up chargers; $Y_{ct}$ – current transducers

The garages, hangars, warehouses and other specially equipped premises (battery, generator, electromechanical, mechanical workshops, etc.) intended for storage, maintenance and repair of vehicles and removed onboard equipment form the third group of objects $Z$. These entities determine the location of objects in the first and second groups. A specific MTF is linked to a certain territory. This territory can be considered as the $Z$ root object. On this territory there are buildings for various purposes, inside which there are rooms premises for the MTF work. Therefore, the objects of the set $Z$ have the same tree structure (Fig. 3).

![Figure 3. Tree of the MTF production premises](image)
The binding objects of the first two groups ($X$ and $Y$) to its location (group objects $Z$) is set by matching

$$q_Z = (X \cup Y, Z, Q_Z),$$

where $X \cup Y$ – conformity dispatch area $q_Z$; $Z$ – conformity arrival area $q_Z$; $Q_Z$ – law of conformity $q_Z$, then

$$Q_Z \subseteq (X \cup Y) \times Z.$$  

The scope for determining this compliance represents the law projection $Q_Z$ on the first component

$$\Pi_1 Q_Z \subseteq X \cup Y.$$  

This set includes only those items from $X$ and $Y$ for which their exact location on the territory of the MTF is determined. These objects can have indicators (numeric or logical values). During the operation of the MTF, the indicators of objects may change over time. Therefore, all objects must be linked not only by location, but also by time. Time is usually set by date (YYYY-MM-DD) and time of day (hh:mm:ss), which is also represented as the $T$ root tree: year consists of months, month of days, day of hours, hours of minutes, minute of seconds. For a specific point in time, an object's indicator is a specific number or logical value. For a time interval, the indicator will be represented by an array of values.

The binding objects $X \cup Y$ to $T$ time is set by matching

$$q_T = (X \cup Y, T, Q_T),$$

where $X \cup Y$ – conformity dispatch area $q_T$; $T$ – conformity arrival area $q_T$; $Q_T$ – law of conformity $q_T$, then

$$Q_T \subseteq (X \cup Y) \times T.$$  

The correspondences (1) and (4) determine the relation of objects $X \cup Y$ to the territorial-temporal space $Z \times T$. This relation is determined by the match

$$q = (X \cup Y, Z \times T, Q),$$

where $X \cup Y$ – conformity dispatch area $q$; $Z \times T$ – conformity arrival area $q$; $Q$ – law of conformity $q$, then

$$Q \subseteq (X \cup Y) \times Z \times T.$$  

Definition 3. The set of triples $I \equiv (X \cup Y) \times Z \times T \supseteq Q$ will be called the MMTF information search space (or simply PE space).

Not all points $(x, z, t) \in I$ where $x \in X \cup Y$, $z \in Z$ and $t \in T$, here will have indicators. Some points in the PE space are logically contradictory (for example, a tractor cannot be located in the accounting department of a management office). Accessing these points to determine its indicators will be accompanied by the message «request error». Some logically consistent points in the PE space may also have no indicators due to underloading of the MMTF database. In this case, when accessing them, the message «there is no data for this object» will be displayed.
In general, each point of the PE space can correspond from zero to different n-indicators (passport data of the technical object, service life, statistics of failures and its elimination, etc.) [7]. With the help of statistical data processing for the same type of objects, the reliability indicators of these technical means, the probability of failure-free operation are calculated, and the terms of their maintenance, preventive and capital repairs are compiled. Here there is a prospect of merging PE space, which provides search and collection of statistical data for specified types of objects, with mathematical support for statistical processing of large information amounts [8–9].

The set of «MTP personnel» also has a tree-like hierarchical structure and each specialist constantly monitors those indicators and achieves their most optimal value, for which he is directly responsible in accordance with the profile of his job responsibilities. The access to the necessary information is provided by hierarchical menus that mirror the tree structures of object search $X$ (Fig. 1), $Y$ (Fig. 2) and $Z$ (Fig. 3). For example, the main menu of the MTF monitoring system can be represented as follows:

The main menu for monitoring the machine and tractor fleet:
1. Service personnel
2. Aggregates and complexes
3. Repair equipment
4. Office premises
5. Exit from the main menu.

When you choose the second point «Aggregates and complexes», a menu consisting of items corresponding to the second tier of the $X$ tree will appear on the computer screen.

Aggregates and complexes for:
1. Grain crops
2. Forage crops
3. Roots
4. ...
5. Return to the previous menu
6. Exit from the main menu.

When you choose the second point «Aggregates and complexes», a menu consisting of items corresponding to the third tier of the $X$ tree will appear on the computer screen.

Aggregates and complexes for grain crops:
1. Tractors
2. Agricultural machinery and tractor trailers
3. Self-operating harvesting machines
4. Stationary machines with individual or group drive
5. Transport vehicles
6. ...
7. Return to the previous menu
8. Exit from the main menu.

