System Intelligence Laboratory

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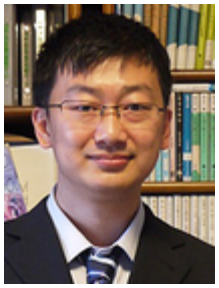

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The main stream in our lab is related to computational intelligence. So far we have focused our study on three key words: recognition, learning and understanding. The goal of our research is to develop some learning models that are flexible enough to adapt changing environment, and also simple enough to be realized, interpreted and re-used. The ultimate goal is to design a system that can think, and decide what to do and how to grow-up based on its own thinking. For this purpose, many approaches have been studied - e.g., neuro-computation, memetic algorithms, reinforcement learning, awareness computing, and so on. Of course, results proposed in conventional symbol based artificial intelligence are also included.

In 2017, we successfully organized the 8-th International Conference on Awareness Science and Technology (iCAST2017), which was technically co-sponsored by IEEE SMC Society. We have been trying to promote awareness scicence and technology through collaboration with different universities or organizations around the world. Our dream is to propose a new and better approach to realization of artificial intelligence.

So far we have used or proposed the following learning models:

- Neural network trees (NNTrees),
- Nearest neighbor classification trees (NNC-Trees),
- Support vector machines (SVMs),
- Neural network ensembles,
- Modular neural networks,
- Cellular automata, and

- Recurrent neural networks.

Based on the above learning models, we have proposed many new algorithms. Examples include:

- IEA: individual evolutionary algorithm (also called the $R4$-rule),
- CoopCEA: cooperative co-evolutionary algorithms,
- EPNet: evolutionary programming neural net,
- Evolutionary design of neural network trees,
- Induction of NNC-Trees with the $R4$-rule,
- Fast neural network for face detection,
- Decision boundary making for inducing high performance neural networks, and
- 3-factor user authentication based on image morphing.

To verify and to improve the models and learning algorithms proposed so far, we have being studying on-line growing of neural network trees, evolution of neural network ensemble, evolutionary design of decision trees, and so on. Currently, we are very interested in applying our models and algorithms to solving practical problems related to producing a "safe, secure and healthy" society. Examples include: face detection, face/expression recognition, automatic image morphing, text mining, user authentication, steganography, and so on.

Refereed academic journal

[peiyan-105-036-01:2017] Yan Pei and Hideyuki Takagi. Research Progress Survey on Interactive Evolutionary Computation. *Journal of Ambient Intelligence and Humanized Computing*, 2018.

We report our research progress on interactive evolutionary computation (IEC). Following description of IEC features, we present our research on IEC user modeling, acceleration of IEC search, several IEC frameworks, evolutionary multi-objective optimization with IEC, and IEC for human science. IEC research is categorized into three fields in general; major part of IEC papers is IEC application-oriented research; almost all the others are research that aims to reduce IEC user fatigue; and very little work researches the use of IEC for human science. In particular, IEC is a data analysis and processing method and tool for the discovery of human psychological and physiological knowledge. We include several of our IEC application-oriented research projects in this paper, and focus on two other research directions, i.e., IEC algorithm research to reduce user fatigue, and IEC for human science research.

[qf-zhao-105-036-01:2017] Rung-Ching Chen Qiangfu Zhao, Chia-Ming Tsai and Chung-Yi Huang. Resident activity recognition based on binary infrared sensors and soft computing. *International Journal on Machine Learning and Cybernetics*, pages 1–9, 8 2017.

