Design principles and architecture of the system “Processing and analysis of images and video streams”

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Abstract. In this paper, we present design principles and architecture of the system “Processing and analysis of images and video streams”. It contains test examples of images and techniques for their processing based on some classical and modern grid methods. Note that our DSS is open in the sense that it contains modules for creating user databases and the reports base “Algorithms performance quality”, as well as for adding a new grid method or a new application module in the DSS. The logic of the actions of these modules is presented in the diagrams of UML. Application modules demonstrate the use of methods for processing and analyzing images and video streams by industry, for example, analyzing the surface quality of a porous material, monitoring the level of liquid in a container, etc. This approach ensures the close connection of the DSS with modern scientific achievements. This is the realization of principles of learning, versatility, and scientific approach.

1. Introduction

At present time, there is a large amount of data on grid methods developed for processing and analyzing images and video streams. However, this information (usually presented as a text) is scattered in various scientific journals, dissertations, and textbooks. Note that certain image processing methods are now available in many computer algebra systems and programming languages (for example, in Python and C#). But these methods are rather old and not free from drawbacks. Thus, they do not implement new knowledge in processing images and video streams, which hampers the research in this field. Therefore, it is important to develop a Decision Support System (DSS) which would systematize the relevant knowledge and represent a tool for improving image processing techniques. We call this DSS “Processing and analysis of images and video streams”. It contains test examples of images and techniques for their processing based on some classical and modern grid methods.

2. Design principles and architecture of the system

The developed DSS can be helpful for various kinds of users such as research workers, graduate and postgraduate students, and programmers in various applied fields. Users have to be authorized in the system. All users of the DSS have the access to one and the same set of tools, but the system creates a separate folder for each user for his/her databases of test images, methods, and application modules. By default, all the contents of a folder are available only to its owner. The latter can open his/her
materials for other users by choosing them from the list. The DSS can be installed as a desktop single- or multi-user application or as a network one.

The structure of the DSS includes a database, a knowledge base, a reference information system, the subsystem "Application modules for various knowledge areas" and modules "User examples", "System methods", "Algorithms performance quality estimation" and "Interface".

When projecting the DSS, we have used such well-known principles of the development of information systems as the system approach, compatibility, standardization, unification, and efficiency, as well as the principles of learning, versatility, scientific approach, and openness. Below we describe the additional principles introduced by us when projecting the DSS.

In the table shown in Figure 1 we describe DSS options available for a user in working with databases and grid methods with various values of user’s parameters for downloading, extracting, adding, and executing algorithms. The table illustrates the structure of the database and the set of methods of the DSS developed by us. Note that the database of the DSS contains test video files and images taken at the database of the University of Princeton [1] and in educational literature and scientific publications [2-5], as well as our own test files.

| Database                  | System                                      |
|---------------------------|---------------------------------------------|
| video                     | Loading, extracting, setting parameters     |
| stationary image          | Storage, connection to modules              |
| allow other users to use it |                                             |

| Database of grid methods for processing and analyzing images and video streams | Method |
|-------------------------------------------------------------------------------|--------|
| video                          | from the camera |
| stationary image               | from a file   |
| allow other users to use it    | of user       |

![Figure 1](image.png)

**Figure 1.** Filters and available options for the use of the database and the set of methods included in the DSS.

The principle of openness assumes that the database of our DSS can be updated by users; we plan to implement this principle in the "User examples" module. The logic of this module is shown as an activity diagram in ArgoUML (see Figure 2). Namely, in the menu “User examples” a user chooses the option “Update the database of user test examples”. Then the DSS proposes a popup menu of possible directions and subdirectories, where the user can choose any option or type a new one. The DSS forms a `pathdir` for saving the file uploaded by the user in accordance with the direction specified by him/her and opens a dialog window for updating user’s test examples. By pressing the “Upload file” button in this dialog window the user opens the corresponding window for choosing the file with an example. Finally, the chosen case appears in the DSS folder with test examples, while the user remains at the dialog window “Updating the database of user test examples”. The same dialog window allows one to delete any of his/her test examples from the user’s folder (by pressing the “Delete file” button) and to open the access of other users to the chosen file(s). Note that the previously chosen direction automatically appears in the dialog window “Updating the database of user test examples”.


Figure 2. The activity diagram of the “User examples” module.
In the popup menu of directions the user can do the following:
- choose a direction: improving the image quality (noise removal, image sharpness increasing, contrast change, image restoration, or a user’s one), outlining, motion detecting (establishing the fact of the motion and its type), tracking objects, etc;
- choose “all” for looking through contents of all directions;
- define one’s own direction (or subdirection), if their list was formed for updating the database (see Figure 2), methods (see Figure 3), or application modules.

Note that the performance structure of the subsystem “Application modules for various knowledge areas” is analogous to that of the module “User examples”.

