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TECHNICAL ENGINE FOR DEMOCRATIZATION OF MODELING, SIMULATIONS, AND PREDICTIONS

Justyna Zander

Harvard University, HHI
SIMULATEDWAY
Cambridge, MA, USA; Berlin, GERMANY

Pieter J. Mosterman

MathWorks
McGill University
Natick, MA, USA; Montreal, CANADA

ABSTRACT

Computational science and engineering play a critical role in advancing both research and daily-life challenges across almost every discipline. As a society, we apply search engines, social media, and selected aspects of engineering to improve personal and professional growth. Recently, leveraging such aspects as behavioral model analysis, simulation, big data extraction, and human computation is gaining momentum. The nexus of the above facilitates mass-scale users in receiving awareness about the surrounding and themselves. In this paper, an online platform for modeling and simulation (M&S) on demand is proposed. It allows an average technologist to capitalize on any acquired information and its analysis based on scientifically-founded predictions and extrapolations. The overall objective is achieved by leveraging open innovation in the form of crowd-sourcing along with clearly defined technical methodologies and social-network-based processes. The platform aims at connecting users, developers, researchers, passionate citizens, and scientists in a professional network and opens the door to collaborative and multidisciplinary innovations. An example of a domain-specific model of a pick and place machine illustrates how to employ the platform for technical innovation and collaboration.

1 MOTIVATION, BACKGROUND, AND VISION

The current exponential growth of technologies is providing novel, frequently as of yet unimagined ways of leveraging its applications for human needs. Ubiquitous communication capabilities allow for a redefinition of computer-based solutions to provide a new and better world for people (e.g., Diamandis and Kotler 2012). Computing plays a critical role in advancing research across almost every scientific discipline. The fact that everyday computing is becoming exponentially cheaper holds the promise to vastly increase manifold data flows and revolutionize the practice of science and engineering. Some of the observed trends are big data, cloud computing, open and interoperable interfaces, social computing, pervasive computation and cyber-physical intersections. These trends will be briefly reviewed in the following to motivate the content of the paper.

The *performance* of computers has shown remarkable and steady growth, doubling every year and a half since the 1970s (Kurzweil 2005). Even smaller and less power-intensive computing devices proliferate, paving the way for new mobile computing and communications applications that vastly increase our ability to collect and use data in real time (cf., Computing Technology Review, 2011). As a consequence data volumes are growing exponentially. The collection, management, and analysis of data is a fast-growing concern of many research groups (MIT Human Dynamics Lab). Automated analysis techniques such as data mining and machine learning facilitate the transformation of data into knowledge, and of knowledge into action (Hey et al. 2009). Strategies to handle "*big data*" are required in many disciplines (Pollak 2006).

Cloud computing, in which users have access through the Internet to shared computing resources, software, and data, makes massive computational and storage capability available to everyone, at a decreasing cost as documented by Hardesty (2010). *Interoperable interfaces* enabling intelligent components to communicate are an important stimulus to innovation and adoption. For example, electronic health records as a common data storage in the cloud can be shared, added, and processed by many parties. Such interfaces may often be *open, public, and transparent* to allow anyone to create products that cater to these interfaces without paying fees.

Further, the emergence of *social computing*, communication, and interaction through social networks, make mechanisms such as crowd-sourcing coordination, and control from a distance available. The manner in which people interact has been transformed. People around the world can collaborate to create things such as an encyclopedia, smart cities, or reliable cars.

Open source software is another important trend. It denotes software whose source code is available to others, often without any financial charge. This software is created by volunteers or by companies who wish to make certain software widely available and enable others to read it or change it.

The *ubiquitous network* that has become a reality has caused an inundation of data. Combined with the exponential growth of computing power, a critical need for understanding computation fundamentals and its application has emerged. The next wave of discovery and innovation comprises powerful computation, data mining, and knowledge and wisdom management (Surowiecki 2004).

Hence, simulation- and prediction-based reasoning is gaining a broad acceptance in multiple disciplines. In general, computing is playing a critical role in advancing both research and daily-life challenges. As a society, we every day apply search engines, social media, and selected advances in engineering to improve personal and professional growth. Recently, leveraging such aspects as behavioral model analysis, simulation, big data extraction, and human computation is gaining particular momentum. The nexus of the above facilitates users in receiving awareness about their surroundings and about themselves. In this paper, customized predictions are envisioned to improve this process.

