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Intellectual System For Analyzing Thermal Compositional Modeling With Chemical Reactions

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Summary

The aim of any oil producing company is daily effective and safe oil production. To maximize the extraction of oil from oil reservoirs, it is necessary to continuously improve the work of the oil industry, carry out various measures to optimize the work of producing and injection wells, maintain optimal reservoir pressure, and use modern approved and tested methods of increasing oil recovery. Also, it is necessary to improve the technology of oil production by automating the management of the production process on the basis of "i-fields" concept. When considering large and complex oil and gas fields, the implementation of such technologies requires their qualitative research. Operative decision-making and optimal exploitation of fields imply the need for modeling and monitoring of these fields in real time with the involvement of modern software and hardware.

When managing a field, real-time collection and processing of information is required. Whereas, not all fields are provided with advanced infrastructure for wireline data collection. For them, it is suggested to collect and pre-process data in the fields in an automatic mode with the help of sensors of the embedded system (FPGA-based system).

Given work devoted to development of the intellectual distributed high-performance information system of analysis of different scenarios of the oil production to determine optimal development parameters of oil fields. Proposed system uses thermal compositional model taking into account chemical reactions and supports high-performance computing based on CUDA technology for mobile platforms and MPI for supercomputers in real-time. System allows rapid sequence reading from wells using sensors and controllers (FPGA) and if necessary preprocess data for usage in further calculations.

The principles of Closed-Loop Reservoir Management (CLRM) methodology will be used as a basis, which is a combination of optimization of the life cycle and comparison of the development history of a field. The implementation of this requires large computational resources with the use of procedures for assessing the Value of Information (VOI). Different methods of data clustering (K-averages, multidimensional scaling and tensor decomposition) comparing to select a limited number of representative members from the ensemble of field models with the choice of the optimal set of controls for multiple modeling scenarios.

Introduction

Every oil production company seeks to make their everyday routine tasks as efficient as possible meanwhile maintaining overall safety of the process. In order to achieve these nontrivial goals company required constantly enhance the operation of a petroleum field, conduct various optimization works on injection and production wells equipment, keep reservoir pressure level at its optimal value, equip most recent, stable and approved enhanced oil recovery methods. On track to achieve abovementioned enterprises have to modernize their automated facilities adding intellectual decision-making capabilities which lead to refined oil production technologies. In recent years few large international companies adopting intellectual automated technologies to improve the management and integrity of their internal technological processes. Every large-scale project such as the development of valuable oil field requires thorough consideration of all sub-processes within it which is incredibility challenging task for qualified personnel because of ambiguity and amount of data to be analyzed. This problem especially hard to solve considering the nature of decisions to be made. The main requirement to such decisions is that they must be made in very limited time. Thus intellectual technologies can help make timely and efficient decisions during field development and exploitation. Moreover, they allow to collect and analyze data in real time using most recent software solutions which guarantees enhanced control over the whole process of petroleum field operation.

Work in this area in the world is relatively recent. The concept of a "smart deposit" was one of the first proposed by Stanford University specialists. The proposed system is aimed at optimizing operations in oil and gas fields in a continuous mode, planning the locations and number of new wells, and consists of two main components: modeling and forecasting processes (Smart Fields Consortium).

Smart technologies are the future of oil companies. Research departments of the world's largest oil and gas companies are working on the principles of an intelligent field, namely «Smart Fields» in Shell (Madahar *et al* (2012)), «Field of the Future» in BP (Field of the Future) (BP Global, Reddick *et al* (2008)) and «iFields» in Chevron company (Hauser (2010)), etc. This indicates that soon the worldwide introduction of "smart technologies" will be an inevitable condition for the survival of oil and gas companies.

