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EDITORIAL

Inventive Approaches to Competitive Systems Engineering — Is There Anything New Under the Sun?

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1. Introduction

Invention is a complicated phenomenon and process which blends informing, envisioning, imagination, discovery, serendipity, luck, inception, conceptualization, detailing, analysis, implementation, and experimentation. A mind-map of the characteristics of the phenomenon of invention is shown in Figure 1. Beyond rhetorical invention (that is generation, selection, and evaluation of verbal arguments) [1], the subject of disciplinary heuristics can be an artefact, a process, a method, an organization, and so forth – practically anything that has been not in existence previously. Thus, the subject of invention usually reflects ingenuity, originality, newness, and creativity [2]. Invention is a unique form of convergence of these and many additional factors such as scientific and market knowledge [3]. The act of inventing also has a lot to do with design, especially with its early conceptualization part, not only procedurally, but also cognitively [4]. As Jiang, P. et al. interpreted it, the novelty and inventive steps of patented mechanical designs increasingly rely on their growing complexity, interacting geometric features, and how they contribute to device functions. These features and interactions are normally incorporated in patents [5]. The subjects of personal and industrial inventions can be (i) non-natural processes, (ii) artefacts and machines, (iii) methods of manufacture, (iv) material compositions, (v) synthetic living plans, and (vi) unique design ideas [6].

Although, each of them relies strongly on imagination, ingenuity, and creativity of the human being, in overall, invention is not the same as discovery or design. Inventiveness is the quality and ability of having or figuring out new and original ideas and approaches, while design is bringing feasible ideas to the gate of a practical realization or production. Inventive researchers, designers, and engineers are good at using their imagination and making prospective decisions [8]. Inventions utilize some affordances and solve particular problems, but not necessarily address a particular application context. Therefore, some of the

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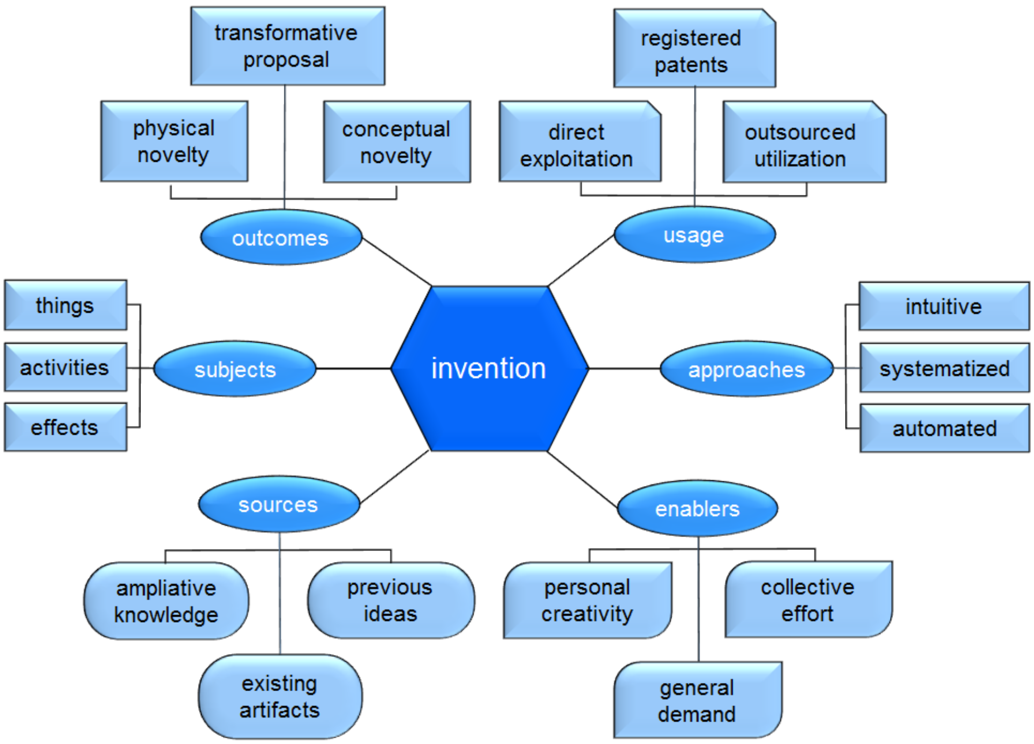