A **technical framework** to explore the utilization of the above trends is introduced herewith. It is represented by a technical online platform for modeling and simulation (M&S) on demand (*'in the cloud'*) to open the technical frontier for technologists and ultimately unlock prediction potential for the masses based on a blend of human and machine computation. In a long-term vision, implementations based on the framework design allow an average technologist to capitalize on the information analysis provided by scientifically-founded extrapolations, reasoning about dynamic system behavior, and big data. The **technical engine** (**TING engine**) behind the platform is proposed as an open source, extendable, crowd-sourcing enabled, and self-sustaining technical environment. It accelerates the use of traditional M&S outcomes from multiple disciplines by offering selected multi-paradigm technologies (cf., Mosterman and Vangheluwe 2004) and integrating the process of using various M&S tools from many different domains. The integration is performed in multiple manners. Multi-domain tools that become accessible from one common environment using the cloud-computing paradigm serve as a starting point. The next step of integration happens when various M&S execution semantics (and models of computation (cf., Lee and Sangiovanni-Vincentelli 1998; Lee 2010) are merged and model transformations are performed. The engine then makes the simulation results accessible and understandable to arbitrary individuals for further analysis (e.g., to unlock the prediction power). This process leverages open innovation and crowd-sourcing along with clearly defined technical methodologies. In this manner, the platform aims to connect users, developers, researchers, passionate citizens, and scientists in a professional social network and opens the door to collaborative and multidisciplinary innovations.

This paper claims that now is the time where technology maturation enables a relatively seamless integration of the above-mentioned concepts into one *comprehensive framework (from both the technical and societal perspective)*. And so, prediction based on (1) big data analysis and on (2) dynamic behavior models can be merged. Scientific computing is then transferred to the cloud and made available independent of the device that is used to perform it. The innovative leverage of social networking advantages, crowd-sourcing, human-based computation (i.e., a computer science technique in which a computational process performs its function by outsourcing certain steps to humans to achieve symbiotic human-computer operation (von Ahn et al. 2008)), and the, even more rapidly growing, multidisciplinary cooperation (from both the multi-paradigm modeling domains and the application domains view) enable, encourage, and trigger the community to make progress as it has always been envisioned but not yet achieved (Levytskyy et al. 2009).

Section 2 first presents a technical introduction to TING engine. Section 3 illustrates some aspects of using the proposed framework based on an industry example. Section 4 constitutes a presentation of related work, whereas Section 5 concludes the paper.

2 TECHNICAL ENGINE

In this section, the user interface, objectives, and the architecture of the engine are presented.

2.1 A technical introduction of the engine

The TING engine **connects passionate** citizens, users, developers, researchers who aim to make a difference in the world by receiving more **awareness** about the current and future-projected surrounding and about themselves, in particular, relating to challenges that matter because of their large **impact**. Underneath the platform, a **technical engine** is continuously available to process information that is provided by researchers and crowd-sourced by the community using the means available through an online portal. The user is defining problems, queries, and challenges that are collectively called *prediction queries*. The engine, in turn, unlocks the potential for receiving computational analyses and ultimately predictions of the future scenarios (e.g., solutions) for a selected **prediction query**. This process occurs by enabling the **technical means** (e.g., creating and/or using existing models, case studies, additional structures), **mechanisms** (e.g., adding and/or applying simulation tools), and **processes** (e.g., big-data mining, transformation algorithms, search and future trends-related algorithms, knowledge management means) for managing, modeling, simulating, and analyzing the adequate and query-specific knowledge. A quick overview of the TING project vision is presented in Figure 1 where a prediction query is the input to the engine and a prediction response is the output. The contents of the engine in the blue rectangular boxes with rounded corners are intended to be collaboratively built and analyzed by the community.

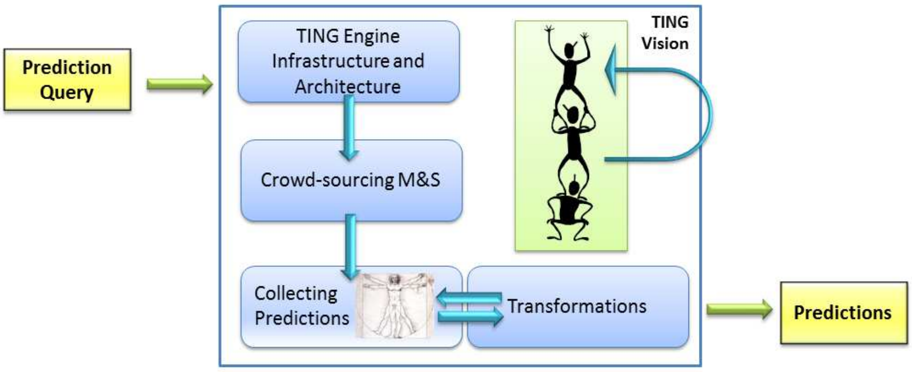


Figure 1: Vision of TING project

2.2 User Interface

The user interface of the TING platform comprises different projections (so called *Views*) as illustrated in Figure 2 that are linked to one another. Each view includes mechanisms and some of the functionalities of other views.