Over the past two years, in all corporate areas, Machine Learning has begun to be studied. But there are still many areas in which this approach could be used. And then Stanford University scientists are among the first to suggest using the "machine learning" method for the oil and gas industry. Namely, in predicting the characteristics of the oil reservoir in uncertain places (Sun *et al* (2016), Chen *et al* (2016), Shirangi *et al* (2015), Barros *et al* (2016)). The application of this technology will improve the quality of input data for calculating a specific task, promptly respond to changes in input data for selecting the optimal development method for increasing oil recovery, and further define existing values.

One of the important tasks of the oil industry is the solution of the problem of fluid flow of a multiphase multicomponent fluid taking into account the chemical reaction. To adequately model the complex fluid flow processes that occur in non-tear strata, it is necessary to take into account the component composition of the phases (Pederson *et al* (2006), Ahmed (2006)). Simulation is complicated by the fact that convection, diffusion, phase transitions and chemical reactions need to be taken into account (Maurand *et al* (2014), Farshidi *et al* (2013), Delshad *et al* (2009)). There are works of foreign researchers on mathematical and computer simulation of the flow of a multicomponent fluid in a porous medium (V.E. Borisov *et al* (2013), Chen (2006), Chen (2007)). Also, the work of the authors of this project is substantive (Imankulov and Akhmed-Zaki (2016)).

Currently, there is a rapid growth in the amount of data used in the calculation of data on supercomputers and, as a consequence, the amount of data requiring visualization to correctly perceive what is happening on the screen. Accordingly, algorithms and technologies for high-performance visualization become increasingly necessary (Bethel *et al* (2016)). One such technology is the Vulkan API (Vulkan Overview), which was released in early 2016 and shows significant visualization efficiency. Due to extremely low-level implementation, this framework is able to work on devices with the widest range of configurations and, as a result, work both on a desktop and mobile devices. It was for this reason that it was decided to use this technology on mobile and desktop devices.

We can say that at the moment the world is on the verge of a grandiose step into virtual reality. On the market every day there are new brands and new technologies in the virtual reality industry. Along with the whole world, the scientific community (Foerster *et al* (2016), Niehorster *et al* (2017)) is also moving in this direction, trying to interpret scientific results in the most convenient way. In addition, in recent years, the rapidly growing branch of augmented reality, which is the imposition of a painted picture on a real image. Therefore, as a next step in the development of the visualization module, it was decided to implement visualization on the described devices.

Recently, developing methods of machine learning for analysis, forecasting of the main characteristics and optimization of the development of oil deposits in conditions of geological uncertainty. The basis is this CLRM (Closed-loop reservoir management), which is a combination of optimization of the life cycle and comparison of the development history of the field. The implementation of this requires large computational resources with the use of procedures for assessing the value of information (VOI) (Bratvold *et al* (2009), Eidsvik *et al* (2015), Trainor-Guitton (2013)). Different methods of data clustering (K-averages, multidimensional scaling and tensor decomposition) compared to select a limited number of representative members from the ensemble of field models with the choice of the optimal set of controls for multiple modeling scenarios (Helmy *et al* (2013), Jafarpour (2008), Jung *et al* (2018), Jansen *et al* (2014)).

The aim of given project is to develop the intelligent distributed high-performance information system for analysis (express analysis) of technologies of enhanced oil recovery from a reservoir with the support of high-performance computing based on CUDA technology for the mobile platform and MPI for supercomputers in real-time mode. The system allows to urgently read data from wells using sensors, drones, and controllers (Arduino, FPGA, ASIC) and if necessary preprocess these data for use in further calculations. Intellectual information system consists of the application server, database, and mobile application.
Modern methods of mathematical modeling, newest visualization technologies, methods of machine learning for analysis, forecasting of characteristics and optimization of field development, modern technologies and equipment for collection and processing of production data are used.

Methods

This system uses a mathematical model of the method of increasing oil recovery for a three-phase system, taking into account the compositional properties of the oil and gas phases. The model takes into account heat/mass transfer processes and chemical reactions. To solve this model, serial / parallel computational algorithms have been developed using MPI / CUDA / OpenMP / OpenCL technologies and hybrid parallelization technologies. For the numerical solution, the Newton-Raphson method is used (Chen (2006), Chen (2007)), an implicit method of the sweep. The parallel algorithm is implemented based on the methods proposed in (Terehov (2010), Samarskii (1978)).