The basic concept of a smart space (SS) is to be aware of the context information related to environmental and human behavioral changes, and to provide appropriate services accordingly. To obtain context information, we may use video cameras, microphones, and other monitoring devices. Although these devices can obtain complex environmental data, they are not suitable for building private smart space (PSS) because of the privacy issue. Human users do not like being monitored in their private spaces. In this study, we investigate the possibility of recognizing certain activities using binary data collected by using infrared sensors. Infrared sensors have been used mainly for detecting the existence/absence of the residents in a region of interest. Here, we consider four types of activities, namely, No-Activity, Very-Weak-Activity, Weak-Activity, and Strong-Activity. Our main goal is to provide a way for building PSS using low-cost and non-privacy-sensitive devices. We have conducted some primary experiments by collecting user activity information using binary infrared sensors. Generally speaking, activity related sensor data are sensitive to various factors. To effectively address this issue, we propose a recognition method based

on fuzzy decision tree. The results of the primary experiments show that the recognition rate of proposed method can be as high as 85.49 percent. The results are encouraging, and show the possibility of building PSS using binary infrared sensors.

[qf-zhao-105-036-02:2017] Yan Yan Jia Hao, Qiangfu Zhao and Guoxin Wang. A Review of Tacit Knowledge: Current Situation and the Direction to Go. *International Journal of Software Engineering and Knowledge Engineering*, 27(5):727–748, 2017.

Currently, tacit knowledge has attracted many research attentions. However, the theoretical foundation of tacit knowledge is still not well formulated, because the researches are very disperse. This work provides a review of the current researches. First, the definition of tacit knowledge is discussed by answering several questions. Next, tacit knowledge sharing, tacit knowledge quantization are identified as two research topics in the current research community. Following that, the technical progress of each topic is summarized and analyzed. Finally, we provide a thumbnail of the researches and identify three research consensuses to answer where we are? While seven research directions are identified to answer where we shall go?

[qf-zhao-105-036-03:2017] Yan Yan Jia Hao, Qiangfu Zhao. A function-based computational method for design concept evaluation. *Advanced Engineering Informatics*, 32:237–247, 4 2017.

Concept generation is an indispensable step of innovation design. However, the limited knowledge and design thinking fxation of designers often impede the generation of novel design concepts. Computational tools can be a necessary supplement for designers. They can generate a big number of design concepts based on an existing knowledge base. For fltering these design concepts, this work presents a computational measurement of novelty, feasibility and diversity based on 500,000 granted patents. First, about 1700 functional terms (terminologies) are mapped to high dimensional vectors (100 dimensional space) by word embedding technique. The resulted database is knowledge base-I (KB-I). Then, we adopt circular convolution to convert patents into high dimensional vectors. The resulted database is KB-II. Based on the two knowledge bases, the computational defnitions of novelty, feasibility and diversity are developed. We conduct six experiments based on KB-II, a random dataset and a real product dataset, and the results show that these metrics can be used to roughly flter a big number of design concepts, and then expert based method can be further

used. This work provides a computational framework for measuring the novelty, feasibility and diversity of design concept.

[qf-zhao-105-036-04:2017] Qiangfu Zhao Jia Hao, Yongjia Zhou. An evolutionary computation based method for creative design inspiration generation. *Journal of Intelligent Manufacturing*, pages 1–19, 8 2017.

Product design is an important part of the manufacturing system from a macro point of view. In the design process, creative design is one of the important factors to survive the fierce competition. During creative design process, designers are the most critical component. However, design fixation often negatively influences the design outcomes. Many researches from cognitive science and design science reveal that the presentation of outer information can alleviate design fixation effectively. Among different kinds of outer information, language terms are proved to be effective. This work presents a method of automatically generating language terms as design inspirations based on 500,000 granted patents. This method adopts evolutionary computation as the fundamental algorithm to retrieve language terms from a vocabulary base. To implement the algorithm, the vocabulary is first encoded by high dimensional vectors through word embedding, which is a three layers neural network. Further, two metrics for measuring the inspiration potential of language terms are defined in a computable manner. This work also conducts experiments to validate the method, and the experimental results show that (1) the algorithm is efficient and has the potential to be extended to larger vocabulary; (2) the generated design inspirations have a positive influence on the design outcomes.