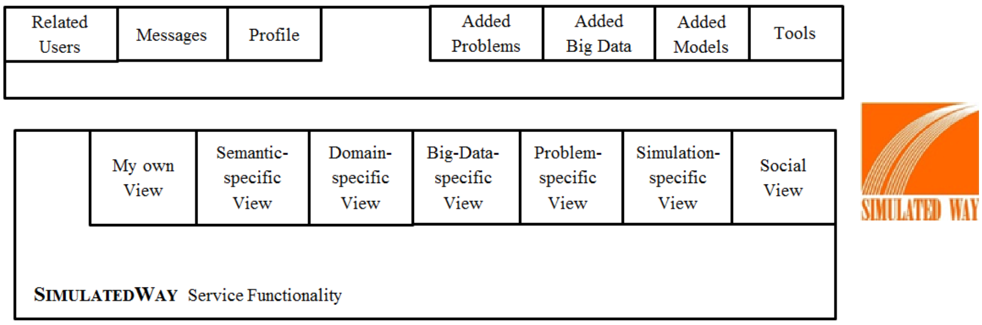


Figure 2: A proposed user interface for TING functionality including the *Views*

The TING engine objectives are strongly motivated by a socio-psychological target introduced by Goetz (2011), with the persuasion that proper technological means provided to society are going to help humans create a positive awareness effect in their lives. To this end, as illustrated in Figure 2, selected *Views* on the TING engine are available to the user:

- A *Social View* is a social business network dedicated to a community of interested in technical advances of M&S and predictions enabling to help each other grow and exchange relevant information.
- A *Simulation-specific View* includes a mechanism to input and manipulate a model for a specific problem or its solution. In addition, a set of simulation, transformation, or analysis tools can be added or applied. This allows the models, their execution traces, and problems that they solve (e.g., prediction query) to be related to each other.
- A *Problem-specific View* comprises a mechanism to enter and manipulate the problem space. A user is then encouraged to contribute to the solution of the particular problem (e.g., a prediction query or grand challenge, etc.) inputting and/or using the data, analysis means, and simulation technologies available in the engine.
- A *Big-Data-specific View* allows for adding and manipulating sets of data that are then applied for the predictions.
- A *Domain-specific View* enables relating the contents of all the above *Views* to a particular application domain (e.g., automotive, aerospace) or development-related domain (e.g., model-based design, models-based testing, and cyber-physical systems).
- A *Semantic-specific View* relates to the technical semantic description of the simulation execution. It mostly supports scientists, researchers, and/or engineers in developing the semantics of dynamic analyses and simulation engines.
- *My own View* is a user-defined view. The user type differs depending on the ultimate purpose and so, for example, a domain expert, modeler, or tool provider has different priorities from a mass-scale user interested in prediction.

The TING engine is a first step contributing to the vision called Computation of Things (CoTh) as defined by Zander et al. (2010) and Zander (2012). CoTh is a concept that sheds light on the application of new trends recognized in today's exponential technology growth for the needs of humanity as suggested by socially-oriented thought leaders (Schneiderman 2002). It is an approach to understanding the individual self and its surrounding based on the micro-scale information that combines with macro-scale data to enable prediction of different life scenarios. It serves to deliver guidance towards sustainable development for an individual, but if projected and combined with behavioral patterns of groups, communities, and nations, it provides knowledge about the world-wide changes and their potential global effects.

2.3 Technical and Scientific Objectives

In the following, the **technical and scientific objectives** of TING project are elaborated. The technical objectives include:

- Conceptualizing the framework and building the platform as an open and extensible open-source and crowd-sourcing enabled engine that includes components for a user-driven mechanism that facilitates platform infrastructure self-extension. In particular, providing an effective and efficient technical mechanism and process for adding such elements as, for example, model design environments, models, simulations, big data, historical and extrapolated data projections, etc., as well as constructing ontologies based on the gathered knowledge.
- Adding a user-driven mechanism to efficiently manage an arbitrary *prediction project* on the TING engine platform that is running online; conceptualizing behavioral user patterns, process, and technical means to implement this process. Building a highly readable and user-friendly front-end interface for adding and processing the prediction queries as well as other elements of the system (i.e., engine) in its specific views (cf., Figure 2)
- Building a collection of transformation patterns and directives to enable a bridge and a translation between a prediction query and selected sets of technical elements (e.g., models, simulation traces, and data).
- A further aim is to analyze the semantics of simulation, execution, and computational advances for numerical integration to ultimately apply Model-Based Design to building dynamic behavior execution engines (e.g., solvers as discussed by Mosterman et al. (2009) and the Simantics platform (Simantics)).

- Business analysis, process analysis, and optimization of the proposed engine.
- Building further technical means for interactive education engineering, collaborative problem/solution definition, teaching and learning, modeling and simulation (M&S), etc.

