Towards Management of Complex Modeling through a Hybrid Evolutionary Identification

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ABSTRACT[1]

Complex systems' modeling and simulation are powerful ways to investigate a multitude of natural phenomena providing extended knowledge on their structure and behavior. However, enhanced modeling and simulation require integration of various data and knowledge sources, models of various kinds, intelligent components in one composite solution. Growing complexity of such composite model leads to the need of specific approaches for management of such model. To support automatic building and management of complex models we propose a general evolutionary computation approach based on an evolutionary investigation of model phase space to identify the best model's structure and parameters.

CCS CONCEPTS

• Computing methodologies → Model development and analysis • Computing methodologies → Bio-inspired approaches • Theory of computation → Evolutionary algorithms

KEYWORDS

Modeling and simulation, complex systems, uncertainty management, data mining, machine learning.

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1 INTRODUCTION

Today the area of modeling and simulation of complex systems (CS) [1] evolves rapidly. As a result, contemporary model of a complex system could be easily characterized by the same features of CS. Within the current research, we are trying to develop a unified conceptual and technological approach to support core operation with a complex model. We consider a combination of evolutionary computation (EC) and data-driven approaches as a tool for building intelligent solutions for uncertainty management and providing the required level of automation, adaptability, extensibility.

2 CONCEPTUAL BASIS

To distinguish between main modeling concepts and operations, we propose a conceptual framework for consideration of key processes and operations during modeling of the CS. The framework may be considered as a generalization and extension of a framework [4, 5] previously defined and used by authors for ensemble-based simulation. The framework considers three main layers of CSs' modeling (model, data, and system) and three key concepts (quantitative parameters, functional characteristics, and structure). We identify six patterns of modeling and simulation of a CS: regular modeling of a system (P1); data-driven modeling (P2); ensemble-based modeling (P3); data-driven complex modeling (P4); EC modeling (P5); investigation of system phase space (P6). Implementing evolution of models within a complex modeling task structure, functional and quantitative parameters are usually considered as genotype whereas model output (data layer) are considered as phenotype. Within the proposed approach we can adapt basic EC

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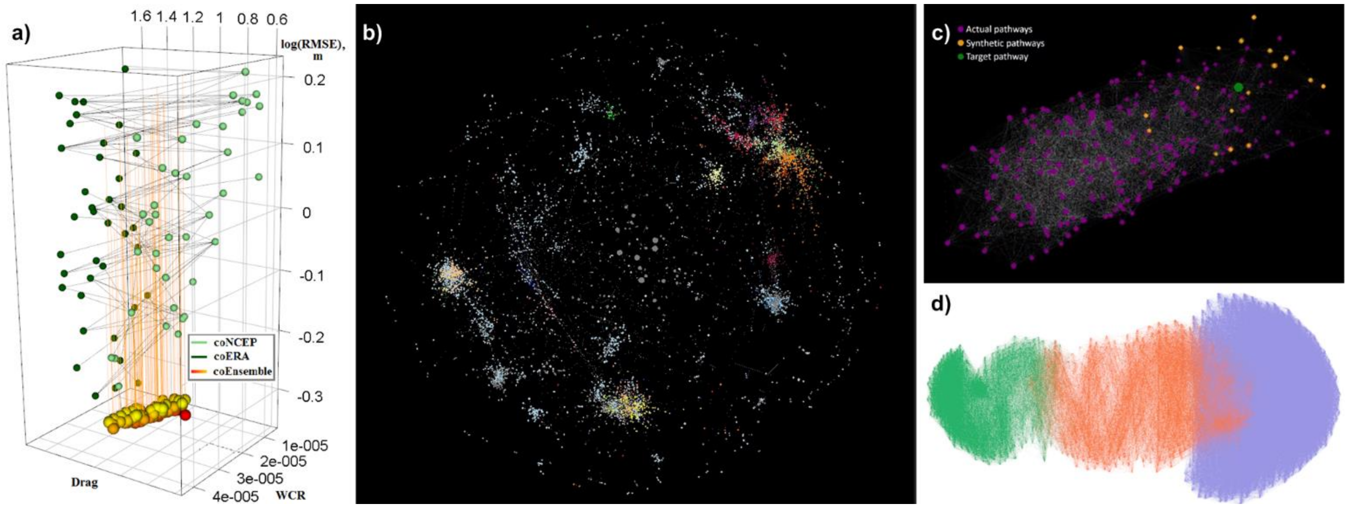

Figure 1: Application examples: a) co-evolution in metocean simulation; b) processes space in healthcare; c) evolution of possible clinical pathways in healthcare; d) graph-based representation of processes space for tree clusters in social media activity.

operations definition within genotype-phenotype mapping [2] and extend them with additional data-driven operations for quality assessment and model management.

3 APPLICATION EXAMPLES

This section presents several practical examples where the proposed approach was applied. The examples were intentionally selected from diverse problem domain to consider generality of the approach.

Metocean Simulation. We design ensemble model (P3) that consists of two instances of the SWAN[2] model for sea wave simulation (with different surface forcings) with two parameters (wind drag and whitecapping rate (WCR)) being calibrated using co-evolutionary algorithms (Fig. 1a shows Pareto frontier for ensemble). The approach shows significant efficiency up to 18 times compared with direct search. Also, the co-evolutionary approach provides 10 % accuracy gain compared with the evolution of ensemble models along (coNCEP, coERA in Fig. 1a).

Modeling healthcare processes are usually related to the enormous uncertainty and variability even when modeling single disease. We applied the proposed approach for identification purposes both in the analysis of historical cases and prediction of single process development. Here we consider processes of providing health care in acute coronary syndrome cases. We introduced a graph-based representation of this space[3] using the proximity of cases (see Fig. 1b). Also, EC algorithms were developed for patterns identification and clustering in such representation [3] and modeling the dynamic development of the process with assimilating of event data[4] (Fig. 1c).

Mining social media. We've collected a dataset of recent (last 100 records) activities of 8K users in largest Russian social network vk.com containing original post (P), re-posts (R), and comment (C). We applied a technique used in the previous example to the investigate the space of processes. In that case, tree intersecting clusters (Fig. 1d) could be interpreted as typical behavior models. This is very early results of the study, but we believe that further extensions could enhance discovery of model structure (P4) and provide deeper insight on social media activity investigation.

4 CONCLUSION

The development of the proposed approach and its applications is still an ongoing project. We are aimed towards further systematization and detailing of the proposed concepts, methods, and algorithms, as well as more comprehensive and deeper implementation of EC-based applications. A set of questions for future consideration include: detailing on the role of data-driven and intelligent operations in EC algorithms, investigation on EC-based discovery of models with an unknown structure for weakly observable systems, formalized and non-formalized knowledge processing and acquisition through the model-based investigation, and others.

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[2] http://swanmodel.sourceforge.net/

[3] Demonstration available at https://www.youtube.com/watch?v=EH74f1w6EeY

[4] Demonstration available at https://www.youtube.com/watch?v=twvfX9zKsY8