Automatic Adviser on Mobile Objects Status Identification and Classification

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Abstract. A mobile object status identification task is defined within the image discrimination theory. It is proposed to classify objects into three classes: object operation status; its maintenance is required and object should be removed from the production process. Two methods were developed to construct the separating boundaries between the designated classes: a) using statistical information on the research objects executed movement, b) basing on regulatory documents and expert commentary. Automatic Adviser operation simulation and the operation results analysis complex were synthesized. Research results are commented using a specific example of cuts rolling from the hump yard.

1. Introduction

For illustrative purposes let us study the railway transport infrastructure mobile objects: cars, cuts, trains, locomotives etc., unlike stationary objects: retarders, compressor stations, measurement instruments, etc. The task is to classify the infrastructure designated objects depending on their status. It is necessary to develop a software product - Automatic Adviser (AA), which provides the service personnel with information about the facility current state and renders an advisory opinion on its further “fate”: “immediately remove from operation”, “send for maintenance within a specified period”, “keep in operation”.

At present, the field of knowledge associated with automata-advisers is actively developing in various fields of science and technology [1, 2, 3]. However, there is still a serious gap between theory and practice [4, 5].

2. Research object description

The AA synthesis process will be commented by the following example.

The cut movement along the hump yard free rolling area (FRA) [6]. Condition of wheel sets and cars braking system has a significant effect on the process and the cut movement results. It is necessary to timely identify and compensate (carry out maintenance) the emerged deviations in a car condition.

Two subtasks are solved in AA:

- identification of the current state specified by the parameter vector:
  \[ X = (x_1, x_2, ..., x_n) \]  

1 The work was supported by Russian Fundamental Research Fund, project No. 17-20-01040.
• object classification by one of the three designated classes: R: remove from a technological process, MAINT: maintenance, W: continue working process.

For the example in question, \( x_1 \) is the cut FRA entry speed; \( x_2 \) is the cut mass; \( x_3 \) is the cut FRA exit speed and so on.

Let us distinguish the different types of object parameters:
• input (there are \( x_1, x_2 \)), identifying the object’s individual properties;
• output (\( x_3 \)), describing its state integrally.

With the same input parameters, the output ones can have different values corresponding to their normal state, requiring maintenance or removal from the process.

3. Methods and tools

3.1. Preliminary data processing

The parameters describing the object operation have different scale and measurement units. For that reason, the unification of actually received data is necessary. The scaling operation serves this purpose. It converts all data into a nondimensional form and into one interval \([0, 1]\):

\[
u = \frac{x-a}{b-a}
\]

where \( a \) is the minimum possible, and \( b \) is the maximum permissible value of variable \( x_i \).

Further let us consider that the stated transformations have already been made and let us use onward the initial designations of the variables (1).

Vector (1) forms a multidimensional feature space. Its permissible research area is an \( n \)-dimensional cube with a single edge. Let us divide it into three subspaces (each of them can consist of several areas), figure 1:

• working area of the studied variable values;
• area requiring maintenance;
• area requiring the object removal from the production process.

Separating boundaries between the designated classes are formed by natural constraints (specified in the user’s manual or assigned by experts [8, 9]) or are calculated statistically.

Resulting from the object monitoring (measuring its parameters) in the feature space, let us obtain a point.

If its coordinates are in the MAINT or R zone, then AA generates a message on possible cause and reference for these actions implementation.

If its coordinates are in the W zone, then the object remains in the production process.
4. Construction method of separating boundaries between classes

4.1. Construction method of separating boundaries between classes using statistical methods
One of the boundaries calculating variants is presented in [7]. Experts define the points of different classes (figure 2) and a separating (piecewise linear) boundary is constructed between them.

Figure 2. Geometrical interpretation of static monitoring.

Figure 3 shows a diagram corresponding to the example in question. The cut simulated by point K has the FRA entry speed equal to $x_{1K}$ and mass of $x_{2K}$. The cut speed at FRA exit is $x_{3K}$. If it was in the AB range, then the car state is normal: it functions normally. If the cut is in the BC range, this cut should be sent to maintenance.

Figure 3. Geometric interpretation of the research feature space.

Similarly, if the $x_{3K}$ speed is in the CK range, the cut should be removed from the process immediately.

Tables of form 1 are constructed for each kind of points (B, C) from general learning sampling to constructing the above mentioned separating boundaries.
Table 1. Data learning sample.

|   | 1   | 2   | 3   | ... | N   |
|---|-----|-----|-----|-----|-----|
| x₁ | ... | ... | ... | ... | ... |
| x₂ | ... | ... | ... | ... | ... |
| x₃ | ... | ... | ... | ... | ... |
| class | ... | ... | ... | ... | ... |

Two surfaces are obtained from calculations:

- \( x_{3B} = f_B(x_1, x_2) \)
- \( x_{3C} = f_C(x_1, x_2) \)

4.2. Construction method of separating boundaries between classes using normative and expert methods

Regulatory documents usually determine the devices operating restrictions with the following expressions (graphical comments are in figures 4 and 5):

- “Parameter \( x \) should not exceed the \( x_b \) value” (considering that all studied variables were converted (2)). This simplest requirement identifies the permissible value zone in the corresponding feature space.
- “Parameter \( x_1 \) should not exceed the \( x_{1b} \) value, and concurrently parameter \( x_2 \) should not exceed the \( x_{2b} \) value”. Let us find the intersection of the corresponding zones. That is, the simplest statements are connected by “and” union (figure 4).
- “Parameter \( x_1 \) should not exceed the \( x_{1b} \) value or parameter \( x_2 \) should not exceed the \( x_{2b} \) value”. Let us find the combination of the corresponding zones. In this case, the simplest statements are connected by “or” union (figure 5).

Obviously, the points of the selected spaces are not equivalent to each other. For example, point A in figure 4 is critical only in one parameter (\( x_2 \)), and point B - in two. The experience has shown that it is possible to equalize the criticality degree by introducing more complex boundaries (inclined line in figure 4).

Similar reasoning can be applied in the second case (figure 5).

Point B is in close proximity to the factors established boundaries and has a lesser criticality degree relative to points of type A which can be represented by changing the class boundaries considering the factors interaction (inclined line).

**Figure 4.** The intersection of sets corresponding to the union “and”.

**Figure 5.** The combination of sets corresponding to the union “or”.
5. Research and modeling results

To configure and verify the AA operation validity, it is necessary to create a complex of mobile objects status operation simulation and prediction results analysis (figure 6).

![Figure 6. Automatic Adviser exhibition model diagram.](image)

The signal generator block contains (figure 6):

- The boundaries generation of the studied areas.
- Noise generation of a given type with the specified parameters. For example: a normally distributed error with zero mathematical expectation and a constant variance with a given value.

The sum of these signals is fed to the AA. It should identify and generate boundaries. The agreement (or disagreement) of the constructed boundaries with the given ones will show the validity of the procedures for models constructing in AA.

The AA second output shows the generated advice. The computer screen displays all comparisons for the user.

6. Conclusion and main findings

The example of cuts rolling from the hump yard shows that the mobile object status identification task can be defined within the pattern recognition theory [10], designating three classes accordingly: an object in the operation status, its maintenance should be carried out, the object should be removed from the production process.

Methods of data preliminary processing and objects classification were analyzed and two methods of separating boundaries construction between the designated classes were described:

- using statistical methods;
- using data of regulatory documents and expert commentary.

Automatic Adviser operation simulation and operation results analysis complex were synthesized.
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