[qf-zhao-105-036-05:2017] Qiangfu Zhao Yuya Kaneda and Yong Liu. Low-Cost and Steady On-Line Retraining of MLP with Guide Data. *Journal of Information Processing*, 27:820–830, 8 2017.

The decision boundary making (DBM) algorithm was proposed by us to induce compact and high performancemachinelearningmodelsforimplementationinportable/wearablecomputingdevices. Toupgradeperformance of DBM-initialized models, we may use all observed data to retrain the model, but the computational cost is high. To reduce the cost, we may use the newly observed datum only, but this often degrades the performance of the model. To solve the problem, we propose on-line training algorithm with guide data (OLTA-GD) in this paper. OLTA-GD updates the model using only a few guide data along with the newest datum. The guide data are selected from all available data. Here, guide data selection is a key point. For this purpose, this paper investigates two methods. The frst method is random se-

lection, and the second one is cluster center based. In the second method, the cluster centers are obtained using k-means algorithm. Experimental results show that, OLTA-GD can upgrade the models more steadily than backpropagation (BP) algorithm, and the frst selection method is better. For the guide data, around 5 dataareusuallyenoughtoupgradetheperformancesteadily,andthusthecomputationalcostisbasicallynotincreased compared with the BP.

Refereed proceedings of an academic conference

[peiyan-105-036-02:2017] Yan Pei. Autoencoder Using Kernel Method. In *2017 IEEE International Conference on Systems, Man, and Cybernetics (SMC)*, 2017.

We propose a method that uses kernel method-based algorithms to implement an autoencoder. Deep learning-based algorithms have two characteristics, one is the high level data abstraction, the other is the multiple level data transformations and representations. The kernel method is one of the approaches that can be used in linear and non-linear transformations. It should be one of the implementations of these transformations in the deep learning. In this paper, the encoder part and decoder part of the autoencoder are implemented by kernel-based principal component analysis and kernel-based linear regression, respectively. As autoencoder is a basic structure and algorithm in deep learning, the proposed method can implement deep learning model and algorithm using duplicate structures. We use image data to evaluate our proposed method. The results show that kernel-based autoencoder can represent and restore image data, but the performance depends on the kernel function and its parameters' selection. We also discuss and analyse some open topics and works towards a study of kernel method-based deep learning.

[peiyan-105-036-03:2017] Yan Pei. Autoencoder Using Kernel Method. In *2017 IEEE International Conference on Systems, Man, and Cybernetics (SMC)*, 2017.

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[qf-zhao-105-036-06:2017] Yuta Kobiyama; Qiangfu Zhao; Ryo Ota; Shoichi Ichimura. Recognition of Frequently Appeared Locations/Activities Based on Infrared Sensor Array. In *3rd IEEE International Conference on Cybernetics (CYBCON2017)*. IEEE, IEEE, 6 2017.

This paper studies the possibility of recognizing resident locations and activities using an infrared sensor array. In our study, we try to build smart homes that are smart enough to help the residents, and at the same time, stupid enough not to touch the resident privacy. For this purpose, we try to use a sparse infrared sensor array to recognize some frequently appeared locations/activities that are informative to recognize the life cycles of the residents and useful for providing needed services. Experimental results show that an array containing 10 sensors can be very good to recognize some specifed locations and activities.

[qf-zhao-105-036-07:2017] Masato Hashimoto; Qiangfu Zhao. An ELM-Based Privacy Preserving Protocol for Implementing Aware Agents. In *3rd IEEE International Conference on Cybernetics (CYBCONF 2017)*. IEEE, IEEE, 6 2017.

