Cloud Service for Sonar Signal Processing

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Abstract. Nowadays, a lot of autonomous unmanned underwater vehicles (AUV) are created in the Institute of Marine Technology Problem FEB RAS. Most of all include side-scan sonar (SSS) EdgeTechSonar with 32-bit resolution. Robots solve different problems. There are bottom map construction, monitoring of underwater channels, tubes, mineral exploration. Signal processing requires complex numerical resources. Unfortunately, AUV doesn't solve these problems on the board independently. Real signal requires additional processing. Hence, sonar data is processed in the laboratory. Currently researchers have large databases of AUV. Data processing in the laboratory is inconvenient. If engineer adds additional processing algorithm he changes all local software. In this paper authors use cloud approach for solving this problem. The data from SSS EdgeTechSonar upload directly to the cloud service. Afterwards, user chooses any filter for sonar image processing. The cloud service includes a database of sonar images with its geolocation. Moreover, user uses different filters for image processing. Filters in cloud service are executed with parallel technology for fastest processing. There are 512 parallel processors with mpi-technology and several GPU-processors. Choice of technology depends on filter properties. Authors research some filters for sonar image processing and design special parallel algorithms for each of them.

1. Introduction
Currently researchers at the Institute of Marine Technology Problem FEB RAS designed a large series of autonomous underwater vehicles (AUV) which are achieved state certifications ISO 9001 and ISO 14001. Autonomous underwater robotic vehicles are equipped with monitoring systems [1]. They solve several problems - sea bottom map construction, surveillance and search operations, monitoring of underwater structures such as pipelines, cable channels [2]. These works have been carried out during more than 40 years. Nevertheless, the problem of signal processing for sea bottom image construction is relevant still today. As known, a hydroacoustic channel is specific due to non-stationarity of refractions and other physical effects which are appeared as multipath propagation or signal interferences [3-5]. These effects distort or completely destroy an image [6-8].

The second problem is saving of side-scan sonar (SSS) data [9]. Different laboratories use the different approach for organization of SSS databases. There is a new image processing method which doesn't applies for data in another laboratory. There are data duplication cases. A local software is unable to manage large data flows and fast data processing. Hence, the conservative approach doesn’t applied to solving contemporary problems of sonar images construction. Achievements of current technologies allow to find the best way such as designing a cloud service for processing and saving...
SSS-data from AUV. On the one hand, there are cross-platform; the uniform of data saving; using of high performance computing which increase velocity of signal filtration; possibilities of adding new algorithms for image processing; unlimited resources in terms of expansion possibility; etc. [10]. On the other hand, user requires a permanent internet connection with the cloud service.

Nowadays, several variants of cloud software for SSS-data processing have existed already, e.g. “Blackwater Acoustic Solutions”. It includes different services such as underwater inspections, underwater site, bottom pro ling, pre-maintenance inspections, liability and claims inspections, sonar scanning, underwater photo and video imaging. It has some disadvantages. There is a big price for using, an inability of adding new algorithms, an inability of processing a confidential data. All of these reasons are motivated to create an independent cloud service for saving and processing SSS-data.

2. The cloud service
Authors formulated the system requirements for the cloud service of SSS-data processing, based on the application area analysis. The system consists of three nodes. There are the Client, the Server and the Cluster (Figure 1).

![Deployment diagram](image)

**Figure 1.** Deployment diagram.

The Client is user’s computer which sent different requests to system. In terms of user the whole system is web-application which is managed by a standard browser. The Server is a php-application on the web-server that receives requests from the Client and sends data and special commands to the Cluster. The Client and the Cluster connect by http-protocol. The Cluster is high performance computing system which includes multi-processors and GPU-processors subsystems. The Cluster storage consist of a database with user data, SSS-data and filters. Each filter is implemented in mpi-technology using different number of nodes and GPU-technology. The choice of the device or of the nodes number depends on each filter and its properties. Further, authors explain a strategy for choosing a filter on the example of the double filtration filter. The Server and The Cluster connect by ssh-protocol. The minimum hardware and software requirements for the system are shown in Tables 1, 2 respectively.

| Table 1. Hardware requirements |
|--------------------------------|
|                       | Cluster | Server | Client |
| CPU numbers           | 512     | 4      | 1      |
| CPU frequency         | 2 GHz   | 2 GHz  | 1 GHz  |
| GPU numbers           | 2       | -      | 1      |
| GPU FMA               | 155 GFlops | -     | -     |
| RAM                   | 8 Gb    | 8 Gb   | 512 Mb |
| HDD                   | 5 Tb    | 2 Gb   | 512 Mb |
Table 2. Software requirements

| OS       | Cluster | Server | Client                  |
|----------|---------|--------|-------------------------|
| Linux    | Linux   | Linux  | Windows/Linux/Android/iOS/etc. |
| Apache 5.4 |         |        |                         |
| Php 5.3  |         |        | Web-browser             |
| Libssh2 – 1.4.2 | |        |                         |

The most computational node is the Cluster which executes complex procedures. The Server acts as an intermediary. It receives data-files and requests from the Client. Afterwards, the Server connects to the Cluster and sends special commands to start filtering process or upload data or adding filter or another operation. The Cluster and the Server exchange by ssh-messages. Hence, the subsystem “Cluster” executes algorithms for filtration and processing of sonar images; uploading and downloading SSS-data; sending messages about processing or about errors. The subsystem “Server” executes connection with the Cluster; sending of filtering images to the Client; receiving of SSS-data from the Cluster; generating a database which include user's personal cab, filenames of SSS-data in the Cluster, GPS-coordinates of this file and other parameters of sonar survey; commands processing of the Cluster, for instance, selecting the way of executing algorithm (GPU or Multi CPU). The system architecture and connection between subsystems' modules are shown in the Figure 2.

