1

A comparative evaluation of supervised machine learning classification techniques for engineering design applications [Texto impreso] / Conner Sharpe, Tyler Wiest, Pingfeng Wang, Carolyn Conner Seepersad

Este artículo se encuentra disponible en su edición impresa y electrónica. Los datos para su localización están accesibles a través del enlace al título de la publicación. Su acceso electrónico es a través del enlace de 'Acceso al documento'.
References: p. 121404(11-12)

Supervised machine learning techniques have proven to be effective tools for engineering design exploration and optimization applications, in which they are especially useful for mapping promising or feasible regions of the design space. The design space mappings can be used to inform early-stage design exploration, provide reliability assessments, and aid convergence in multiobjective or multilevel problems that require collaborative design teams. However, the accuracy of the mappings can vary based on problem factors such as the number of design variables, presence of discrete variables, multimodality of the underlying response function, and amount of training data available. Additionally, there are several useful machine learning algorithms available, and each has its own set of algorithmic hyperparameters that significantly affect accuracy and computational expense. This work elucidates the use of machine learning for engineering design exploration and optimization problems by investigating the performance of popular classification algorithms on a variety of example engineering optimization problems. The results are synthesized into a set of observations to provide engineers with intuition for applying these techniques to their own problems in the future, as well as recommendations based on problem type to aid engineers in algorithm selection and utilization.

Journal of mechanical design. -- 2019 (December), v. 141, n. 12, p. 121404(1-12)

1. Classifiers 2. Design automation 3. Design exploration 4. Machine learning 5. Simulation-based design

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2

Computational creativity via assisted variational synthesis of mechanisms using deep generative models [Texto impreso] / Shrinath Deshpande, Anurag Purwar

Este artículo se encuentra disponible en su edición impresa y electrónica. Los datos para su localización están accesibles a través del enlace al título de la publicación. Su acceso electrónico es a través del enlace de 'Acceso al documento'.
References: p. 121402(10)

Computational methods for kinematic synthesis of mechanisms for motion generation problems require input in the form of precision positions. Given the highly nonlinear nature of the problem, solutions to these methods are overly sensitive to the input—a small perturbation to even a single position of a given motion can change the topology and dimensions of the synthesized mechanisms drastically. Thus, the synthesis becomes a blind iterative process of maneuvering precision positions in the hope of finding good solutions. In this paper, we present a deep-learning-based framework which manages the uncertain user input and provides the user with a higher level control of the design process. The framework also imputes the input with missing information required by the computational algorithms. The approach starts by learning the probability distribution of possible linkage parameters with a deep generative modeling technique, called variational auto encoder (VAE). This facilitates capturing salient features of the user input and relating them with possible linkage parameters. Then, input samples resembling the inferred salient features are generated and fed to the computational methods of kinematic synthesis. The framework postprocesses the solutions and presents the concepts to the user along with a handle to visualize the variants of each concept. We define this approach as variational synthesis of mechanisms. In addition, we also present an alternate end-to-end deep neural network architecture for variational synthesis of linkages. This end-to-end architecture is a conditional-VAE, which approximates the conditional distribution of linkage parameters with respect to a coupler trajectory distribution. The outcome is a probability distribution of kinematic linkages for an unknown coupler path or motion. This framework functions as a bridge between the current state of the art theoretical and computational kinematic methods and machine learning to enable designers to create practical mechanism design solutions.

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1. Human machine collaboration 2. Deep generative models 3. Path synthesis 4. Motion synthesis 5. Planar linkage synthesis 6. Machine learning (ML) for user experience 7. ML for managing uncertainties 8. ML for computational creativity 9. Deep learning 10. Conceptual design 11. Creativity and concept generation 12. Mechanism synthesis 13. Computational kinematics

3

A computer-aided design based research platform for design thinking studies [Texto impreso] / Molla Hafizur Rahman, Corey Schimpf, Charles Xie, Zhenghui Sha

Este artículo se encuentra disponible en su edición impresa y electrónica. Los datos para su localización están accesibles a través del enlace al título de la publicación. Su acceso electrónico es a través del enlace de 'Acceso al documento'.
References: p. 121102(11-12)

Design thinking is often hidden and implicit, so empirical approach based on experiments and data-driven methods has been the primary way of doing such research. In support of empirical studies, design behavioral data which reflects design thinking becomes crucial, especially with the recent advances in data mining and machine learning techniques. In this paper, a research platform that supports data-driven design thinking studies is introduced based on a computer-aided design (cad) software for solar energy systems, energy3d, developed by the team. We demonstrate several key features of energy3d including a fine-grained design process logger, embedded design experiment and tutorials, and interactive cad interfaces and dashboard. These features make energy3d a capable testbed for a variety of research related to engineering design thinking and design theory, such as search strategies, design decision-making, artificial intelligent (AI) in design, and design cognition. Using a case study on an energy-plus home design challenge, we demonstrate how such a platform enables a complete research cycle of studying designers" sequential decision-making behaviors based on fine-grained design action data and unsupervised clustering methods. The results validate the utility of energy3d as a research platform and testbed in supporting future design thinking studies and provide domain-specific insights into new ways of integrating clustering methods and design process models (e.g., the function–behavior–structure model) for automatically clustering sequential design behaviors.