Scientific objectives are related to the technical objectives and can be summarized as:

- Better understanding of computation theory, model semantics, execution semantics, etc.
- M&S consistency check and practice improvements by acquiring additional knowledge and its influences from multiple application disciplines and various user types.
- Human-computer interactions, usability, and interrelations and permeation of the technology to the *Social View*.
- Design of user-related interactions in a *Social View* interlinked with technical *Views.*
- *Views* for unlocking the collaborative power and social dimensions of the problem and solution definition; usability studies.
- Decision making and human-technology feedback loop (cf., Goetz 2011).
- Query parsing and machine learning application based on existing algorithms (e.g., see Google Prediction Application Programming Interface (API)).
- Prediction preconditions and prerequisites definition.
- Software patterns, transformations, and transformation patterns design for extracting prediction scenarios.
- Model transformation patterns, directives, templates, and guidelines.

Figure 3 illustrates the technical aspects for TING. It consists of two logical components: a Technology Management System (TMS) and a Knowledge Management System (KMS). TMS includes such components as views, IT resources management unit, cloud-based tools and technologies, technical execution engine, guidelines and patterns for the users, and other possible extensions.

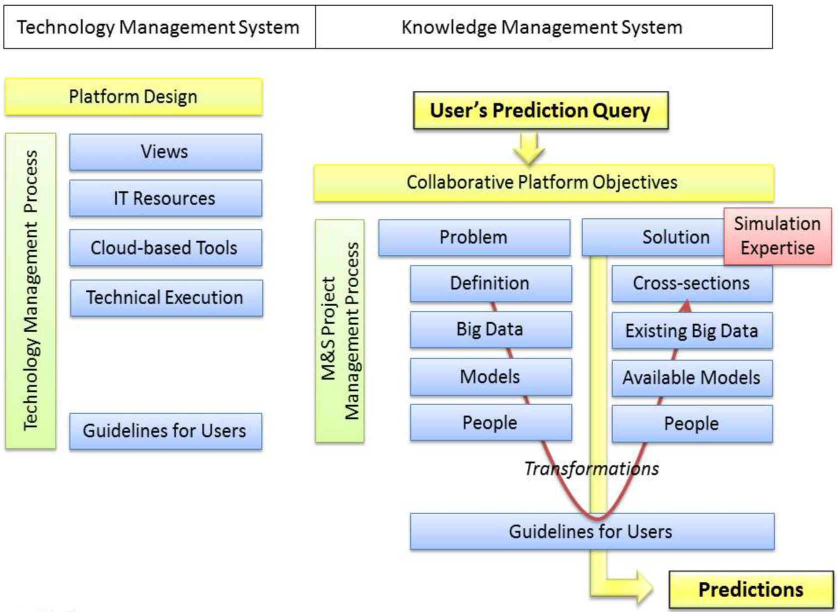


Figure 3: The TING engine—detailed view on its logical components

There is a TMS-based process in place to allow the user easy manipulation between the views, tools, and other resources stored in the engine. The engine resources include a space for a collection of problems and solutions that comprise big data, models, simulation traces, technologies, and people who belong to the involved community. People are a crucial component of the TING engine as it is the community who fills the engine with the content in terms of both TMS (e.g., adding cloud-based tools to the engine) and KMS (e.g., defining problems, creating models, adding big data, proposing solutions). This is why a social business network must be included in the design of the entire platform and seamlessly integrated with the technical infrastructure and technical means offered to solve the problems. The execution-based *computational semantics framework* described by Mosterman et al. (2011) is incrementally advancing here as well.

2.4 Architecture

The architecture of the TING engine is based on cloud-computing as illustrated in Figure 4. Assuming that the Infrastructure as a Service is delivered as a platform virtualization from another party (e.g., Amazon Web Service (AWS)) TING offers Platform as a Service (e.g., logical units of TMS and KMS) and Software as a Service (e.g., simulation-specific tools accessible from the TMS).

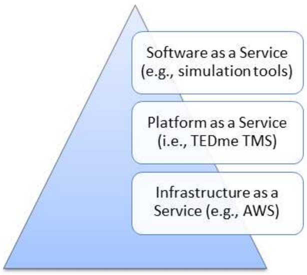
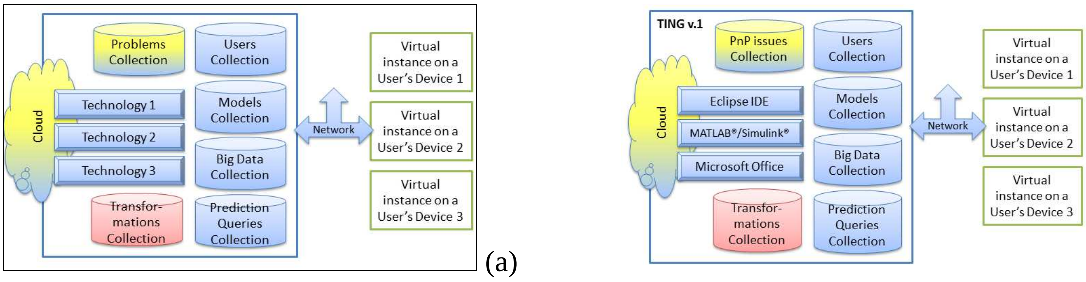


Figure 4: Presentation of TING embedded in cloud computing

An initial architecture of TMS components is illustrated in Figure 5(a). From the user perspective, working with the TING to solve a selected problem amounts to finding the correct set of internally- or externally-located services (e.g., simulation tools in the *Simulation-specific View*) that are available in the cloud. Figure 5(b) presents an instance of a TMS that includes such technologies as Eclipse Integrated Development Environment, MATLAB®/Simulink® , and Microsoft® Office Suites.