Figure 1: A mind-map of the characteristics of the phenomenon of invention

inventions do not add any worth. The major conditions generally required for success are such as desirability, feasibility, and viability. The sense of invention is often confused with the sense of innovation. Though the words innovation and invention overlap semantically, they are quite distinct concepts in practice and should not be used interchangeably [7]. Valuable inventions are converted into incremental or breakthrough innovations, but not vice versa. I read somewhere that the first telephone was an invention, the first cellular telephone was either an invention or an innovation, and the first smartphone was an innovation. In their seminal work, Myers, S. and Marquis, D.G. stated that "innovations are the units of technological change" [9]. As defined by Sternberg et al., innovation is "the channelling of creativity so as to produce a creative idea and/or product that people can and wish to use." [10]. Innovations are frequently triggered by needs and chances. That is, invention is about bringing in something new that has not existed in that form, while innovation introduces a change into an existing reality towards fulfilment or improvement.

The above introductory thoughts were deemed to be useful to describe the very focus, interest, and context of this special issue of JIDPS. In the knowledge economy innovation is mandatory [11], but what is with inventions? More specifically, how inventiveness can be achieved in such a conventional domain as general systems engineering? Can we see milestones of invention such as a steam engine, a transformer, a transistor, a television, a computer, and the like in the current days? Are there mentally fabricated original engineering marvels in our rapidly changing modern age? Or, are there only derivable inventions and incremental innovations that are driven by the need for continuous improvement? Are the published inventions and patent proposals based on the results of the ongoing ground-braking scientific inquiry and learning, or do they involve only small steps and low risk of adaptation? Is there anything new under the sun of engineering approaches?

This last question is not a poetic one. On a request, I tried to make an inventory and compile a position paper on inventive, non-traditional system engineering theories, methodologies, methods, tools, and processes. In the knowledge aggregation phase, a search with the term "systems engineering" resulted in approximately 20.000.000 results on Google and some 406.000 hits on Google Scholar. Another search with the term "competitive engineering" resulted in more than 255.000 hits on Google and 4.120 hits on

Google Scholar, respectively. I could conclude that the current grand-challenges for competitive engineering were such as sustainable mobility, healthcare and well-being, renewable energy generation, networked industry, convergence of disciplinary technologies, digital society and economy, smart built environments, and digital food production. It also became evidential that there are many key technologies in our days which can support inventive approaches in system engineering such as smart embedded systems, cyber-physical-social systems, industrial internet of things, DEFCH (dew/edge/fog/cloud/high-performance) computing, embodied artificial intelligence, massive data processing, system of systems integration platforms, self-supervised software technologies, and bits/atoms/neurons/genes fusion (bang) technologies. Conversely, to my largest surprise, the search phrase "inventive engineering approaches" provided only 4 (!) hits on Google and 1 relevant hit on Google Scholar.

This special issue was designed to cast light on some inventive approaches to competitive systems engineering. The motivation came from the outcome of the abovementioned effort to get deeper insights in resources of non-traditional system engineering as well as in the interest of the journal concerning the phenomenon and manifestation of convergence in the creative and inventive practices. The literature evidenced that an enormous number of phenomena were investigated and massive development efforts were invested in competitive systems engineering in the past. However, the relative lack of publications on novel inventive and creative approaches have indeed raised the impression that only the past efforts are revisited in different contexts currently, based on different technologies, tools, and methods, and with the goal of incremental innovation. But, is it really true that only known things are coming back in novel forms and contexts in system engineering approaches?

Obviously, the eight papers included in this special issue cannot provide a complete coverage of the research domain of inventive engineering approaches. Notwithstanding, they cast light on the wide variety of purposes for which inventive approaches have been dreamt up as well as on the variety of contexts in which they could be utilized. Most of the papers were presented in the open-access Proceedings of the Thirteenth International Conference on Tools and Methods of Competitive Engineering (TMCE 2020) Symposium. The papers released for a public debate in this special issue have been revised according to the COPE guidelines and with the intension to expose the ability and way of thinking of new ideas and methods. Their quest for inventiveness can be better understood if the essence and manifestation of invention is grasped. The following discussion is intended to support this.