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1. Computer-aided design 2. Data clustering 3. Design process 4. Design decision 5. Sequential design decision 6. Solar energy systems design 7. Unsupervised learning

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4

A data-driven approach to product usage context identification from online customer reviews [Texto impreso] / Dedy Suryadi, Harrison M. Kim

Este artículo se encuentra disponible en su edición impresa y electrónica. Los datos para su localización están accesibles a través del enlace al título de la publicación. Su acceso electrónico es a través del enlace de 'Acceso al documento'.
References: p. 121104(13)

This paper proposes a data-driven methodology to automatically identify product usage contexts from online customer reviews. Product usage context is one of the factors that affect product design, consumer behavior, and consumer satisfaction. The previous works identify the usage contexts using the survey-based method or subjectively determine them. The proposed methodology, on the other hand, uses machine learning and Natural Language Processing tools to identify and cluster usage contexts from a large volume of customer reviews. Furthermore, aspect sentiment analysis is applied to capture the sentiment toward a particular usage context in a sentence. The methodology is implemented to two data sets of products, i.e., laptop and tablet. The result shows that the methodology is able to capture relevant product usage contexts and cluster bigrams that refer to similar usage context. The aspect sentiment analysis enables the observation of a product's position with respect to its competitors for a particular usage context. For a product designer, the observation may indicate a requirement to improve the product. It may also indicate a possible market opportunity in a usage context in which most of the current products are perceived negatively by customers. Finally, it is shown that overall rating might not be a strong indicator for representing customer sentiment toward a particular usage context, due to the moderate linear correlation for most of the usage contexts in the case study.

Journal of mechanical design. -- 2019 (December), v. 141, n. 12, p. 121104(1-13)

1. Customer reviews 2. Design methodology 3. Natural Language Processing 4. Usage context

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5

Design for crashworthiness of categorical multimaterial structures using cluster analysis and bayesian optimization [Texto impreso] / Kai Liu ... [et al.]

Este artículo se encuentra disponible en su edición impresa y electrónica. Los datos para su localización están accesibles a través del enlace al título de la publicación. Su acceso electrónico es a través del enlace de 'Acceso al documento'.
References: p. 121701(14-15)

This work introduces a cluster-based structural optimization (CBSO) method for the design of categorical multimaterial structures subjected to crushing, dynamic loading. The proposed method consists of three steps: conceptual design generation, design clustering, and Bayesian optimization. In the first step, a conceptual design is generated using the hybrid cellular automaton (HCA) algorithm. In the second step, threshold-based cluster analysis yields a lower-dimensional design. Here, a cluster validity index for structural optimization is introduced in order to qualitatively evaluate the clustered design. In the third step, the optimal design is obtained through Bayesian optimization, minimizing a constrained expected improvement function. This function allows to impose soft constraints by properly redefining the expected improvement based on the maximum constraint violation. The Bayesian optimization algorithm implemented in this work has the ability to search over (i) a real design space for sizing optimization, (ii) a categorical design space for material selection, or (iii) a mixed design space for concurrent sizing optimization and material selection. With the proposed method, materials are optimally selected based on multiple attributes and multiple objectives without the need for material ranking. The effectiveness of this approach is demonstrated with the design for crashworthiness of multimaterial plates and thin-walled structures.

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1. Structural optimization 2. Finite element-based optimization 3. Bayesian optimization 4. Metamodel-based design 5. Unsupervised machine learning 6. Clustering 7. Multimaterial structures 8. Design optimization 9. Metamodeling 10. Multidisciplinary design and optimization

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Extracting customer perceptions of product sustainability from online reviews [Texto impreso] / Nasreddine El Dehaibi, Noah D. Goodman, Erin F. MacDonald

Este artículo se encuentra disponible en su edición impresa y electrónica. Los datos para su localización están accesibles a través del enlace al título de la publicación. Su acceso electrónico es a través del enlace de 'Acceso al documento'.
References: p. 121103(11-12)