(a) (b)

Figure 5: Technology Management System architecture connected to the users' devices

3 METHODOLOGY BASED ON AN INDUSTRY EXAMPLE

In this section the usability of the engine is described in the context of a manufacturig application that comprises a pick and place machine. The designer defines a set of problem statements in the *Problem View*. Then, the technical specification is added. For example, the *Domain-Specific View* serves as a means to help the designer implement the modeling and simulation concepts. Clearly, the *Social View* and *Simulation-specific View* are helpful in identifying and refining human and technical components and cross-sections of the interacting domains that had been defined in the *Problem View*.. When the designer completes the tasks, behavioral predictions are the target that the TING engine should be able to derive (cf., Figure 1).

For the example that is introduced for the purpose of illustration in this paper,the *challenge* in the *Problem View* is formulated as follows. It is required to automatically move a set of objects from one location to another in a certain order using the currently available technologies (cf., *physics* Simulink subsystem in Figure 6). As such, it is a specification of a supervisory control and data acquisition (SCADA) system that includes exemplary robotics operation and that is prototypical of manufacturing applications. Such a system is referred to as a pick and place machine (PnP).

Moving ahead to the *Domain-Specific View,* and choosing a *cyber-physical-system (CPS) dimension*, the PnP is defined so that it may interact with *smart objects* that are to be moved. These objects may communicate with the PnP. For example, they can inform the PnP how fast they move, what their motion limits are, or what their load balancing is.

CPS is frequently characterized as smart systems that includes digital and cyber technologies, software, and physical components (PCAST 2007). A CPS is intelligently interacting with other systems across information and physical interfaces. It is expressing an emerging behavior and so creates multiple live functionalities during its deployment. A CPS is sensing the external world and reacts to the state of the surrounding environment.

The objects (i.e., blocks) to be picked and placed are specified as *smart* because of their functional flexibility encoded in software. For example, if the blocks want to be stacked in a selected manner, their own local control algorithm is modified while the PnP functionality remains unchanged. The end result is *an emerging behavior* such as a globally ordered stack of blocks that results from the local intelligence of the blocks. The PnP machine does not have to be reconfigured to achieve a different behavior, because the blocks include the logics that allows for their own internal control.

The benefit of using the *smart blocks* is that the supervisory algorithm of the PnP machine does not have to be changed, and so, there is no necessity to redesign and reapprove (e.g., certify) its functionality. The aspect of complexities related to a new design is shifted from the overall specification of the machine to localized models of the blocks. Clearly, any novel specification still requires a human factor, discussions, organizations that can be accomplished in the *Social View*, however, the complexities are reduced and filtered out by using a structured design framework where the domains are separated for the user's convenience, but still, functionaly related to each other.

Let us take one specific functionality of the PnP system as **an example**. The simplest case for illustrating the smart blocks interactions is an implemention of the Tower of Hanoi (ToH) (Hofstadter 1985; Gardner 2008). It is an algorithmic puzzle and it is also defined as a challenge in the *Problem View* in the engine. Conceptually, there are three rods (in the CPS version, locations where a stack of blocks can be placed), and two disks (in the CPS version, smart blocks) of different sizes that can slide onto any rod. The puzzle starts with the disks in a neat stack in ascending order of size on one rod, the smallest at the top, thus making a conical shape.

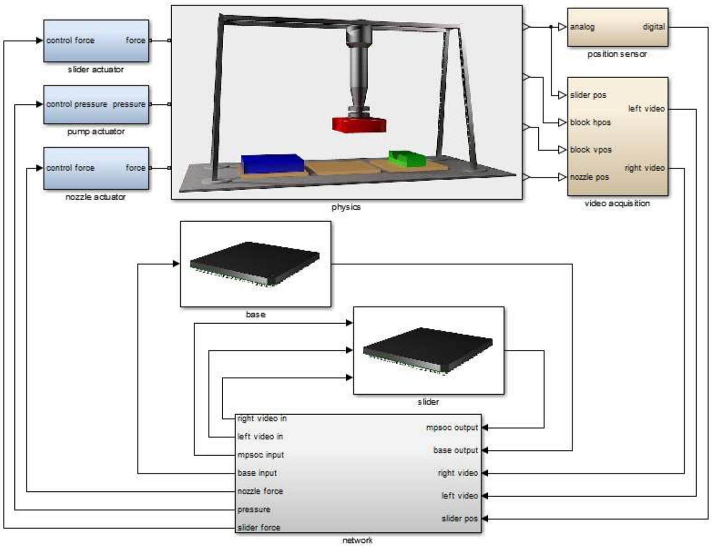


Figure 6: Intitial design of PnP in MATLAB®/Simulink®

The objective of the puzzle is to move the entire stack to another rod, obeying the following rules:

- Only one disk may be moved at a time
- Each move consists of taking the upper disk from one of the rods and sliding it onto another rod, on top of the other disks that may already be present on that rod
- No disk may be placed on top of a smaller disk

With two disks, the puzzle can be solved in three moves.