2. What Does Invention Actually Mean and Imply?

In general, invention is depicted as a dominantly mental activity which also outreaches to the physical realm [12]. In practice, invention is a down-to-earth activity enabled by imagination, creativity, and knowledge, as fundamentals [13]. Typically, it is a creative problem-solving activity which is characterised by an innate indeterminism with regards to its procedures and its outcomes. Various psychological factors, like absorptive capacity [14] and morphological associations [15], have a strong influence on the conduct of inventive procedures. The categorization proposed by Kivenson, G. identified: (i) single or multiple concept combinations, (ii) concepts and devices for labour saving, (iii) direct solutions to a problem, (iv) adaptation of an old principle to solve an old problem, (v) application of a new principle to solve an old problem, (vi) application of a new principle to a new problem, and (vii) application of an accidental discovery as the most frequent types of inventions [16]. As a capacity, the inventive potential is influenced by (i) the competencies, gender, age, and education of the individuals specialised in a given activity, (ii) the organization of the work (free-lancer, team, crowd, and network), and (iii) attitudinal characteristics of the employers. As a performance, the inventive potential is also influenced by many other factors such as scientific knowledge, intellectual capacities, creative mind-set, professional insights, assumed benefits, social commitment, positive/negative experiences, market interest, etc.

Uncountable examples of inventions are known from the human socio-technical history. Inventions and inventors have been playing an influential role in the cycles of changes that the techno-scientific world has gone through along a timeline of evolution and growth [17]. The industrial revolutions could have not happened without a continuing accumulation of substantial, artefactual, technological, and procedural inventions. While inventions were associated with the work of outstanding scientists and engineers in the past, most inventions are nowadays created by researchers and developers working for large international corporations. Nevertheless, inventors can be (i) private inventors (competitive individuals), (ii) academic inventors (researchers and engineers), and (iii) industrial inventors (professionals and managers) [18]. According to their technological and social scales and impacts, (i) micro-level, (ii) mezo-level, (iii) macro-level, and (iv) mega-level inventions have been identified. As Robinson, W.K. posited, small businesses, solo inventors, women, and minorities lag behind their counterparts in patenting [19].

As key characteristics of invention processes, the importance of (i) pre-existing information and knowledge, (ii) accumulation of life experiences and know-how, (iii) triggering the emergence of inventive ideas, and (iv) application of immediate rational-empirical scrutiny is mentioned. Current understanding is that invention has neither theoretically robustly underpinned methodologies, nor all-embracing systematized procedural models due to its heuristic, intuitive, probabilistic, and emergent nature [20]. Even TRIZ does not have a scientifically derived and verified background theory, though it proposes a conceptual framework and a set of interrelated methods. It includes pragmatically chosen methodical elements such as the exactly 40 principles of inventive problem solving and the use of contradiction matrix. The compositional searches and creative associations are supported by, for instance, (i) problem modelling methods [21], (ii) analogical reasoning methods [22], (iii) formal ontologies [23], and (iv) meta-knowledge [24]. Arciszewski, T. provided a concise but comprehensive overview of the role of morphological analysis in methodological achievement of inventive engineering [25]. The bottom line is that successful invention requires individual creativity to happen, in which imagination and reasoning play an equal role.

Inventions are not for a direct satisfaction of technical and social demands and requirements, but they might be triggered indirectly by these. In the current time, inventions are in a closed loop with patenting. On the one hand, patents are the first, technically non-disclosing publications of inventions. On the other hand, the information available from patent documents and the surveys of inventions also trigger the thinking about new solutions and approaches. As Huber, J.C. argued, patents are commonly recognised as creative output and protected intellectual properties [26]. A large part of industrial and industrial inventors are patent originators, whose patenting activity depends on individual characteristics, knowledge flows, decisions in/about the R&D process, and business relations [27]. Evidentially, the joint use of knowledge sources from science-related channels (university and research centres) and from market-related actors (suppliers, customers, and competitors) positively influences both the quantity and the quality of patents produced by inventors [28].

3. Recent Approaches to Triggering Inventions

The literature of invention engineering methodologically differentiates (i) intuitive, (ii) systematic, and (iii) automated approaches. The intuitive invention approaches build on creative human abilities, heuristics, and activities. Researchers working in this field explain invention as the dialectic interaction of cognitive/creative capabilities (including individual problem-solving skills and human social learning abilities) and objective circumstances (scientific knowledge, technological affordances, organizational inertia, and business situations). Inventors may work according to their own individual processes or the institutional processes of their employers, but their ideas do not fall down from the sky. Ideas build on ideas and can be triggered! The former implies that inventions usually involve some level of replication, transformation, and recombination. The typical cognitive mechanism of ideation and invention is associative thinking. To facilitate idea generation, various cognitive techniques such as brainstorming, 635, random associations, SCAMPER, and synectics have been proposed [29]. Fleming, L. and Sorenson, O. argued that, in the history of technology, inventions have been described by a popular view as a process of recombination of technological components, where the latter refers to any fundamental bits of knowledge that may be used to develop inventions [30].