In order for a sustainable product to be successful in the market, designers must create products that are not only sustainable in reality but are also sustainable as perceived by the customer—and reality versus perception of sustainability can be quite different. This paper details a design method to identify perceptions of sustainable features (PerSFs) by collecting online reviews, manually annotating them using crowdsourced work, and processing the annotated review fragments with a natural language machine learning algorithm. We analyze all three pillars of sustainability—social, environmental, and economic—for positive and negative perceptions of product features of a French press coffee carafe. For social aspects, the results show that positive PerSFs are associated with intangible features, such as giving the product as a gift, while negative PerSFs are associated with tangible features perceived as unsafe, like sharp corners. For environmental aspects, positive PerSFs are associated with reliable materials like metal while negative PerSFs are associated with the use of plastic. For economic aspects, PerSFs mainly serve as a price constraint for designers to satisfy other customer perceptions. We also show that some crucial sustainability concerns related to environmental aspects, like energy and water consumption, did not have a significant impact on customer sentiment, thus demonstrating the anticipated gap in sustainability perceptions and the realities of sustainable design, as noted in previous literature. From these results, online reviews can enable designers to extract PerSFs for further design study and to create products that resonate with customers' sustainable values.

Journal of mechanical design. -- 2019 (December), v. 141, n. 12, p. 121103(1-12)

1. Design automation 2. Customer perceptions 3. Online reviews 4. Sustainable design

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An investigation of surrogate models for efficient performance-based decoding of 3D point clouds [Texto impreso] / James D. Cunningham, Timothy W. Simpson, Conrad S. Tucker

Este artículo se encuentra disponible en su edición impresa y electrónica. Los datos para su localización están accesibles a través del enlace al título de la publicación. Su acceso electrónico es a través del enlace de 'Acceso al documento'

References: p. 121401(11)

This work investigates surrogate modeling techniques for learning to approximate a computationally expensive function evaluation of 3D models. While in the past, 3D point clouds have been a data format that is too high dimensional for surrogate modeling, by leveraging advances in 3D object autoencoding neural networks, these point clouds can be mapped to a one-dimensional latent space. This leads to the fundamental research question: what surrogate modeling technique is most suitable for learning relationships between the 3D geometric features of the objects captured in the encoded latent vector and the physical phenomena captured in the evaluation software? Radial basis functions (RBFs), Kriging, and shallow 1D analogs of popular deep 2D image classification neural networks are investigated in this work. We find the nonintuitive result that departing from neural networks to decode latent representations of 3D objects into performance predictions is far more efficient than using a neural network decoder. In test cases using datasets of aircraft and watercraft 3D models, the non-neural network surrogate models achieve comparable accuracy to the neural network models. We find that an RBF surrogate model is able to approximate the lift and drag coefficients of 234 aircraft models with a mean absolute error of 1.97 × 10-3 and trains in only 3 seconds. Furthermore, the RBF surrogate model is able to rank a set of designs with an average percentile error of less than 8%. In comparison, a 1D ResNet achieves an average absolute error of 1.35 × 103 in 38 min for the same test case. We validate the comparable accuracy of the four techniques through a test case involving 214 3D watercraft models, but we also find that the distribution of the performance values of the data, in particular the presence of many outliers, has a significant negative impact on accuracy. These results contradict a common perception of neural networks as an efficient “one-size-fits-all” solution for learning black-box functions and suggests that even within systems that utilize multiple neural networks, potentially more efficient alternatives should be considered for each network in the system. Depending on the required accuracy of the application, this surrogate modeling approach could be used to approximate an expensive simulation software, or if the tolerance for error is low, it serves as a first pass which can narrow down the number of candidate designs to be analyzed more thoroughly.

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1. Computer-aided design 2. Conceptual design 3. Design automation 4. Generative design 5. Metamodeling

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A machine learning enabled multifidelity platform for the integrated design of aircraft systems [Texto impreso] / Ana Garcia Garriga, Laura Mainini, Sangeeth Saagar Ponnusamy

Este artículo se encuentra disponible en su edición impresa y electrónica. Los datos para su localización están accesibles a través del enlace al título de la publicación. Su acceso electrónico es a través del enlace de 'Acceso al documento'.

References: p. 121405(11-12)

The push toward reducing the aircraft development cycle time motivates the development of collaborative frameworks that enable the more integrated design of aircraft and their systems. The ModellIng and Simulation tools for Systems IntegratiON on Aircraft (MISSION) project aims to develop an integrated modelling and simulation framework. This paper focuses on some recent advancements in the MISSION project and presents a design framework that combines a filtering process to down-select feasible architectures, a modeling platform that simulates the power system of the aircraft, and a machine learning-based clustering and optimization module. This framework enables the designer to prioritize different designs and offers traceability on the optimal choices. In addition, it enables the integration of models at multiple levels of fidelity depending on the size of the design space and the accuracy required. It is demonstrated for the electrification of the Primary Flight Control System (PFCS) and the landing gear braking system using different electric actuation technologies. The performance of different architectures is analyzed with respect to key performance indicators (fuel burn, weight, power). The optimization process benefits from a data-driven localization step to identify sets of similar architectures. The framework demonstrates the capability of optimizing across multiple, different system architectures in an efficient way that is scalable for larger design spaces and larger dimensionality problems.