Now, because the challenge regarding the ToH exists in the TING engine , the designer may find an existing specification or even an implementation of the required algorithms. This saves time and redundant design. It also allows for investing the effort into refinement of the exisiting model instead of designing it *ab initio*.

Further, because the engine offers an interconnected *Social View*, it is possible to contact the authors of the specification or implementation. This feature creates a collaborative environment and opens novel ways of humans interactions in terms of technology exchange.

Embedding the puzzle in a complex setting, the particular PnP in this work includes a variety of *multiple-domains specific* operations such as:

- Stereoscopic image processing for depth perception when searching for objects to be picked
- Creating an airflow around objects to lift an object
- Services for composing pick and place operations
- Low-level feedback control to horizontally position the pick and place slider

Feedforward control to vertically position the pick and place nozzle

- Wireless communicatioin between the sensors, actuators, and processors
- Coordinating information exchange between the slider, nozzle, and objects
- Scheduling of the software tasks that provide the various services

Taking advantage of the TING engine, there is a *Simulation-View* that enables experimentation with the functionalities in the preinstalled tools available in the framework. In other words, the user is not required to install any technical application to investigate the above mentioned functionalities. Instead, they are available for a quick run and analysis. The PnP case study used for the purpose of this paper is designed in MATLAB®/Simulink® software as illustrated in Figure 6.

The **main benefits** of using the engine in this case study are the following:

(I) As mentioned before, by using a **structured design framework**, different views are architecturally separated so that the user can assimilate selected issues in separation, however, they are still, logically and functionaly related to each other. It is opening a frontier for democratic interaction between the designers to collaboratively develop and intelligently integrate different components, objects, systems, and humans as early as *at the design level*, according to model-based development cycles (Mosterman et al. 2005).

Simplified User Interfaces for the TING engine illustrating the *Domain-Specific View* are presented in Figure 7. First, the industry type, the approach, and tools can be selected for a specific problem. Next, a design can be provided by the user. At the same time, all other functionalities are available and can be linked to each other.

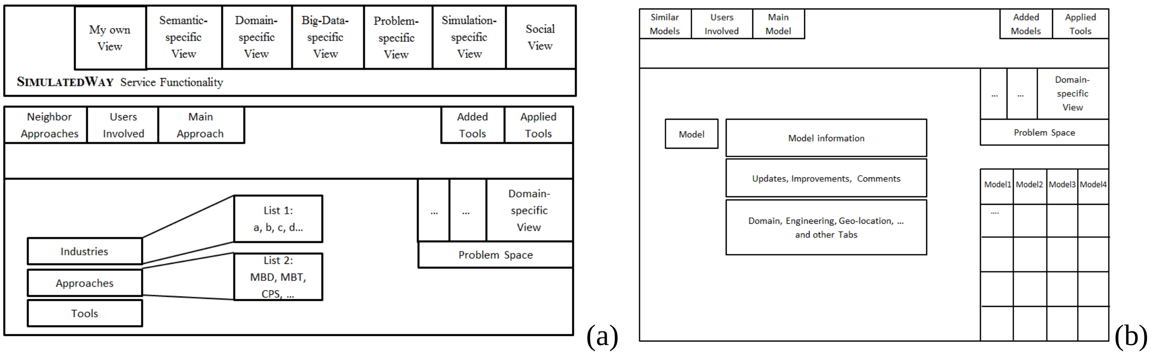


Figure 7: Simplified User Interfaces for TING engine illustrating the *Domain-Specific View*

(II) As far as the prediction engine functionality is considered, the **predictions** that the **designer** may be interested in are: (1) What is the frequency of pick and place operations? (2) Show a performance graph of pick operations versus a performance graph of place operations? (3) How long does it take to pick and place 50 objects of equal size/of different size?

(III) For the **mass-scale user** of the typical prediction engine interest may be in forecasts such as: (1) What is the expected energy consumption. (2) How do weather and climate conditions relate to the motion, depending on where the machine is being applied (e.g., think of kitchen robots and household facilities).

(IV) Further, from the designer viewpoint, *the evaluation, validation, and verification phases* of the entire system become simpler. Because of the clearly defined structure of the TING framework and all the embedded functionalities and interactions between the different views in the engine, specific metrics are pre-defined. They measure the success of the selected system design and integration phases. Based on those qualitative and quantitative measurements, improvement methods and patterns are suggested. Accumulative metric serves as a means for evaluating the predictions.