For designing the cloud service authors use different program languages for different subsystem, e.g. most filters on the Cluster code on C++ incl. mpi or CUDA packages. Algorithms for transformation SSS-data to image code on Python. The Server code on PHP. The Client code on JavaScript incl. JQuery and Ajax lib.

3. Data processing by the cloud service on example of the double filtration filter

In this section authors explain the filtering process on the Cluster. The Cluster receives request from the Server for processing SSS-file which is choosed by user. Next step, the Cluster analysis a state of the system, i.e. it searches free resources – number of free nodes or GPU-processors. Afterwards, it sent message with properties to the Server which decides “where filter executes” and “how much nodes are involved in the filtering process”. The way of the strategy (GPU or Multi CPU) depends on the velocity of filter implementation. Further, authors consider deferent implementation on the double filtration filter example.

The algorithm of double filtration is based on the interpolation theory of function with finite spectrum. As the name implies the double filtration consists of 2 stages. On the first stage an impulse noise is vanished by the Aisenberg formula. On the second stage a low-amplitude noise is filtered by least-squares method with window 3. The main object is sonar image which represents in a two-
dimensional array. Thereby, each column of array processed by double filtration algorithm. Afterwards, this column is printed to an output file.

3.1. CPU Implementation
For Multi CPU technology each column or column group are sent to various processors. The Figure 3. is showing the program runtime (t) plotted against the process number (n). As seen runtime is decreased before 16 processors. This is described that algorithm requires additional time for data transmitting from the main processor to subsidiaries processors. Thus, the Cluster executes this filter with 16 CPU processors, i.e. 2 cluster nodes.

![Figure 3. Program runtime (t) for Multi CPU technology.](image_url)

3.2. GPU Implementation
An algorithm designing for GPU processors requires to research setup for several GPU parameters [15]. There are numbers of threads, file size, and characteristics of GPU. In the serial algorithm, all columns are processed independently but nodes of column depend on next and previous elements. Thereby, for designing of algorithms authors use technology of parallelization by columns. Author analyze two GPU processors. There are NVIDIA GEFORCE 610M (#1) and 750M (#2).

Let $n = \{32, 64, 128, 256, 512\}$ denotes the number of threads per one block, and $s = \{211, 1054, 3160\}$ denotes the file size in kilobytes (Kb). The researching consists of several stages. At first, it includes comparing of two different GPU processors and different file size.

Note

$$\frac{\partial t_i^s(n)}{t_{\text{max}}^s(n)} = \frac{t_i^s(n)}{t_{\text{max}}^s(n)}, \#(2)$$

here $t_i$ denotes program runtime of GPU #1 if $i = 1$ and GPU #2 if $i = 2$. Moreover, each column uses one thread only.
In the fig. 1, 2, 3 shown the GPU #1 decreases program runtime up to 27% independently of file size. It is worth to note despite the specifications of GPU #2, GPU #1 is more usable for double filtration algorithm.

At second stage, authors compare the relativity runtime of GPU #1 and different file size. Relativity time is calculated by using (2).

![Function graphs](image-url)
As seen from the fig. 4, the relativity runtime is similar. Hence, the double filtration algorithms is applicable for different input data because it has constant increasing runtime coefficient which is independent of file size. Moreover, the optimal number of threads is 128 because algorithm shows the best result for different files.

At third stage, authors consider program runtime depending on number of columns per one thread and with the same file size $s = 211$ kilobytes by GPU #1. Thus, several columns are processed by one thread. Program runtimes are shown on the fig. 5.

![Figure 5](image)

Figure 8. Functions $t_3^s$ – bolt line, $t_4^s$ – dot line, $t_5^s$ – dot-dash line.

Here, $t_3^s, t_4^s, t_5^s$ denote program runtimes of processing by 1, 2, 4 columns per thread, respectively. Thereby, least runtime estimates by one column per one thread. Furthermore, runtime increases with increasing number of column per thread.

As described above the double filtration filter executes on Multi CPU and GPU-processors. In this case the strategy way depends on free resources in the request time. There are algorithms which are implemented successfully on GPU or Multi CPU only. In this case the Server enqueuers request on image processing.

4. Conclusion

Thus, authors have designed the cloud service for SSS-data processing. This system includes well-known and new algorithms which designed by authors or engineers at the Institute of Marine Technology Problem FEB RAS. The service solves the following problems – reducing filter runtime; fast access to data processing; controlling for duplicating data; processing of confidential data; the possibility of service extending in terms of computational resources or adding new filters (e.g. [11-18]) or new procedures for SSS-data processing. Further, authors are going to append in the cloud service additional clusters.

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Acknowledgments
The reported study was funded by RFBR according to the research project № 18-31-00050.