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Information Processing and Management of Uncertainty in Knowledge-Based Systems

18th International Conference, IPMU 2020
Lisbon, Portugal, June 15–19, 2020
Proceedings, Part I

Springer

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Preface

We are very pleased to present you with the proceedings of the 18th International Conference on Information Processing and Management of Uncertainty in Knowledge-Based Systems (IPMU 2020), held during June 15–19, 2020. The conference was scheduled to take place in Lisbon, Portugal, at the Instituto Superior Técnico, University of Lisbon, located in a vibrant renovated area 10 minutes from downtown. Unfortunately, due to the COVID-19 pandemic and international travel restrictions around the globe, the Organizing Committee made the decision to make IPMU 2020 a virtual conference taking place as scheduled.

The IPMU conference is organized every two years. Its aim is to bring together scientists working on methods for the management of uncertainty and aggregation of information in intelligent systems. Since 1986, the IPMU conference has been providing a forum for the exchange of ideas between theoreticians and practitioners working in these areas and related fields. In addition to many contributed scientific papers, the conference has attracted prominent plenary speakers, including the Nobel Prize winners Kenneth Arrow, Daniel Kahneman, and Ilya Prigogine.

A very important feature of the conference is the presentation of the *Kampé de Fériet Award* for outstanding contributions to the field of uncertainty and management of uncertainty. Past winners of this prestigious award are Lotfi A. Zadeh (1992), Ilya Prigogine (1994), Toshiro Terano (1996), Kenneth Arrow (1998), Richard Jeffrey (2000), Arthur Dempster (2002), Janos Aczel (2004), Daniel Kahneman (2006), Enric Trillas (2008), James Bezdek (2010), Michio Sugeno (2012), Vladimir N. Vapnik (2014), Joseph Y. Halpern (2016), and Glenn Shafer (2018). This year, the recipient of the *Kampé de Fériet Award* is Barbara Tversky. Congratulations!

The IPMU 2020 conference offers a versatile and comprehensive scientific program. There were four invited talks given by distinguished researchers: Barbara Tversky (Stanford University and Columbia University, USA), Luísa Coheur (Universidade de Lisboa, Instituto Superior Técnico, Portugal), Jim Keller (University of Missouri, USA), and Björn Schuller (Imperial College London, UK). A special tribute was organized to celebrate the life and achievements of Enrique Ruspini who passed away last year. He was one of the fuzzy-logic pioneers and researchers who contributed enormously to the fuzzy sets and systems body of knowledge. Two invited papers are dedicated to his memory. We would like to thank Rudolf Seising, Francesc Esteva, Lluís Godo, Ricardo Oscar Rodriguez, and Thomas Vetterlein for their involvement and contributions.

The IPMU 2020 program consisted of 22 special sessions and 173 papers authored by researchers from 34 different countries. All 213 submitted papers underwent the thorough review process and were judged by at least three reviewers. Many of them were reviewed by more – even up to five – referees. Furthermore, all papers were examined by the program chairs. The review process respected the usual

conflict-of-interest standards, so that all papers received multiple independent evaluations.

Organizing a conference is not possible without the assistance, dedication, and support of many people and institutions.

We are particularly thankful to the organizers of special sessions. Such sessions, dedicated to variety of topics and organized by experts, have always been a characteristic feature of IPMU conferences. We would like to pass our special thanks to Uzay Kaymak, who helped evaluate many special session proposals.

We would like to acknowledge all members of the IPMU 2020 Program Committee, as well as multiple reviewers who played an essential role in the reviewing process, ensuring a high-quality conference. Thank you very much for all your work and efforts.

We gratefully acknowledge the technical co-sponsorship of the IEEE Computational Intelligence Society and the European Society for Fuzzy Logic and Technology (EUSFLAT).

A huge thanks and appreciation to the personnel of Lisbon's Tourism Office 'Turismo de Lisboa' (www.visitlisboa.com) for their eagerness to help, as well as their enthusiastic support.

Our very special and greatest gratitude goes to the authors who have submitted results of their work and presented them at the conference. Without you this conference would not take place. Thank you!

We miss in-person meetings and discussions, yet we are privileged that despite these difficult and unusual times all of us had a chance to be involved in organizing the virtual IPMU conference. We hope that these proceedings provide the readers with multiple ideas leading to numerous research activities, significant publications, and intriguing presentations at future IPMU conferences.