Trew, R., & Calder, J. reminded us to the saying of Alexander Graham Bell: "Great discoveries and improvements invariably involve the cooperation of many minds. I may be given credit for having blazed the trail, but when I look at the subsequent developments I feel the credit is due to others rather than to myself" [31]. The abovementioned authors posited sharing and collaboration as two important elements of the basis of modern (industrial) inventions. Recently, education for invention and for inventive engineering design has received strong attention [32]. Both the issue of organizing learning processes towards creativity [33] and the issue of development of creative problem solving thinking were addressed [34]. From the perspective of industrial innovation, Cohen, W.M. and Levinthal, D.A. discussed the concept of absorptive capacity as the potential of a firm to recognize, assimilate, and exploit external knowledge to facilitate inventions and patents [14].

Research is still in debt with clarification of what triggers (i) the inception or invasion of new ideas rooted in reality, (ii) invention in terms of the unconscious and undifferentiated "noise", (iii) guiding pragmatic random idea combination, and (iv) elaboration of invention frameworks for approaches such as parametric, epistemic, dialectic, and para-logical invention. The idea of computer aided invention (CAI) emerged in the 1990s with the aim to use computers as supporting devices for creative intellectual processes. [35] On the other hand, scientists evidenced that certain human cognitive and behavioural characteristics are non-computational in nature and placed computation and cognition into juxtaposition [36]. Their major argument is that the extensional and intensional equivalence of computation and cognition is not given. It means that significant limitations are to be encountered in terms of what can be accomplished with respect to simulating or replicating creative human abilities by digital machinery-based computation, and to reproducing the near unlimited degrees of freedom of human discovery and inventiveness [37].

Systematic invention approaches question and challenge the emphatic heroic theory (inventive genius) of invention [38]. They suggest that (i) inventiveness is a matter of scientific preparation, technological development, and (societal culture, and (ii) inventions can be stimulated and enhanced by systematic and collaborative approaches. Boufeloussen, O. and Cavallucci, D. emphasized that systematic invention means bringing together engineering problems and basic science knowledge [39]. Systematic invention approaches focus on structured processes, creative methods, and other resources of invention, and on the development of computational tools and methods. Arthur, W.B. argued that the process of invention has a certain logical structure common to all cases and that the process may be initiated by a need and/or a phenomenon and runs from principle exploration to working technology [40].

Typical examples of systemic approaches to invention are: (i) the morphological combination approach (MCA) [41], (ii) the TRIZ (also called TIPS) [42] [43], and (iii) the IDM [44]. They rely on different principles and practices. The creative principle of MCA is systematic - possibly multi-dimensional - composition. The fundamentals of TRIZ are: (i) a large number of inventive principles, (ii) aggregation of genuine ideas and novel patterns of technological enablers, and (iii) systematic (algorithmic) resolution of contradictions among these [45]. The inventive design methodology (IDM) includes a dynamic set of structured procedures aiming at ideation of a technical product or system design, starting with (i) initial situation analysis and (ii) formulating poly-contradictions, and terminates with (iii) generation of solutions concepts and (iv) selection of break-through solutions [46]. An accompanying goal of development of inventive design theories and formalized methodologies is proposing software tools for deployment. In the last two decades, ontology-based approaches were frequently proposed to enable systematized creativity [47].

Supported by the new spring of artificial intelligence research, the complex problematics of automated invention (re-)emerged in the last two decades [48]. The fact of the matter is that integration of disciplinary knowledge, convergence of technologies, and deeply-rooted synthesis methods together make it possible to think of non-human forms of invention that cut across disciplinary boundaries and provide transdisciplinary solutions [49]. An early forerunning example is unsupervised deep learning. Still in an embryonic stage, AI-powered invention systems would either execute a systematic exploration of search (or composition) spaces or apply randomized massive composition of principles and concepts, and would select the most promising solutions based on their fit for purpose and feasibility. These systems are assumed to be characterized by (i) free-choice goal setting, (ii) productive creativity, (iii) rational cognitive ability, (iv) autonomous operation, (v) evolving performance, (vi) communicative learning, (vii) massive efficiency, and (viii) unpredictable results.