Aware agents (A-agents) are systems that can be aware of user intention, preference, situation, etc., and can provide proper solutions. To support user's daily lives, we try to implement A-agents in portable/wearable computing devices (P/WCDs). However, a P/WCD usually does not have enough computing resource and battery to implement high performance A-agents. Cloud computing is a technology to augment the computing power of P/WCDs. But there are two well-known problems, namely, information leakage and privacy invasion. To solve these problems, extreme learning machine (ELM) based privacy preserving protocol has been proposed by us for developing cloud-based A-agents on P/WCDs. The basic idea of the protocol is division of the ELM neural network. The cloud server holds weights of hidden neurons, and the P/WCD holds

weights of output neurons. The A-agents are implemented by combining the cloud server and the P/WCD. In this paper, we try to improve the safety of the protocol by adding redundancy. Although adding redundancy can make it more diffcult for an unauthorized party to analyze the data and the A-agent model, the computational time cost will be not increased. The required memory will be larger, but this is not a big problem with the current memory technology.

[qf-zhao-105-036-08:2017] Tomoya Furukawa; Qiangfu Zhao. Interpreting Multilayer Perceptrons Using 3-Valued Activation Function. In *3rd IEEE International Conference on Cybernetics (CYBCONF 2017)*. IEEE, IEEE, 6 2017.

Multilayer perceptrons (MLPs) have been successfully applied to solving many problems, but in most cases, they are used as black boxes which are not interpretable. That is, even if an MLP can provide correct answers, we cannot understand the reasons why it makes these decisions. In this study, we try to interpret a single hidden layer MLP by discretizing the hidden neuron outputs into 3 values (e.g. -1, 0, and 1). The 3 values correspond to false, unknown, and true, respectively. The basic process is (1) train an MLP first, (2) discretize the hidden neurons, (3) retrain the output layer of the MLP, (4) add more hidden neurons if needed, and (5) induce a decision tree based on the hidden neuron outputs. Experiments on several public datasets show that the proposed method is feasible for acquiring interpretable knowledge.

[qf-zhao-105-036-09:2017] Tomoya Furukawa; Qianfgu Zhao. On Extraction of Rules from Deep Learner: The Deeper, the Better? In *2017 IEEE Cyber Science and Technology Congress(CyberSciTech)*. IEEE, IEEE, 2017.

In recent years, multilayer perceptron (MLP) has been successfully used for solving various problems in different fields. However, it is difficult to interpret the reasoning process of an MLP, and therefore in most cases the MLP is used as a black box. In our previous study, we tried to extract rules from a learned shallow MLP based on the hidden neuron outputs. In this study, we investigate the possibility of extracting simpler and better rules from a deep MLP. It is believed that hidden layers closer to the output layer can learn more abstract concepts. It is natural to expect that simpler and better rules can be extracted from higher layers. Experimental results on several public datasets reveal that this is true because the decision trees designed based on hidden layers closer to the output layer are actually smaller. That is, it is possible to extract more understandable knowledge from a deep MLP, even if the MLP as a whole is difficult to understand. In addition, based on the complexity of the extracted

knowledge, it is also possible to determine the number of layers needed for solving a given problem.

[yliu-105-036-01:2017] Y. Liu. Computational awareness for learning neural network ensembles. In *Proceedings of the 2017 IEEE International Conference on Information and Automation*, pages 376–380. IEEE, July 2017.

This paper proposes a hybrid negative correlation learning in which each individual neural network in an neural network ensemble would either learn a data point by negative correlation learning or learn to be different to the neural network ensemble. The implementation is through randomly splitting the training set into two subsets for each individual neural network in learning. On one subset of the training data, the individual neural network would be trained by negative correlation learning. On the other subset of the training data, the individual neural network would be trained to be different to the neural network ensemble. The purpose of such random splitting of the training data is to allow each individual neural network to build up its self-awareness of the learning direction on each given data point.

[yliu-105-036-02:2017] Y. Liu. Build correlation awareness in negative correlation learning. In *Proceedings of 2017 13th International Conference on Natural Computation, Fuzzy Systems and Knowledge Discovery*, pages 32–36. IEEE, July 2017.