System Architecture

The architecture of the system consists of an application server, a database, and a mobile application. The database stores the technological parameters, the history of the results of calculations, scenarios, and recommendations for the development of deposits, etc. The mobile application supports the work in offline (offline) mode and access to the application server (online). The results of calculations able to be visualized on a mobile device using the Vulkan framework. The web application allows the user to work through the browser and implements the same functionality (Figure 1).

When managing a field, real-time collection and processing of information are required. Whereas, not all fields are provided with advanced infrastructure for wireline data collection. For them, it is suggested to collect and pre-process data in the fields in an automatic mode with the help of sensors of the embedded system (FPGA-based system). Further data transfer will be done through various types of wireless communication (GPRS, WiFi, LoRa, etc.). In the case of unavailability of wireless dial-up communication, the information in the processed form will be stored on the device, and data transmission from the wells will be carried out at the start of the special drone. Next, the information will be collected on the application server, where the calculations will be launched. All the information necessary for the operator and the calculation management interface will be available in the mobile application. The exchange of information between the terminal server and the mobile application is carried out through rest and push services. Calculations are available not only on a supercomputer but also on mobile devices by connecting a mobile device to an embedded system via a Wi-Fi access point.

Developed an interactive mobile application based on the Android platform with support for multithreaded distribution of tasks. Parallel algorithms have been developed for the implementation of enhanced oil recovery tasks using mobile devices of GPUs with CUDA technology.