The paradigm of automated artificial creativity/invention is surrounded by intense philosophical speculations, doctrinal debates, and economic foundations, as discussed by Dornis, T.W. [50]. According to many researchers, matured automated invention may create solutions that go beyond human imaginations. Walch, K. argued that this creative intelligence comes from: (i) the ability to generalize knowledge from one domain to another by taking knowledge from one area and applying it elsewhere, (ii) the ability to make plans for the future based on knowledge and experiences, and (iii) the ability to adapt to the environment as changes occur [51]. At the same time, there are many researchers who take a position on the other side and express their reservations. They argue about the lack of theories or fully-fledged computational approaches for handling phenomena such as emergence and understanding [52]. Another general concern is patentability of non-human inventions.

In view to patenting, AI-based invention is not only a cognitive, technological, and computational challenge, but also a legal issue and a social influencer. In fact, the relationship of automated inventions and juridical patenting has grown into a hot and urgent issue. The current law is devoid of doctrines, regulations, rules, and ethics for artificial creativity. In the current practice, typical requirements for patentability are (i) having human originators, (ii) uniqueness over a period of time, and (iii) presumable commercial/social usefulness. Knutson, K.R. stated that AI cannot satisfy the conception requirement of patent inventorship [53]. He also elaborated on some possible consequences of excluding AI from patent registration. Nevertheless, the main argument to deal with the issue of automated invention is that AI systems are becoming able to produce output independently and without direct human influence as their capabilities and autonomy are increasing exponentially. Frueh, A. came to the conclusion that “the current use of the term inventorship is not future-proof and calls for policy adjustments” and that “*droit moral* considerations should be eliminated from substantive patent law altogether” [54]. Yanisky-Ravid, S. and Liu, X. argued that “traditional patent law has become outdated, inapplicable, and irrelevant with respect to inventions created by AI systems” and urged to address the “issue of patentability of inventions created by AI systems” [55]. Should AI systems be capable of independently developing inventions, which are comparable with those historically created by humans, these should be patentable, for instance by the owner and/or the developer of the system.

As the above overview suggests, not only the propagation, but also the ministering and facilitation of invention are current hot topics. Nevertheless, the most fundamental issue remains the scientific understanding of the nature of creativity [56] in the context of systemic innovation [57]. Interestingly, Barrat, J. referred to artificial intelligence as our final invention and the end of the human era [58].

4. Introducing the Contributed Works

The above overview also intended to shed light on the fact that researchers studying innovation typically focus on four generic phenomena: (i) understanding the fundamentals and manifestation forms of human creativity and inventiveness, (ii) application of scientific knowledge and cognitive human capabilities to develop innovative ideas and solutions, (iii) transferring creative and inventive human capabilities to engineered systems (relying on artificial general intelligence), and (iv) documentation, assessment, and management of inventions in patents and publications. The overwhelming majority of papers submitted for review dealt with topics that belonged to item (ii). This explains why the main title of this Special Issue has been “*Inventive Approaches to Competitive Systems Engineering*”. In order to achieve a relatively high-level coherence in terms of its contents, only those papers have been accepted for publication which offered something really inventive. This could be achieved by (i) combining known approaches in a novel and creative way, (ii) introducing and realizing a technical idea that has been not documented in the literature, or (iii) addressing a scientific or professional problem with a dedicated non-standard approach. The reader may be interested to learn what the essence of these novel and indigenous approaches is. Towards this end, let us take a close look at the actual contributions of the published papers and see what the essence of their inventiveness is.

The first paper in the queue was submitted by Sophia Salas Cordero, Marc Zolghadri, Rob Vingerhoeds, and Claude Baron under the title "*Identification and Assessment of Obsolescence in the Early Stages of System Design*". The phenomenon the authors addressed is progressive obsolescence of systems. In the context of systems engineering, this phenomenon was recognized almost 30 years ago. However, no solution was proposed for avoiding or reducing the chances of its occurrence in the early stage of design. This motivated the authors to understand and model system obsolescence and the propagation of its possible consequences by linking it to the fundamental concepts of systems engineering. They argued that a deeper understanding of the phenomenon obsolescence and its propagation mechanisms is essential for planning the management of obsolescence. Based on past analogies, they invented two approaches to support the identification and assessment of obsolescence, which they dubbed as the House of Obsolescence and the House of Quality, respectively. Having these means, they managed to map the propagation of obsolescence via dependencies and to determine if changes in the system architecture are desired or imposed by external actors. The proposed system obsolescence criticality analysis assigns an obsolescence criticality index to the identified risks and prioritizes them for solution or mitigation of the critical components during the analysis phase. This approach is inventive since (i) different architectures can be analyzed during the early stages, (ii) facilitates taking technology and/or component maturity into account for a given application, and (iii) may lead to a complementary view on the risk of system or component obsolescence.