April 2020

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Theoretical and Applied Aspects of Imprecise Probabilities

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Similarities in Artificial Intelligence

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Belief Function Theory and Its Applications

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Aggregation: Theory and Practice

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Aggregation: Pre-aggregation Functions and Other Generalizations

Humberto Bustince	Public University of Navarra, Spain
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Aggregation: Aggregation of Different Data Structures

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Fuzzy Methods in Data Mining and Knowledge Discovery

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Computational Intelligence for Logistics and Transportation Problems

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Fuzzy Implication Functions

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Soft Methods in Statistics and Data Analysis

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Image Understanding and Explainable AI

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Mathematical Methods Towards Dealing with Uncertainty in Applied Sciences

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Discrete Models and Computational Intelligence

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Current Techniques to Model, Process and Describe Time Series

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Mathematical Fuzzy Logic and Graded Reasoning Models

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How Action Shapes Thought

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When you ask someone a question they can't answer, the response is often a shrug of the shoulders, arms outstretched, elbows bent, palms up. Translated into words, that shrug means "dunno" or "who knows?" An expression of uncertainty. It's instantly understood that way as well. No need for translation to words, the meaning of the gesture is clear. Now consider another gesture, one made by a preschooler known to shrug her shoulders on other occasions, asking about her day. The answer: not a shrug, but a hand outspread horizontally, teeter-tottering between thumb and baby finger. Or, on another occasion, one thumb up, one thumb down. The shrug seems to say, there's an answer, but I don't know it. The information is in the air, but I haven't caught it. The teeter-tottering hand and up and down thumbs seem to express a different kind of uncertainty, I have the information but it's not decisive, it goes both ways, It goes up and down, back and forth; it's balanced. Now I step out of my usual role as a cognitive psychologist and adopt the role of a linguist, where anecdotes are the stuff of thought and analysis. This preschooler distinguishes two fundamental kinds of uncertainty, one where the information might (or might not) be out there but I don't have it and the other where I have the relevant information but I can't decide one way or another, the information tilts both ways, Not only does this preschooler know the distinction between the two types of uncertainty, she can express them.

To express either kind of uncertainty –and many other thoughts– she doesn't use words, she uses gestures. Gestures come faster than words, are more direct than words, and more precise than words. Let's start with the simplest of gestures, pointing. Babies point long, in baby-time, before they speak. Points direct the eyes to pin-point spots in the world; "there" can't do that unless accompanied by a string of spatial descriptors that are likely to be vague or wrong or both. From where to how, contrast showing how to open a jar or insert a drawer to explaining how to open a jar or insert a drawer. Gestures truncate and abstract actions in the world to convey actions on things. They also use abstractions of actions to convey actions on thought, raising arguments for and against and placing them on sides of the body, an imaginary whiteboard, then pointing to indicate each side in turn. You have undoubtedly seen speakers do this, you have likely done it yourself; those two sides in space, on your right and on your left, help you keep track of the pros and cons whether you are speaker or listener. Gestures help both speakers and listeners to think and to talk. When asked to sit on their hands, speakers flounder finding words. When people are asked to study and remember descriptions of spatial layouts or actions of mechanical systems, most spontaneously

gesture. Their gestures make models of the space or of the actions. When asked to sit on their hands while studying, people remember less and realize fewer of the inferences needed for deep understanding. Thus gestures, abstractions of actions on objects used to represent actions on thought, enable thought and embody thought both for thinkers and for their audiences.

Gestures can be regarded, justly, as diagrams in the air. Gestures are fleeting; transforming them to a page keeps them, and allows scrutinizing them, drawing inferences from them, revising them, by individuals or by groups. Like gestures, graphics use marks in space and place in space to convey meanings more directly than words. Points stand for places or ideas; lines connect them, showing relationships; arrows show asymmetric relations; boxes contain a related set of ideas and separate those from others. Ideas that are close in space are close on any dimension; ideas high in space are high on any dimension, ideas that are central are just that, central. Concepts and relations that are created and understood immediately, in contrast to words, whose meanings are mediated.

Our unnamed preschooler spontaneously expressed two basic senses of uncertainty in her gestures, uncertainty due to absence of information and uncertainty due to indecisive information. Conveying these forms of uncertainty, and perhaps others, for different content in diagrams is still finding its way. Error bars and fuzzy lines are some of the ways diagrams express imprecise quantitative information. Expressing absent or imprecise or undecisive information for qualitative information has been challenging.

Language, too, carries these spatial meanings. We've grown closer, or farther apart. The central argument is… Someone's on the top of the heap or fallen into a depression. That space is wide open, To mix spatial metaphors: navigating the crisis will be a delicate balance.