This paper proposed to implement negative corre- lation learning (NCL) in optimizing the two different learning functions on the two separated subsets without overlapping. Because the two subsets could be randomly generated for each individual neural network (NN), they would be different for every pair of individual NNs in an neural network ensemble (NNE). When the two learning functions in NCL could be optimized separately, each individual NN could avoid the conflicts in learning by always having the unique learning direction on a given data sample. Therefore, each individual NN is clearly aware of its own learning direction on every training data. Such self- awareness is essential to create a set of cooperative NNs for an NNE. Experimental results show that the individual NNs by NCL with such separate learning could remain the difference, and have the stable performance even in the longer training process.

[yliu-105-036-03:2017] Y. Liu. Hybrid negative correlation learning with randomly splitting data. page 4 pages, 2017.

[yliu-105-036-04:2017] Y. Liu. Random separation learning for neural network ensemble. In *Proceedings of 2017 10th International Congress on Image*

and Signal Processing, BioMedical Engineering and Informatics, page 4 pages. IEEE, October 2017.

In order to prevent the individual neural networks from becoming similar in the long learning period of negative correlation learning for designing neural network ensembles, two approaches were adopted in this paper. The first approach is to replace large neural networks with small neural networks in neural network ensembles. Samll neural networks would be more practical in the real applications when the capability is limited. The second approach is to introduce random separation learning in negative correlation learning for each small neural network. The idea of random separation learning is to let each individual neural network learn differently on the randomly separated sub- sets of the given training samples. It has been found that the small neural networks could easily become weak and different each other by negative correlation learning with random separation learning. After applying large number of small neural networks for neural network ensembles, two combination methods were used to generate the output of the neural network ensembles while their performance had been compared.

[yliu-105-036-05:2017] Y. Liu. Bidirectional negative correlation learning. In Z. Chen Y. Liu K. Li, W. Li, editor, *Communications in Computer and Information Science, Volume 873 of Communications in Computer and Information Science*, pages 84–92. Springer, 2018.

Negative correlation learning method is to create different individual learners for building a committee machine. In the original version of negative correlation learning, the learning target on a give data point was set to be the same for all the individual learners in the committee. The same learning target could lead the individual learn- ers to become similar to each other if the learning process would be conducted for long. In order to create more different and cooperative individual learners for a committee machine, different learning targets should be set on each learning data for different individual learners in negative correlation learning. In this paper, negative correlation learn- ing with two different learning targets was implemented. On learning each training data, the individual learners could go to the two differ- ent learning directions so that there would be little chance for them to become similar even if the a long learning process would be performed. Experimental results would show how the two different learning targets would allow the individual learners to become both weak and different in negative correlation learning.

Unrefeered proceedings of an academic conference

[peiyan-105-036-04:2017] Yan Pei. Principal Component Selection Using Interactive Evolutionary Computation. In *12th Evolutionary Computation Meeting*, 2017.

Writing a textbook or technical book

[qf-zhao-105-036-10:2017] Qiangfu ZHAO and Tatsuo Higuchi. *Artificial Intelligence - from Fundamentals to Intelligent Search*. Kyoritsu Shuppan Co., Ltd., 7 2017.

[yliu-105-036-06:2017] Z. Chen Y. Liu (Eds.) K. Li, W. Li. *Computational Intelligence and Intelligent Systems*. Number 873 in Communications in Computer and Information Science. Springer, Berlin Heidelberg, 2017.

This two-volume set (CCIS 873 and CCIS 874) constitutes the thoroughly refereed proceedings of the 9th International Symposium, ISICA 2017, held in Guangzhou, China, in November 2017.The 101 full papers presented in both volumes were carefully reviewed and selected from 181 submissions. This first volume is organized in topical sections on neural networks and statistical learning: neural architecture search, transfer of knowledge; evolutionary multi-objective and dynamic optimization: optimal control and design, hybrid methods; data mining: association rule learning, data management platforms; Cloud computing and multiagent systems: service models, Cloud engineering; everywhere connectivity: IoT solutions, wireless sensor networks.