The second paper, *"A Mechanism to Assess the Effectiveness of Anomaly Detectors in Industrial Control Systems"*, presents the results of the work of Salimah Liyakkathali, Francisco Furtado, Gayathri Sugumar, and Aditya Mathur. It is documented in the literature that the total number of attacks on industrial control systems (ICS) is rapidly increasing, while the variability of the attacks is also increasing. Consequently, there is an imperative for the development of anomaly detection mechanisms (ADMs) that are able to address a set of attacks. The authors proposed an inventive method, acronymed as 'icsres', that is able to create and launch simulated attacks on ICS and may stimulate better designs. The underpinning idea is mutating the data exchanged between any two PLCs through the communication networks, and the sensors and actuators connected to them via a remote input/output unit. Using first-order deterministic mutation operators and mutation testing in the case of anomaly detectors for ICS is also a novelty. The authors made performance and utility tests with the intention to compare the results with that of humanly generated and launched set of attacks. Three ADMs were installed in an operational water treatment testbed and used to assess their completeness with respect to the generated attacks. Complex attacks are realized by combining attacklets and launched on multiple sensors and actuators. The authors concluded that the results proved the effectiveness of 'icsres' and the related tools at exploring the strength and weaknesses of the ADMs.

Eckhard Kirchner, Stefan Schork, Gunnar Vorwerk-Handing, and Sven Vogel are the co-authors of the paper entitled "*Using a Signal Flow Analysis to Develop Prototypes of Sensing Machine Elements*". The background of this work is the proliferating use of sensors and sensor-embedding physical components I smart cyber-physical systems. The state-of-the-art is that the physical system components are reproduced in the form of digital twins that provide the opportunity for both reactive and proactive control in a comprehensive and adaptive manner. The key issues are the quality of middle-of-life data and the reliability of networked communication. Making physical components capable to collect data runtime by augmenting sensor elements has become a daily practice in the industry. However, developing prototypes of sensing machine elements and analyze their signal flows in critical situations is deemed to be a novelty. The proposed signal flow analysis makes it possible to explore those effects that may negatively influence the functionality of the product as a whole. The paper presents examples of different sensing machine elements and for the analysis of the related signal flows. The proposed approach allows chunking a complex system into subsystems that can be tested individually. The authors argue that their signal flow analysis is inventive and help increase the understanding of the system as a whole and decrease the number of unknown factors and unexpected events.

The novelty of the work of David Ross-Pinnock, Glen Mullineux, and Patrick S Keogh concerning "*Temperature Sensor Position Planning*" is in that it intends to reduce the effect of the ambient conditions on temperature measurements. The avoidance of this kind of biases in a hot issue of system metrology since it is often difficult, if not impossible, to control the changing ambient influences. The authors argue that the results of dimensional measurement results are more often than not influenced by those conditions and it is of paramount importance to apply some form of compensation. They also argue that thermal compensation of dimensional measurement depends primarily on the ability to properly measure temperature across physical volumes. The main contribution of the authors' work is a method for planning the placement of actor nodes of a temperature sensor network. This is supposed to facilitate thermal compensation. The authors explained that appropriate methods to quantify and optimize uncertainty are indispensable to improve confidence as the demand for digital twins in production increases. A virtual test bed has been created for the design, testing, and optimization of temperature sensor networks supported by physical simulation. Virtualization is seen as a new element of the approach. To determine some initial rules for sensor network design, random search optimization was carried out on a subset of the nodes of the sensor network. As means of interpolating the ambient field polynomial fitting and kriging have been investigated. The authors found that the positioning of the sensors within the measurement volume and the method of reconstructing the temperature field were more important than the capability of the individual sensors. This invention has led to a sensitive temperature measurement strategy and a method for quickly testing and optimizing sensor networks.