Spatial thinking is the foundation of all thought. Not the entire edifice but the foundation. All creatures must move in space and interact with things in space to survive. Even plants must move in response to wind, rain, and sun. The evidence comes from many places, from gesture, from language, from diagrams and sketches. It also comes from neuroscience: the same places in hippocampus that represent places are used to represent people, events, and ideas. The same places in entorhinal cortex that map spatial relations also map temporal, social, and conceptual relations, In humans, for the most part, in real space, feet do the navigation and hands do the interaction with things. In conceptual spaces, it's fingers and hands that navigate in the air or on the screen just as it's fingers and hands that interact with points in conceptual spaces in the air or on the screen.

Thus, actions in real space on objects in real space get truncated and abstracted to form gestures that express actions on ideas in spaces in the air. The same truncated abstracted actions create actions on ideas on the space of the page. This cycle of actions in space that are transformed to gestures that create abstractions in the air or to marks that create abstractions on the page can be unified in the concept, *spraction*, a contraction for the never-ending cycle of space, action, and abstraction.

Reference

Tversky, B.: Mind in Motion: How Action Shapes Thought. Basic, NY (2019)

Biography

Barbara Tversky studied cognitive psychology at the University of Michigan. She held positions first at the Hebrew University in Jerusalem and then at Stanford, from 1978–2005 when she took early retirement. She is an active Emerita Professor of Psychology at Stanford and Professor of Psychology at Columbia Teachers College. She is a fellow of the Association for Psychological Science, the Cognitive Science Society, the Society for Experimental Psychology, the Russell Sage Foundation, and the American Academy of Arts and Science. She has been on the Governing Boards of the Psychonomic Society, the Cognitive Science Society and the International Union of Psychological Science. She is Past-President of the Association for Psychological Science. She has served on the editorial boards of many journals and the organizing committees of dozens of international interdisciplinary meetings.

Her research has spanned memory, categorization, language, spatial cognition, event perception and cognition, diagrammatic reasoning, sketching, creativity, design, and gesture. The overall goals have been to uncover how people think about the spaces they inhabit and the actions they perform and see and then how people use the world, including their own actions and creations, to remember, to think, to create, to communicate. A recent book, Mind in Motion: How Action Shapes Thought, Basic Books, overview that work. She has collaborated widely, with linguists, philosophers, neuroscientists, computer scientists, chemists, biologists, architects, designers, and artists.

Making Sense Out of Activity Sensing in Eldercare

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With the increase in the population of older adults around the world, a significant amount of work has been done on in-home sensor technology to aid the elderly age independently. However, due to the large amounts of data generated by the sensors, it takes a lot of effort and time for the clinicians to makes sense of this data. In this talk, I will survey two connected approaches to provide explanations of these complex sensor patterns as they relate to senior health. Abnormal sensor patterns produced by certain resident behaviors could be linked to early signs of illness. In seven eldercare facilities around Columbia, MO operated by Americare, we have deployed an intelligent elderly monitoring system with summarization and symptom suggesting capabilities for 3 years.

The first procedure starts by identifying important attributes in the sensor data that are relevant to the health of the elderly. We then develop algorithms to extract these important health related features from the sensor parameters and summarize them in natural language, with methods grounded in fuzzy set theory. We focus on making the natural language summaries to be informative, accurate and concise, and have conducted numerous surveys of experts to validate our choices. While our initial focus is on producing summaries that are informative to healthcare personnel, a recent grant centers on providing feedback to the elders and their families. The Amazon Echo Show is used as the communication device to provide simplified graphics and linguistic health messages.

The second approach is a framework for detecting health patterns utilizing sensor sequence similarity and natural language processing (NLP). A context preserving representation of daily activities is used to measure the similarity between the sensor sequences of different days. Medical concepts are extracted from nursing notes that allows us to impute potential reasons for health alerts based on the activity similarity. Joining these two approaches provide a powerful XAI description of early illness recognition for elders.

Biography

James M. Keller received the Ph.D. in Mathematics in 1978. He is now the Curators' Distinguished Professor Emeritus in the Electrical Engineering and Computer Science Department at the University of Missouri. Jim is an Honorary Professor at the University of Nottingham. His research interests center on computational intelligence: fuzzy set theory and fuzzy logic, neural networks, and evolutionary computation with a focus on problems in computer vision, pattern recognition, and information fusion including bioinformatics, spatial reasoning in robotics, geospatial intelligence, sensor and information analysis in technology for eldercare, and landmine detection.