The knowledge base of the DSS includes
- both classical well-known methods and new grid algorithms for processing images and video streams. Grid methods included in our DSS were found in Russian and International papers published in 2008-2017 [2-5]. We treat all these methods as system ones;
- techniques for collecting and visualizing data on the performance quality of algorithms included in the DSS. These techniques are available in the module “Algorithms performance quality estimation”. This module allows one to do the following: to look through the database “Algorithms performance quality” that is included in the DSS, to create (from the scratch) a user database with results of testing algorithms, to make a user copy of the database “Algorithms performance quality” that is included in the DSS (allowing updating), to test the quality of the current method, to save results of testing (either by creating a new file or updating the user database of testing results), to look through the user database of testing results, to form or to add a user dialog window for testing the algorithm performance;
- the database of reports “Algorithms performance quality”. This database is developed by us for all directions and subdirections of processing images and video streams. This database can also be copied as a user version; the user can further update it and/or open an access to it for other users.

The principles of openness of the DSS knowledge base is realized with the help of the submodule “Updating user methods” of the module “System methods” (see the activity diagram in ArgoUML given in Figure 3).

Note that the content of the dialog window “Updating user methods” depends on whether the user has chosen a direction from the proposed list or defined a new one. This dialog window generates a daughter one titled “Variables of the method”. The latter window contains the list of input and output variables of the method together with their description. If some method is already included in the DSS, then the latter would form this list for the chosen direction and propose the user to enter names and descriptions of the method variables. If the direction is a new one (i.e., previously it was not included in the “System methods” module of the DSS), then the dialog window “Variables of the method” becomes simpler, namely, in this case, the user has just to enter all corresponding input and output variables.

Note that the dialog window “Updating user methods” has to contain the “Upload file” button. When the user presses this button, chooses the necessary file in the popup dialog window, and presses the “ok” button, the DSS defines the location of the user file with a new method automatically. Then the dialog window closes, while the DSS saves the path to the file with the user method and the file name.

After that, the user has to press the “Add method” button in the dialog window. This would make the DSS define the path for saving the uploaded file; the latter would represent a new module of the DSS. Moreover, all relevant menus of the system interface would be interactively updated. The new user module becomes a working one. It is placed in the folder of user methods of the DSS. Analogously one can delete any user module from the mentioned folder by pressing the “Delete method” button in the dialog window. The same window also allows one to open an access to his/her method for other users of the DSS.
Figure 3. The activity diagram of the “System methods” module.

Note that the dialog window “Updating user methods” assumes that a user fills the proposed fields and chooses certain options. Namely, he/she can specify:
- options for processing an object (an image or a video stream uploaded from a camera or a file);
- the direction of processing an image or a video stream;
- the name of a grid method.
Note that our DSS is open in the sense that it contains modules for creating user databases and the reports base “Algorithms performance quality”, as well as for adding a new method or a new application module in the DSS.

Application modules demonstrate the use of methods for processing and analyzing images and video streams by industry, for example, analyzing the surface quality of a porous material, monitoring the level of liquid in a container, etc. This approach also ensures the close connection of the DSS with modern scientific achievements. This is the realization of principles of learning, versality, and scientific approach.

The principle of learning is also realized in the “Reference information” module. The activity diagram of this module is given in Figure 4. Note that the “Reference information” module should include the following components:

**Figure 4.** The activity diagram of the “Reference information” module.
- the help information on using the DSS;
- the help information on classical and modern grid methods for processing images and video streams included in the DSS, together with references to relevant papers and scripts of this methods in Mathematica, Matlab, Python, C#, and other software packages;
- reference information on application modules that use grid methods for processing images and video streams;
- scripts of used application modules.

Note also that a user of our DSS can do the following:
- use the reference system for getting acquainted with the theoretical description of methods, including formulas implemented in algorithms and relevant bibliographical references;
- get acquainted with merits and drawbacks of a certain method (they are available on user requests at the dialog window “System methods”);
- get acquainted with applied branches, for which the chosen grid method is most suitable;
- demonstrate the online work of the chosen method with test data (either included in the DSS or user ones);
- test the performance quality of methods for test examples and data within the chosen (by the user) direction and subdirection;
- save the testing results in the knowledge base of the DSS. This allows one to update the knowledge base of the learning system and to identify problems connected with the implementation of algorithms included in the DSS;
- visualize testing results as diagrams in accordance with user requests;
- browse, run, or copy (by pressing the “Script” button) the script of the method separately from the DSS;
- generate (with the help of the Report dialog window generated by the Method dialog window) reports of the solution of a certain applied problem by a certain method.

3. Conclusion
The Decision Support System (DSS) proposed in this paper can be used in teaching and research work for improving the quality of methods for processing images and video streams. It integrates the teaching of the latter methods, the research work, and the practical application of images and video streams processing methods in various branches of knowledge. The DSS allows one to concurrently learn classical and modern grid methods for processing images and video streams in various research areas and to develop the corresponding programming skills.

References
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