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1. Conceptual design 2. Design integration 3. Design of multiscale systems 4. Multidisciplinary design and optimization 5. Simulation-based design 6. Systems design 7. Systems engineering

9

Mining and representing the concept space of existing ideas for directed ideation [Texto impreso] / Yuehun He ... [et al.]

Este artículo se encuentra disponible en su edición impresa y electrónica. Los datos para su localización están accesibles a través del enlace al título de la publicación. Su acceso electrónico es a través del enlace de 'Acceso al documento'.
References: p. 121101(19-20)

Design innovation projects often generate large numbers of design ideas from designers, users, and, increasingly, the crowd over the Internet. Such idea data are often used for selection and implementation but, in fact, can 1also be used as sources of inspiration for further idea generation. In particular, the elementary concepts that underlie the original ideas can be recombined to generate new ideas. But it is not a trivial task to retrieve concepts from raw lists of ideas and data sources in a manner that can stimulate or generate new ideas. A significant difficulty lies in the fact that idea data are often expressed in unstructured natural languages. This paper develops a methodology that uses natural language processing to extract key words as elementary concepts embedded in massive idea descriptions and represents the elementary concept space in a core–periphery structure to direct the recombination of elementary concepts into new ideas. We apply the methodology to mine and represent the concept space underlying massive crowdsourced ideas and use it to generate new ideas for future transportation system designs in a real public sector-sponsored project via humans and automated computer programs. Our analysis of the human and computer recombination processes and outcomes sheds light on future research directions for artificial intelligence in design ideation.

Journal of mechanical design. -- 2019 (December), v. 141, n. 12, p. 121101(1-20)

1. Computer-aided design 2. Conceptual design 3. Creativity and concept generation

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Multifidelity and multiscale bayesian framework for high-dimensional engineering design and calibration [Texto impreso]/ Soumalya Sarkar ... [et al.]

Este artículo se encuentra disponible en su edición impresa y electrónica. Los datos para su localización están accesibles a través del enlace al título de la publicación. Su acceso electrónico es a través del enlace de 'Acceso al documento'.
References: p. 121001(11)

This paper proposes a machine learning–based multifidelity modeling (MFM) and information-theoretic Bayesian optimization approach where the associated models can have complex discrepancies among each other. Advantages of MFM-based optimization over a single-fidelity surrogate, specifically under complex constraints, are discussed with benchmark optimization problems involving noisy data. The MFM framework, based on modeling of the varied fidelity information sources via Gaussian processes, is augmented with information-theoretic active learning strategies that involve sequential selection of optimal points in a multiscale architecture. This framework is demonstrated to exhibit improved efficiency on practical engineering problems like high-dimensional design optimization of compressor rotor via implementing its multiscale architecture and calibration of expensive microstructure prediction model. From the perspective of the machine learning–assisted design of multiphysics systems, advantages of the proposed framework have been presented with respect to accelerating the search of optimal design conditions under budget constraints.

Journal of mechanical design. -- 2019 (December), v. 141, n. 12, p. 121001(1-11)

1. Bayesian optimization 2. Design automation 3. Design methodology 4. Design optimization 5. Expensive model calibration 6. Machine learnign 7. Metamodeling 8. Multifidelity modeling 9. Multiphysics design

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11
Multifidelity physics-constrained neural network and its application in materials modeling [Texto impreso] / Dehao Liu, Yan Wang

Este artículo se encuentra disponible en su edición impresa y electrónica. Los datos para su localización están accesibles a través del enlace al título de la publicación. Su acceso electrónico es a través del enlace de 'Acceso al documento'.
References: p. 121403(13)

Training machine learning tools such as neural networks require the availability of sizable data, which can be difficult for engineering and scientific applications where experiments or simulations are expensive. In this work, a novel multi-fidelity physics-constrained neural network is proposed to reduce the required amount of training data, where physical knowledge is applied to constrain neural networks, and multi-fidelity networks are constructed to improve training efficiency. A low-cost low-fidelity physics-constrained neural network is used as the baseline model, whereas a limited amount of data from a high-fidelity physics-constrained neural network is used to train a second neural network to predict the difference between the two models. The proposed framework is demonstrated with two-dimensional heat transfer, phase transition, and dendritic growth problems, which are fundamental in materials modeling. Physics is described by partial differential equations. With the same set of training data, the prediction error of physics-constrained neural network can be one order of magnitude lower than that of the classical artificial neural network without physical constraints. The accuracy of the prediction is comparable to those from direct numerical solutions of equations.

Journal of mechanical design. -- 2019 (December), v. 141, n. 12, p. 121403(1-13)

1. Machine learning 2. Multifidelity model 3. Physics-constrained neural networks 4. Materials modeling 5. Partial differential equations 6. Computer-aided engineering 7. Simulation-based design