[yliu-105-036-07:2017] Z. Chen Y. Liu (Eds.) K. Li, W. Li. *Computational Intelligence and Intelligent Systems*. Number 874 in Communications in Computer and Information Science. Springer, Berlin Heidelberg, 2017.

This two-volume set (CCIS 873 and CCIS 874) constitutes the thoroughly refereed proceedings of the 9th International Symposium, ISICA 2017, held in Guangzhou, China, in November 2017. The 101 full papers presented in both volumes were carefully reviewed and selected from 181 submissions. This second volume is organized in topical sections on swarm intelligence: cooperative Search, swarm optimization; complex systems modeling: system dynamic, multimedia simulation; intelligent information systems: information retrieval, e-commerce platforms; artificial intelligence and robotics: query optimization, intelligent engineering; virtualization: motion-based tracking, image recognition.

Research grants from scientific research funds and public organizations

[qf-zhao-105-036-11:2017] Qiangfu ZHAO. Activity recognition based on a small-scale sensor network, 2017.

[yliu-105-036-08:2017] Y. Liu. The Grant-In-Aid for Scientific Research Fund (Kakenhi), 2015-2017.

Academic society activities

[qf-zhao-105-036-12:2017] Qiangfu ZHAO, 2017.

Associate Editor of IEEE Transactions on Cybernetcis

[qf-zhao-105-036-13:2017] Qiangfu ZHAO, 2017.

Associate Editor of IEEE SMC Magazine

[qf-zhao-105-036-14:2017] Qiangfu ZHAO, 2017.

Associate Editor of International Journal on Machine Learning and Cybernetics (Springer)

[qf-zhao-105-036-15:2017] Qiangfu ZHAO, 11 2017.

Steering committee co-chair of iCAST2017 (Taichung, Taiwan)

[qf-zhao-105-036-16:2017] Qiangfu ZHAO, 2017.

Chair of the Technical Committee on Awareness Computing, IEEE SMC Society.

[yliu-105-036-09:2017] Y. Liu, 2017.

Program Co-Chair of the 2017 13th International Conference on Natural Computation, Fuzzy Systems and Knowledge Discovery, 2017

[yliu-105-036-10:2017] Y. Liu, 2017.

General Co-Chair of the 9th International Symposium on Intelligence Computation and Applications, 2017

Advisor for undergraduate research and graduate research

[qf-zhao-105-036-17:2017] Masato Hashimoto. Master thesis, Graduate School, The University of Aizu, 3 2017.

[qf-zhao-105-036-18:2017] Tomoya Furukawa. Master thesis, Graduate School, The University of Aizu, 3 2017.

[qf-zhao-105-036-19:2017] Ryota Fukuzawa. Graduation thesis, The University of Aizu, 3 2017.

[qf-zhao-105-036-20:2017] Shoichi Ichimura. Graduation thesis, The University of Aizu, 3 2017.

[qf-zhao-105-036-21:2017] Hiroshi Naito. Graduation thesis, The University of Aizu, 3 2017.

[qf-zhao-105-036-22:2017] Takumi Saito. Graduation thesis, The University of Aizu, 3 2017.

[yliu-105-036-11:2017] Tojio Hirakubo. Graduation Thesis: Realistic Characterization of Player Status by Physical Types, University of Aizu, 2018.

Thesis Advisor: Y. Liu

[yliu-105-036-12:2017] Kazutoshi Sugita. Graduation Thesis: Forecasting Bitcoin Price with Prophet, University of Aizu, 2018.

Thesis Advisor: Y. Liu

Contributions related to syllabus preparation

[qf-zhao-105-036-23:2017] Made syllabus for

Contribution related to educational planning management

[yliu-105-036-13:2017] a member of Academic Affairs Committee