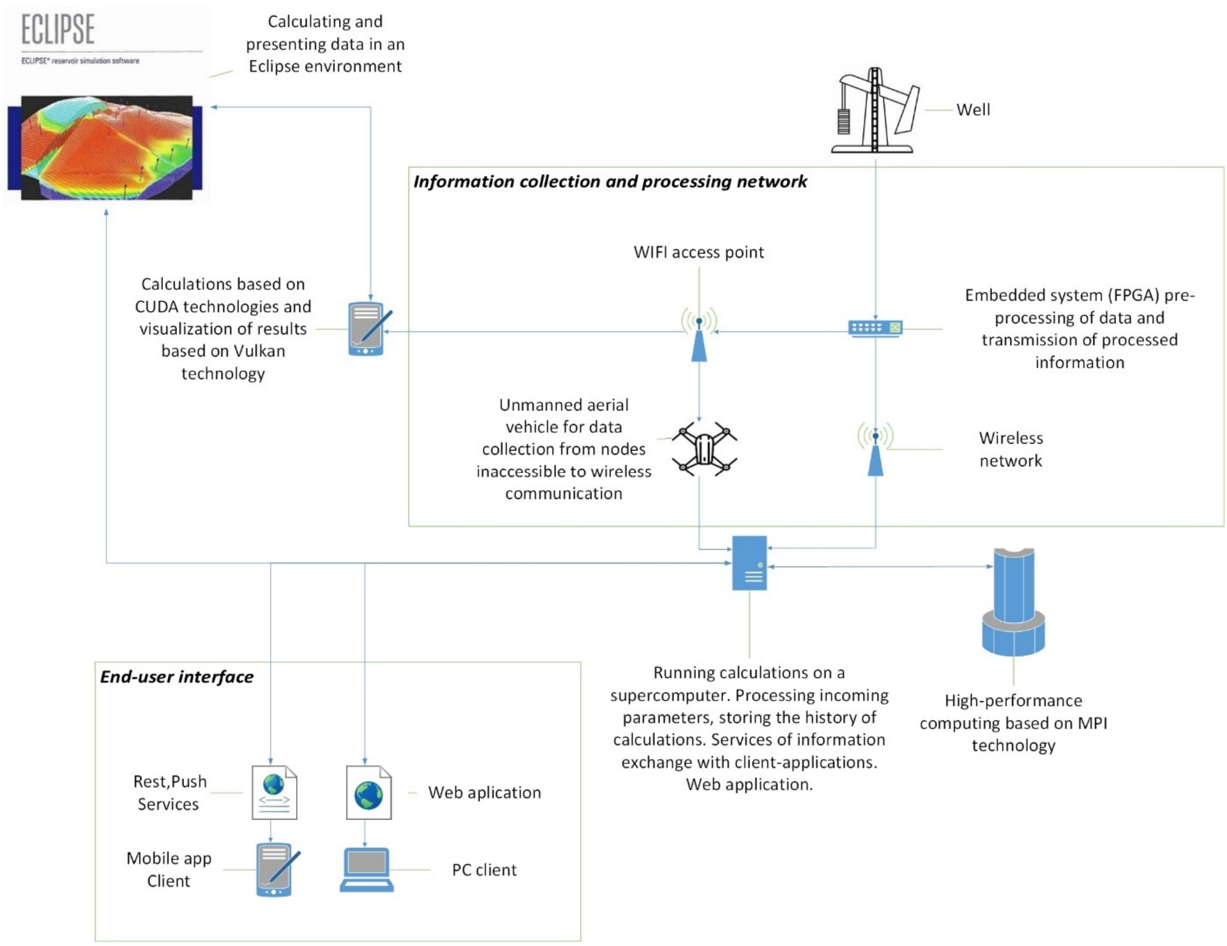


Figure 1 *Integration of a mobile application with a distributed system of devices for reading and processing information from wells.*

Visualization of results

A module for visualizing the results of computing on mobile platforms using the Vulkan standard and on a Web browser using WebGL with upgrading for the latest virtual and/or augmented reality systems is developed. The visualization is carried out in the form of a three-dimensional interactive model of oil and gas reservoir with the drawing of the grid. The images are drawn for the demonstration in interactive mode with the help of glasses of virtual or augmented reality systems.