4 STATE OF THE ART

Although a framework that comprises the entire set of above-mentioned concepts does not exist yet, there is a remarkable amount of related work in terms of certain isolated or partially coupled innovations. As early as in the nineties, *collaborative modelling and simulation environments* have been discussed. For example, Iazeolla and D'Ambrogio (1998) elaborate that the effort to develop a simulation application can be drastically reduced if the user is enabled to access libraries of simulation models, retrieve a model of interest, modify it for reuse at the local site in a local application, and run the local application by accessing a simulation tool available elsewhere. They propose a web-based environment that helps a user discover which types of models or simulation tools exist elsewhere on the Internet, download the models, integrate and, finally, run them, accessing a tool at a remote site.

Concerning *big data analysis*, the Google Prediction API provides a means to analyze data based on a process including: data storage, training using machine learning, and prediction. For example, it allows for creating a basic movie recommendation, depending on what kind of data are available and how many calls are made to the prediction engine. The end-to-end movie prediction example examines the query: *given a movie and its genres, how likely will it be that a user likes it, on a scale from one to five?* Examples of TING-like *problem/solution–oriented frameworks* include the SPRUCE portal (cf., SPRUCE 2012) that is sponsored by the U.S. Office of Secretary of Defense and executed by the Air Force Research Laboratory Information Directorate or InnoCentive platform (cf., InnoCentive 2012). SPRUCE is an open web portal to bring together the broad Computer Science field represented by software developers, users, and software engineering researchers by collaborating on specifying and solving software producibility challenges. SPRUCE's concept of operations is designed to capture challenge problems and motivate a community to pursue solutions. Key features include: (1) self-organizing communities-of-interest, (2) dynamically evolving challenge problems with accompanying artifacts, and (3) built-in experimentation facilities to reproduce the problems and evaluate solution benchmarks. The content is broad and refers to real-time and embedded systems, multi-core architectures, and feature-oriented software analytics. InnoCentive is even broader in scope, it is a platform that incorporates the idea of crowd-sourcing. Here, the so-called challenges in any possible domain are identified by the users to quickly generate creative solutions to tackle them. To that end, an open innovation platform to drive sustainable change is proposed. The platform allows for a specific type of research and development, innovation, and product development to generate increased returns on innovation investments for a user. The TING engine presented in this paper limits the scope to computational and prediction-oriented computational thinking (see Report of a Workshop on The Scope and Nature of Computational Thinking, 2010) using M&S techniques as main solution drivers.

With respect to *simulation semantics* analysis, in particular in case of the semantics of dynamic analysis execution, it is imperative to study software development practices and Model-Based Design techniques (Mosterman and Vangheluwe 2004) because they allow inherently enforced domain constraints (e.g., laws of physics). Computational modeling as such is an important element in the design of engineered systems. For example, computational models, because of their predictive power, are an essential part in designing efficient control strategies (e.g., Mosterman et al. 2005), decision-making (Kahneman and Klein 2009), and early-warning systems (Coyle and Meier 2009). Given that a good model is one that helps solve the particular task at hand, a physical system may be represented by many different models. Each of these models is then most efficient for solving the particular issue under study, and, therefore, ideally only those phenomena observed in the system that are considered of importance are embodied by the model. All other phenomena are best abstracted away. This has brought about a need to raise the level of abstraction and to remove any 'accidental complexity' from the separate design activities. Model-Based Design has demonstrated its success in tackling these issues when building complex systems by supporting requirements traceability, executable specifications, automatic code generation, and facilitating continuous test and verification. In the *Semantic-specific View* of the TING engine, aspects such as modeling behavioral and physical phenomena, numerical methods used for simulation of the resulting models, and application of computational representations are addressed. Various simulation paradigms are explored (i) *discrete event* for the operations planning, (ii) *discrete time* for the signal processing, (iii) *continuous time* for the physics, and (iv) *discrete event* simulation of the network between sensors and actuators. An example of a platform for collaborative simulation-semantics studies is formerly mentioned Simantics platform for integrating simulation solvers and different engineering design systems.

Methods such as, for example, *online marketing, search optimization, and usability* relate to the business dimension objective (cf., von der Burg et al. 2011). Here such fast-growing companies as Recorded Future or Wolfram Alpha are prominent examples. Recorded Future is an undertaking that attempts to provide linguistic analysis about the future to a larger audience. Wolfram Alpha is a search engine that can understand a query such as "nuclear explosions in China" and deliver relevant information such as maps and kilotonnes per explosion. IBM developed Watson in a large research project dedicated to processing questions asked in natural language, based on four terabytes of structured and unstructured data sets, including the full text of Wikipedia. Quid data platform aims to map the world's emerging technologies, allowing other entitiess to gain more insight about specific sectors. It includes Microsoft among its customers as provided in Wired Magazine (2011).

