H.F.R.I.
Hellenic Foundation for Research & Innovation

Description of the funded research project

1st Call for H.F.R.I. Research Projects to Support Faculty Members & Researchers and Procure High-Value Research Equipment

BALSAM

Beyond Worst-Case Analysis in Approximation Algorithms and Mechanism Design

Title of the research project: **Beyond Worst-Case Analysis in Approximation Algorithms and Mechanism Design**

Principal Investigator: **Dimitris Fotakis**

Reader-friendly title: **BALSAM**

Scientific Area: **Theoretical Computer Science, Algorithms and Complexity**

Institution and Country: **National Technical University of Athens, Greece**

Host Institution: **National Technical University of Athens**

Collaborating Institution: **University of Wisconsin-Madison**

Budget: **170.000 E**

Duration: **36 months**

ΕΛ.Ι.Δ.Ε.Κ.
Ελληνικό Ίδρυμα Έρευνας & Καινοτομίας

Research Project Synopsis

We aim at circumventing strong lower bounds and negative results, imposed by worst-case analysis, and at a deeper understanding of the algorithmic properties of fundamental problems in the research areas of Approximation Algorithms and Algorithmic Mechanism Design for “typical” instances that appear in practice.

We will study central problems in the research areas above, under realistic assumptions on the structure of the input. These assumptions will be deterministic, e.g., that the optimal solution is stable to small input perturbations, or stochastic in nature, e.g., that the valuation functions of the participants in an auction follow some fixed distribution.

In the area of Approximation Algorithms, we will investigate the computational complexity and the approximability of clustering problems, such as the problems of *k*-median, *k*-means and *k*-center, and network infrastructure design problems, such as the problems of facility location and minimum spanning tree, when the connection costs are time-evolving. We will focus on perturbation-stable instances, where the perturbation stability assumption will be appropriately adjusted to take the temporal dimension of the problems into account.

In the area of Algorithmic Mechanism Design, we will determine the tradeoff between the level of perturbation stability and the approximation ratio (with respect to the social welfare) achievable by truthful mechanisms for *k*-facility location games on the line and in general metric spaces, and for combinatorial auctions.

Project Originality

The research agenda of so-called “*beyond worst-case analysis*”, which aims at a deeper understanding of the algorithmic properties of fundamental computational problems for practically relevant instances, has been significantly developed in the last few years and keeps developing rapidly.

The project aims to make a substantial research contribution to the research agenda of beyond worst-case analysis. Its originality concerns the following, among others:

- This is the first time that the methods and the techniques of beyond-worst-case analysis have been applied to the design of efficient truthful mechanisms and of efficient approximation algorithms for optimization problems with time-evolving costs.
- This is the first time that “typical” practical instances of optimization problems with time-evolving costs and combinatorial auctions have been investigated, and the notion of perturbation stability has been used as a means of characterizing such instances.
- The project develops novel algorithmic techniques for optimization problems with time-evolving costs and aims at a deeper and unified understanding of their algorithmic properties, which is missing from current literature.
- The project studies, for the first time, how the design of efficient truthful mechanisms can be facilitated, if we focus on practically relevant instances, and proposes new forms of truthful mechanisms that best exploit this direction.

Expected Results and Research Project Impact

- A deeper understanding of the algorithmic properties of optimization problems with time-evolving costs and the development of a unified approach to the design and analysis of efficient approximation algorithms for such problems.
- The extension of the notion of the stability of the optimal solution to small perturbations of the input, and its exploitation for the characterization of “typical” practical instances in the contexts of combinatorial auctions and optimization problems with time-evolving costs.
- The development of a wide knowledge framework related to the design of efficient truthful mechanisms for perturbation stable instances.
- The formation of a research group, mostly consisted of young researchers, with top-notch expertise in the important and timely research directions of optimization over time-evolving costs and truthful mechanism design.
- Accumulation of state-of-the-art algorithmic knowledge, with significant practical applications and potential of economic and social growth though its application and exploitation.
- Further development of research culture related to high quality, high risk and high gain algorithmic research.

The Importance of This Funding

The research project involves basic research, purely theoretical in natural, in the area of Theoretical Computer Science, and specifically, in the field of Algorithms and Complexity.

Basic research of this kind is impossible to be conducted without financial support from research agencies, such as HFRI, which encourage and provide funding for high-risk-high-gain research.

More specifically, the financial support of this project allows us to:

- Form a solid research group, mostly consisted of young researchers, with state-of-the-art algorithmic knowledge in important and technological timely sectors.
- The further development of the collaboration and the knowledge transfer from a world leading research group in the field, that of UW-Madison.
- Accumulation of state-of-the-art algorithmic knowledge in the project's research directions and the further development of the algorithmic research culture.

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