Reasons for choosing the research topic

The energy consumption is becoming a critical issue due to the significant increase of operation costs in modern computer systems. In consequence, reducing the energy consumption turns into the primary objective for scientific and industrial environments, which are related to large-scale calculations. It is estimated that reducing the energy consumption by one megawatt could save about 1 million $ per year. Given the rapidly climbing power bills, as well as the negative impact of energy production technologies on the environment, achieving power and energy efficiency of parallel systems and applications has become one of the most challenging issues.

Problems with computer systems requiring excessive energy have led to the introduction of massively parallel architectures such as many-core graphics processors GPU. It is highly conceivable that some future processor designs will not be faster but "only" more power-efficient than their predecessors. This trend started in the mobile and embedded market, but will soon hit scientific computing as well.

Due to the increasing energy requirements of computer systems, the energy optimization becomes a very promising direction of research and development. To a large degree, this is addressed by the manufacturers of computer systems at the level of hardware and operating system.
Taking up the challenge at the level of application development requires to design new methods and algorithms which provide high performance of computations keeping relatively low power consumption. The success of these efforts in conjunction becomes crucial for the future of large-scale computations.

Objective of the project

The goal of our research is investigating the correlation between the performance and energy consumption in parallel computing environments, and managing them to minimize the energy consumption while keeping the high performance of computation. On this basis it will be possible to estimate the minimum energy consumed by an application, and ensure a favorable balance between the energy consumption and performance of calculations.

In particular, it becomes possible to determine a time in which the algorithm can be performed on a computing system, assuming that it should use the lowest possible energy. This time can be given in the form of an interval considering different models of the algorithm execution. In addition, based on the knowledge of characteristics of the algorithm and computing architecture it will be possible to introduce modifications to the algorithm, or to develop recommendations for developers of new algorithms, that allow for the execution of the resulting algorithm with a predefined energy consumption budget or within a given period of time, assuming the lowest energy consumption in this time.

We can also reduce the power consumption in numerical simulations providing for existing algorithms a similar level of computing performance by developing management mechanisms for computing platforms, without any modifications of the algorithms.

Description of the basic research to be carried out in the broject

The research planned in the project will include the following methodological aspects:

- Analytical and experimental models for forecasting the energy consumption and performance of calculations.
- Technique of dynamic voltage and frequency scaling (DVFS) for processors and memory, which is widely used in the process of saving energy.
- Redistributing part of an application to more specialized units - accelerators (GPU, Intel MIC, etc.) that achieve a higher performance at a lower energy cost for a given type of calculations.
- Modification of algorithms at the stage of their design and implementation, and delivery of mechanisms for managing computing platforms in order to reduce the energy consumption.
- Technique of self-adaptation of computations to multi- and manycore architectures, with a particular emphasis on machine learning methods, in order to model and optimize the energy consumption while keeping the high performance.
- Scheduling mechanisms which ensure high-performance calculations while minimizing energy costs.

The objectives of the project require a detailed monitoring of energy consumed by an application that is performed on a specific hardware platform. The energy consumption can be measured using the energy sensors located inside components of computer platforms. To analyze the collected results, it will be necessary to apply adequate metrics, such as GFlops per Watt, power consumption, computation intensity, etc. In order to collect the necessary information from the system, we will use a set of tools, including: EnerMon, SchedMon, EML: Energy Measurement Library, PowerPack tool, Intel Running Average Power Limit (RAPL).