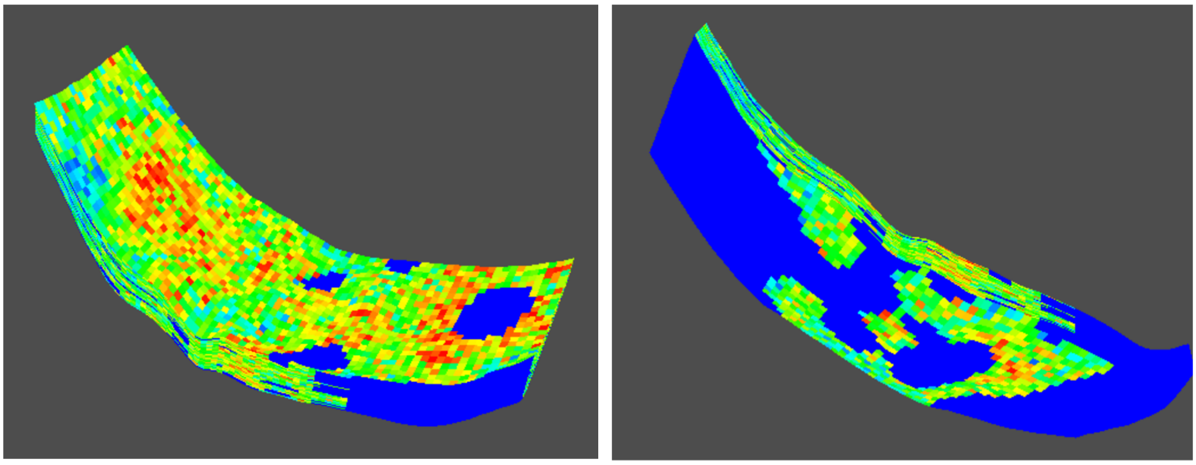


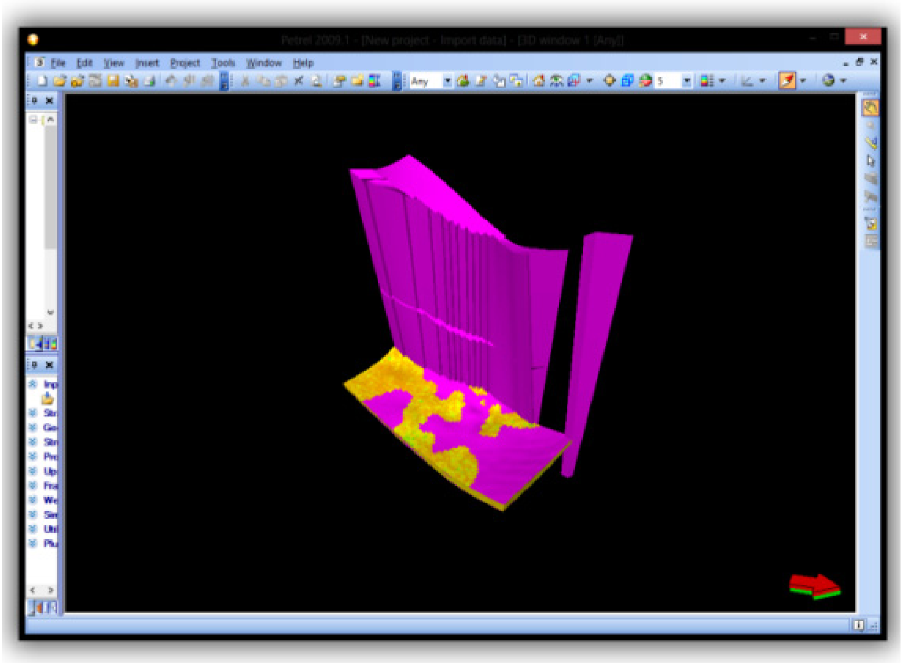
Figure 2 *Demonstration of the visualization module using the Vulkan API.*

Conclusions

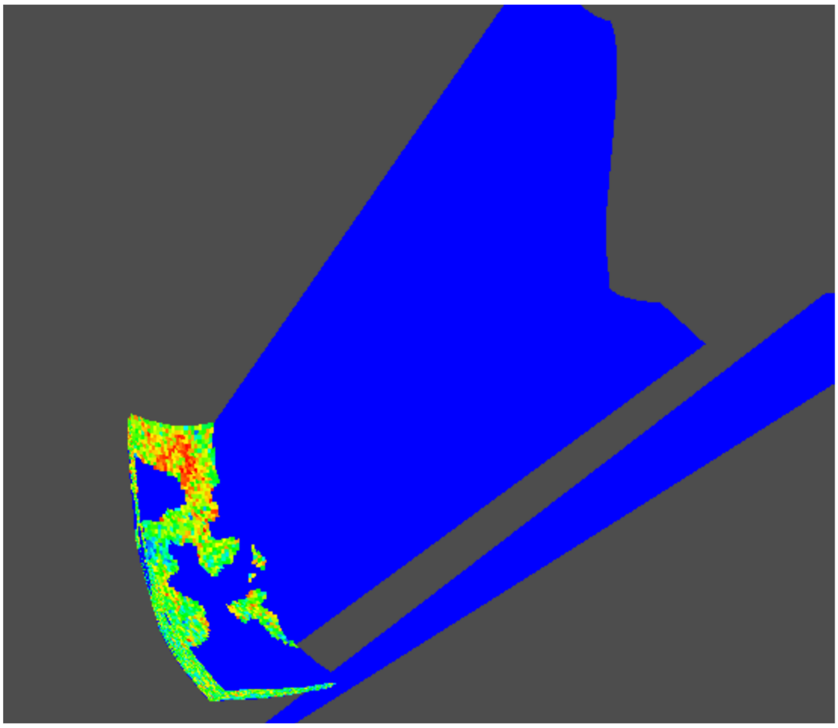
The proposed architecture uses a service-oriented approach, consisting of a three-tier system. The first level is the level of resources, consists of distributed computing resources and a repository of scientific data, as well as a register of scientific applications for uploading to the lower-level application management service. The second, service level consists of an application management service, a task launch service on clusters and a scientific data service. The top layer is a client layer, consists of client applications running on the Web and mobile platforms, as well as the associated web services interfaces providing data from the top-level scientific data service (Figure 1).