Human feedback loop exploration relates to educational powers of the platform. MIT OpenCourseWare, MITx, edX (cf., edX platform), Stanford online courses, and similar efforts have started to emerge and so the TING engine aims to serve in the role of a hands-on education platform. The potential of the feedback loop to affect behavior was explored already in the 1960s by Bandura. He observed that giving individuals a clear goal, rewards, and a means to evaluate their progress toward that goal greatly increased the likelihood that they would achieve it. The TING engine objective is to investigate this topic in terms of data analysis.

5 CONCLUSIONS

In this paper, an online platform for M&S, and predictions has been proposed. Dynamic system simulation, big data, and cloud computing are the core concepts behind the service. The platform is an open source, crowd-sourced, and self-sustaining engine, called TING. It accelerates the use of traditional M&S outcomes from multiple disciplines by offering selected multi-paradigm technologies and integrating the process of using various M&S tools from different domains in one common environment. Finally, it makes the simulation results accessible and understandable to arbitrary individuals.

Societal innovation of the TING engine includes the following aspects: (1) democratizing the service of M&S to a technologically-literate citizen, (2) opening the design areas to the communities that currently have no direct and straightforward access to the combination of M&S technologies and assisting methodologies, (3) unlocking cross-pollination of knowledge from many areas (e.g., in the scope of *computation for humanity,* cf., Zander and Mosterman 2013), (4) unlocking the prediction ability, (5) leveraging human-based contribution (e.g., human-based computation, cf., Ushaidi, Wikipedia, etc.) to explore challenges that matter for the society and not only to the entertainment indstry (cf., Facebook purchasing Instagram (Yahoo News 2012)).

The expected *technical innovation* includes aspects such as: (1) application of cloud computing and virtualization (cf., spoon.net service), and open-source content management systems for M&S,(2) social view component, including crowd-sourcing, human-based computation, and social networking, (3) scientifically-based predictions, (4) convergence of multiple application domains, (5) raising societal modeling awareness and quality responsibility, (6) exploration of semantic autoverification, (7) exploration of autocomparison of simulation execution semantics (e.g., based on solvers), (8) facilitating education, project-based training, and hands-on experience.

The stakeholders that are anticipated to be interested in the TING engine are categorized into (1) a domain expert, simulation tool expert, simulation analyst, for building the contents of the engine (2) process analyst, business analyst, for business campaign, and proposer business models exploration, (3) infrastructure expert, for using and building the necessary technical means for the engine core, and (4) mass-scale user, such as, for example, a citizen analyst. Further work includes making the platform available publicly and implementing case studies that combine three selected domains.

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AUTHOR BIOGRAPHIES

JUSTYNA ZANDER is a postdoctoral research scientist at **Harvard University** and Harvard Humanitarian Initiative Fellow in Cambridge MA, USA. She is involved in creation of scientific programs and teaching at **Gdansk University of Technology** in Poland as a Visiting Professor and at **Singularity University** in California, USA as a Teaching Fellow. She is currently working on the execution engine and application areas related to **Computation of Things for Humanity**. In 2011, she founded **SIMULATEDWAY** for democratization of modeling, simulation, and predictions (patented solutions). Before, she was a researcher and project manager at the **Fraunhofer Institute for Open Communication Systems** in Berlin, Germany (2004-2010). She holds Ph.D. (2008) and M.Sc. degrees in the field of Computer Science and Electrical Engineering from Technical University Berlin in Germany, and a B.Sc. degree in Environmental Protection and Management from Gdansk University of Technology in Poland (2003). She received multiple international research and career awards (selection rates of 0.04%) from Poland, Germany, European Union, and USA. Her web page is https://sites.google.com/site/justynazander/ and her email address is justyna.zander@gmail.com.

PIETER J. MOSTERMAN is a Senior Research Scientist at **MathWorks** in Natick, MA and an Adjunct Professor at the School of Computer Science of **McGill University**. Before, he was a Research Associate at the **German Aerospace Center** (DLR) in Oberpfaffenhofen. He has a Ph.D. degree in Electrical and Computer Engineering from **Vanderbilt University** in Nashville, TN, and a M.Sc. degree in Electrical Engineering from the **University of Twente**, Netherlands. His primary research interests are in **Computer Automated Multiparadigm Modeling** with principal applications in design automation, training systems, and fault detection, isolation, and reconfiguration. Dr. Mosterman designed the Electronics Laboratory Simulator that was nominated for **The Computerworld Smithsonian Award** by *Microsoft Corporation* in 1994. In 2003, he was awarded the **IMechE Donald Julius Groen Prize** for his paper on the hybrid bond graph modeling and simulation environment HyBrSim. In 2009, he received the **Distinguished Service Award** of *The Society for Modeling and Simulation International* (SCS) for his services as Editor-in-Chief of *SIMULATION: Transactions of SCS*. His web page is http://msdl.cs.mcgill.ca/people/mosterman/. His email address is pmosterman@yahoo.com.