The fifth paper, entitled "*Connecting Building Design with the Digital Factory by Design Languages to Explore Different Solutions*", is co-authored by Christopher Voss, Frank Petzold, and Stephan Rudolph. The addressed phenomenon is a representative of the manifestation and open issues of disciplinary convergence. To facilitate the exchange of data between different engineering domains, the authors propose using of graph-based design languages (GBDLs) in a model-based systems engineering (MBSE) approach. The authors argued that this approach (i) allows making the more or less hidden couplings between the different design domains explicit, (ii) supports the interfacing between different software applications, and (iii) reduces the need and efforts for manual model creation and data exchange. Obviously, the concepts of GBDLs, UML, MBSE, digital factory, and factory building design are not new in themselves. However, their (creative) combination reflects striving for an inventive solution. The twin research question was (i) how the engineering knowledge used in the preliminary design of a factory building can be formally described using graph-based design languages, and (ii) how the production line of the digital factory can be used as an input to automatically create valid preliminary designs for the factory building. The three most important design languages used in combination were: (i) the design language for the preliminary design of the production hall, (ii) the design language for specification of the digital factory of an engine hood, and (iii) the connector design language to link two other design languages. The use of system engineering approaches, in particular design languages, is a front-end initiative in the AEC industry. On the other hand, the research has demonstrated that using graph-based design languages is useful means for cross-domain knowledge integration. They can efficiently support automatic generation of valid designs differing in their structure and parameters.

Like the previous one, the paper, *"Performance Comparison of Particle Swarm Optimization and Genetic Algorithm Combined with A* Search for Solving Facility Layout Problem"*, by Mariem Besbes, Marc Zolghadri, Roberta Costa Affonso, Faouzi Masmoudi, and Mohamed Haddar, is an example for realizing a novel and more effective approach by combining known means and methods. The essence of their novel approach is using an optimization metaheuristics to solve design problems by (i) browsing large spaces of solutions, (ii) significantly reducing the design time, and (iii) proposing more realistic and better designs. The paper compared the speed and performance of using particle swarm optimization (PSO) and genetic algorithm (GA) in combination with an A* algorithm (i.e. <PSO, A*> versus <GA, A*>) in solving a constrained facility layout task as a search-based optimization problem. PSO and GA were used to configuration of the facilities, whereas the A* algorithm was used to find the shortest path considering the physical obstacles. The authors found that the two chosen metaheuristics were efficient at finding the minimum total distance that products needed to travel between the workstations in the workshop. The results showed that GA provided a better solution than PSO in terms of the total travelled distance, while PSO yielded faster. The layout optimization was applied in the case of eight facilities.

The seventh paper is entitled *"Preliminary Study of End-Effector Compliance for Reducing Insertion Force in Automated Fluid Coupling for Trains"*. It presents the work and results of Kourosh Eshraghi, Pingfei Jiang, Daniele Suraci, and Mark Atherton. In my reading, inventiveness originated here in matching practical experiments and rational considerations. The authors started out from the observation that the literature does not propose dedicated solutions for handling large misalignments of the passive end-effector in such applications as a robot end-effector for train fluid servicing. The end-effector compliance was supposed to be the key to a successful alignment. The authors applied a hybrid approach (combining physical experiments and numerical modeling/simulations) to investigate the magnitude of the insertion forces during misaligned couplings. The conducted physical experiments showed that large insertion forces might be required even in the case of small misalignments. A kind of digital twin was formed by the physical set up and the simulation model. The latter captured the configurable parameters for robot compliance and peg-in-hole friction, and was informed by the results of the physical experiments. The numerical simulation model was calibrated based on the results of the physical experiments. It was shown that the characteristic insertion force curve obtained with the calibrated simulation model was a truthful representative of what could be measured in the physical experiments. Thus, it can reduce the physical efforts and labor that is needed for the testing of end-effectors. However, the testing of the calibrated simulation model for other robot and misalignment configurations showed greater error, suggesting that the model can be used only for the calibrated configuration.