The proposed system has the following advantages:

- access from anywhere in the online mode;
- the analyzer program is located on a high-performance resource, which facilitates the process of administration, service, debugging and revision of the program;
- calculations are performed on computing clusters, which significantly reduces the time of decision making;
- the ability to connect and integrate with databases of the head offices of oil companies;
- Mobility (rapid analysis of oil recovery technologies on mobile devices, execution of calculations directly on the field, where access to complex programs such as Eclipse, tNavigator is not available, but at the same time, operational miscalculation of possible development scenarios with the use of enhanced oil recovery technologies);
- Performance (the ability to perform calculations on high-performance systems and process data on the fly);
- service (the user is not required to purchase the whole product, but only those services that he needs);
- the ability to quickly read data and optimize well parameters in field conditions (sensors, drone, controllers);
- preprocessing of data on wells from sensors;
- synchronization of well parameters on the model in real time in field conditions (synchronization with the Web and mobile applications).



a)



b)

Figure 3 *The Kenbai test model using the Petrel visualizer and the simulator visualizer with the Vulkan API.*

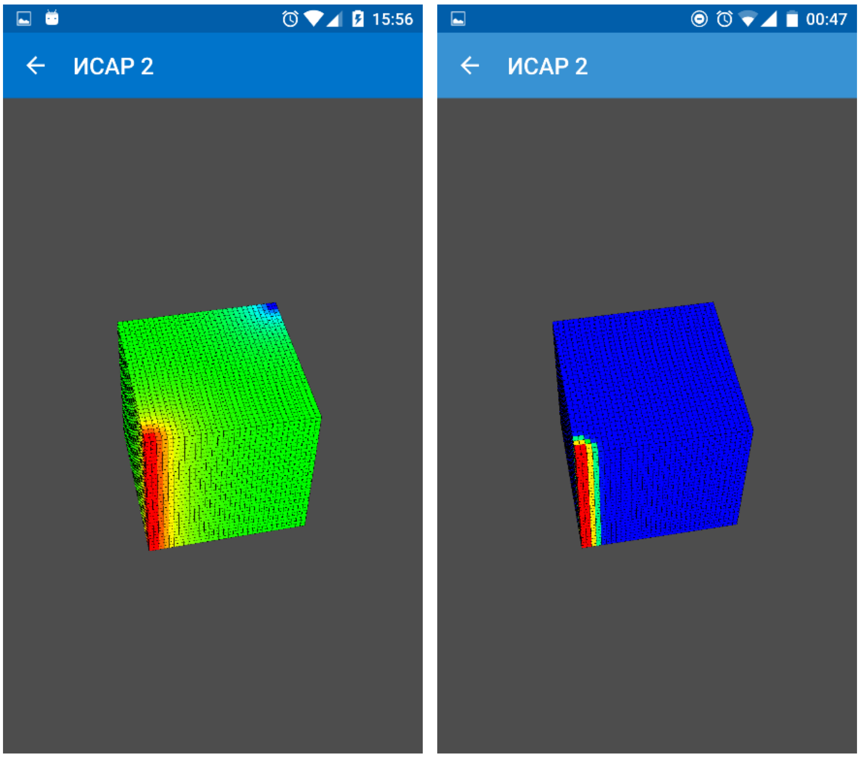


Figure 4 *Visualization of calculations on a mobile platform.*

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