When you choose the first point «Tractors», the menu will display a list of tractors with the corresponding garage number. When you select any of it, a new menu will appear. For example:

Tractor Belarus, garage no. 08
1. Indicators
2. DVS
3. 6STS-50EMS Battery
4. PTO
5. Chassis
6. ...
7. Return to the previous menu
8. Exit from the main menu.
This object already has indicators (numeric and/or logical values). When you choose the first point «Indicators», a menu appears on the monitor screen with a list of indicators corresponding to this tractor. Thus, the hierarchical structuring here is based on a given hierarchy of objects, on the basis of which, taking into account the semantics of its description, a classification of indicators and accumulated statistics of its changing values is designed. This concept, in addition to the obvious practical benefits obtained in the development of specialized monitoring (in this case, MMTF), is also an important scientific interest in terms of theoretical research of the properties of the PE space and related information search root trees (great-trees). The hierarchy of objects identified at the system design stage is then incorporated into the development of the user interface. This interface is represented here by the system of hierarchical menus described above. Its use allows the user to easily describe a subject area or complex object in terms of objects and indicators of the PE space.

The software implementation of the user interface is supposed to be implemented as an add-on to the Microsoft Access DBMS using the Visual Basic for Applications (VBA) programming language built into it.

To evaluate the effectiveness of applying the hierarchy to the semantic description of structured objects, we introduce the following numerical characteristics.

The compactness characteristic of the X tree of objects is defined as:

$$\lambda(X) = \frac{l(X) + n}{m + n}$$

(8)

where $n = |X|$ - the number of indicators (X hanging tree nodes),

$m - X$ number of internal tree vertices,

$l(X)$ - total length of the tree description is defined as the total length of X tree branches.

The compactness of the indicator tree shows how much computer memory costs are reduced while describing the semantics of system indicators due to the hierarchical structuring of this description.

The characteristic of a priori performance of the search for indicator in X is defined as:

$$\tau(X) = \frac{(1 + n)n}{2} / l(X).$$

(9)

This characteristic shows how many times the speed of indicator search improves due to structuring.

Enter the average length of the object tree:

$$\bar{l}(X) = l(X)/n.$$ 

(10)

It is obvious that between the characteristics $\lambda(X)$, $\bar{l}(X)$, $\tau(X)$ there is a certain functional relation. From (9) and (10)

$$n = 2\bar{l}(X)\tau(X) - 1,$$

(11)

and from (8) and (11) we get

$$\lambda(X) = \frac{(2\bar{l}(X)\tau(X) - 1)\bar{l}(X) + 1}{m + 2\bar{l}(X)\tau(X) - 1}$$

(12)

On the basis of two criteria $\lambda(X)$ and $\tau(T_X)$, the task of two-criteria optimization is set to find effective structures for searching for indicators, meaning by effective structures the Pareto optimal structures for the criteria $\lambda(X)$ and $\tau(X)$.

If it is impossible to vary n and m, the problem is solved trivially (any structure is effective in this sense). To solve this problem, we introduce a certain class of trees (a subclass of root trees), which are called ST-trees – trees with a trunk. ST-trees have a trunk – i.e., an open sequence of vertices $<d_1,d_2,...,d_r>$, connected by edges; each such vertex $d_i$ can only have edges leading to hanging vertices or to a vertex $d_{i+1}$. The case $r=1$ is possible. The set of hanging vertexes coming from the vertex $d_1$ forms
a tier of the ST-tree (here, for convenience, we have slightly departed from the traditional concept of «tier», we believe that the root has the 0th tier, not the 1st). The examples of ST-trees are shown in Figure 4.

![Figure 4. Examples of ST-trees](image)

**Conclusion**

The specialized databases (statistical information processing system) developed on the basis of the proposed tools for optimizing the search for the MTF indicators will allow a specialist in the subject area to perform statistical analysis of a large volume of source information with a multi-level structure [10]. Combining the statistical analysis tools and data manipulation tools into one integrated system makes it possible to dramatically increase the volume of processed information and significantly reduce the time for making managerial decisions.

**References**

[1] G V Redreev, A A Luchinovich, E I Ustiyantsev and A S Laskin 2018 Information System of Machines and Tractors Fleet Technical Service Journal of Physics: Conference Series Volume 1059 https://doi.org/10.1088/1742-6596/1059/1/012003

[2] G V Redreev, A V Shimokhin and P V Kiyko 2018 Perfection of Technical Service of Manufacturing Plants Equipment Journal of Physics: Conference Series 1059 https://doi.org/10.1088/1742-6596/1059/1/012008

[3] History of the CODASYL committee [link]

[4] Joe Celko 2012 Trees and Hierarchies in SQL for Smarties 2nd Edition. – Morgan Kaufmann p. 296

[5] I V Chervenchuk, V D Chervenchuk 2013 Some means of information support for environmental monitoring Current state and potential of tourism development in Russia: materials of scientific and practical conference, Omsk: Publishing House of the Omsk State Institute of Service 215-217

[6] I V Chervenchuk 2012 Automation of the preliminary processing of statistical information Mathematical and software systems in the industrial and social spheres: international collection of scientific works - Magnitogorsk: Publishing House of Magnitogorsk State Technical University named after Nosov 52–57

[7] D Christopher Manning, Prabhakar Raghavan, Heinrich Schutze 2011 Introduction to information search M.: Williams p. 528.

[8] Takase S, Okazaki N, Inui K rapid and large – scale uncontrolled extraction of relations - 2015.

[9] D A Devyatkin, R E Suvorov, I V Sochenkov 2016 «Architecture of the search and analytical system and research of the information space associated with the Arctic zone» 01 INTELLIGENT SYSTEMS AND TECHNOLOGIES 37-46.
[10] Hoffman R. et al. 2011 Knowledge-based weak supervision of information extraction from overlapping relations proceedings of the 49th annual meeting of the Association for computational linguistics: human language technologies 1 Association for computational linguistics 541-550.