Included as the last in this special issue, the paper *"A Novel Implementation of Energy-Based Homogenization Method"*, Shuzhi Xu, Xinming Li, Yiming Rong, and Yongsheng Ma, speaks for itself in terms of its inventiveness. As the title informs us, the kernel of this contribution is an innovative energy-based homogenization method, which is underpinned by a rigorous mathematical foundation of the homogenization method. This method has been developed with the goal of enabling an accurate and efficient prediction of the mechanical performance of composite materials. The novelty of the proposed method lies in the combination of automatic (i) domain discretization, (ii) feature extraction, (iii) unification of the feature model, and (iv) periodic boundary condition application. The paper presents the theoretical model of the energy-based homogenization for a cellular solid element and a shell element. The generated model can be best characterized as fairly compact (small scale) construct. Therefore, it can be embedded directly into gradient-based, multiscale, structure optimization programs. The numerical calculations were implemented using commercial CAE software tools (e.g. Autodesk Inventor, ANSYS, and MATLAB) and the integration algorithm was programmed in a third-party language. Examples of the use of cellular solid elements and stiffened plate elements in cellular material design are presented. These were regarded as practical validation of the proposed energy-based homogenization method, which can be adapted to and extended into many other application fields, such as predicting the heat conductivity and the thermal expansion of composite materials. Beyond the scientific propositions, it is also a message of the paper that there can be many new things under the Sun even on such a conventional field of computer aided engineering as final element analysis.

5. Some Closing Remarks and Acknowledgment

Do the current engineering research and development address other than already known engineering challenges and do they propose other than only incremental advancements in different contexts? Is there anything new under the Sun in the field of competitive systems engineering? These were the main questions for the whole of the Special Issue and especially for this Editorial. The overview of the state-of-the-art revealed what invention actually means and what it implies in systems engineering.

The Editorial also identified the three major approaches to enabling of inventions, and explained the related past and current activities. Nevertheless, it left the question and possibility of automated artificial creativity and invention open, in spite of the efforts made in the domain of artificial general intelligence

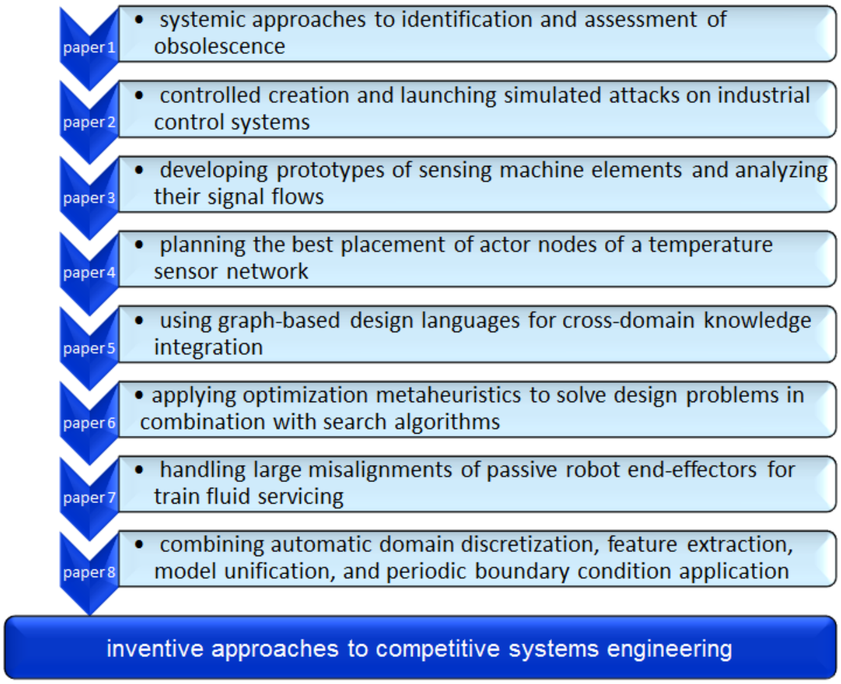

Figure 2: Contribution of the accepted papers to the topic of inventive approaches to competitive systems engineering

development and application, and of the buzzling arena of patentability of the potential inventions created by AI systems.

The papers included in this special issue provide representative examples and demonstrate the best practices. Figure 2 summarizes their contribution to the topic of inventive approaches to competitive systems engineering in a graphical form. In view of the latest developments, I tend to deny the truth of the old proverb which says: “What has been will be again, what has been done will be done again; there is nothing new under the Sun.” Incremental and even radical inventions and innovations are happening and will be emerging in the field of competitive systems engineering. Actually, the duality of an ever-growing need for competitiveness and the technological affordances is forcing researchers, engineers, and designers to think out of the box and invent new systems engineering approaches.

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