His industrial and government funding sources include the Electronics and Space Corporation, Union Electric, Geo-Centers, National Science Foundation, the Administration on Aging, The National Institutes of Health, NASA/JSC, the Air Force Office of Scientific Research, the Army Research Office, the Office of Naval Research, the National Geospatial Intelligence Agency, the U.S. Army Engineer Research and Development Center, the Leonard Wood Institute, and the Army Night Vision and Electronic Sensors Directorate. Professor Keller has coauthored over 500 technical publications.

Jim is a Life Fellow of the Institute of Electrical and Electronics Engineers (IEEE), a Fellow of the International Fuzzy Systems Association (IFSA), and a past President of the North American Fuzzy Information Processing Society (NAFIPS). He received the 2007 Fuzzy Systems Pioneer Award and the 2010 Meritorious Service Award from the IEEE Computational Intelligence Society (CIS). He has been a distinguished lecturer for the IEEE CIS and the ACM. Jim finished a full six year term as Editor-in-Chief of the IEEE Transactions on Fuzzy Systems, followed by being the Vice President for Publications of the IEEE Computational Intelligence Society from 2005–2008, then as an elected CIS Adcom member, and is in another term as VP Pubs (2017–2020). He was the IEEE TAB Transactions Chair as a member of the IEEE Periodicals Committee, and is a member of the IEEE Publication Review and Advisory Committee from 2010 to 2017. Among many conference duties over the years, Jim was the general chair of the 1991 NAFIPS Workshop, the 2003 IEEE International Conference on Fuzzy Systems, and co-general chair of the 2019 IEEE International Conference on Fuzzy Systems.

From Eliza to Siri and Beyond

Luísa Coheur[1,2]

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Since Eliza, the first chatbot ever, developed in the 60s, researchers try to make machines understand (or mimic the understanding) of Natural Language input. Some conversational agents target small talk, while others are more task-oriented. However, from the earliest rule-based systems to the recent data-driven approaches, although many paths were explored with more or less success, we are not there yet. Rule-based systems require much manual work; data-driven systems require a lot of data. Domain adaptation is (again) a current hot-topic. The possibility to add emotions to the conversational agents' responses, or to make their answers capture their "persona", are some popular research topics. This paper explains why the task of Natural Language Understanding is so complicated, detailing the linguistic phenomena that lead to the main challenges. Then, the long walk in this field is surveyed, from the earlier systems to the current trends.

Biography

Luísa Coheur graduated in Applied Mathematics and Computation and has an M.Sc. degree in Electrical and Computer Engineering, both from Instituto Superior Técnico (IST). In 2004, she concluded her Dual degree Ph.D in Computer Science and Engineering (IST), and Linguistique, Logique et Informatique (Université Blaise-Pascal). She is a researcher at INESC-ID since 2001, and a lecturer at IST since March 2006. Luísa Coheur has been working in the Natural Language Processing field since her Master's thesis. Her main research interest is Natural Language Understanding, being Question/Answering, Dialogue Systems and Machine Translation her key application scenarios. She strongly believes that science should be in service to the public good, and she is currently building a prototype that translates European Portuguese into LGP (Língua Gestual Portuguesa), using an avatar. She participated in several national and international projects; she supervised and/or co-supervised 55 masters' and 6 Ph.D students. Luísa Coheur is also a part-time writer. She has 3 published books and two short stories, which won literature prizes.

Average Jane, Where Art Thou? – Recent Avenues in Efficient Machine Learning Under Subjectivity Uncertainty

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In machine learning tasks an actual 'ground truth' may not be available. Then, machines often have to rely on human labelling of data. This becomes challenging the more subjective the learning task is, as human agreement can be low. To cope with the resulting high uncertainty, one could train individual models reflecting a single human's opinion. However, this is not viable, if one aims at mirroring the general opinion of a hypothetical 'completely average person' – the 'average Jane'. Here, I summarise approaches to optimally learn efficiently in such a case. First, different strategies of reaching a single learning target from several labellers will be discussed. This includes varying labeller trustability and the case of time-continuous labels with potential dynamics. As human labelling is a labour-intensive endeavour, active and cooperative learning strategies can help reduce the number of labels needed. Next, sample informativeness can be exploited in teacher-based algorithms to additionally weigh data by certainty. In addition, multi-target learning of different labeller tracks in parallel and/or of the uncertainty can help improve the model robustness and provide an additional uncertainty measure. Cross-modal strategies to reduce uncertainty offer another view. From these and further recent strategies, I distil a number of future avenues to handle subjective uncertainty in machine learning. These comprise bigger, yet weakly labelled data processing basing amongst other on reinforcement learning, lifelong learning, and self-learning. Illustrative examples stem from the fields of Affective Computing and Digital Health – both notoriously marked by subjectivity uncertainty.

Biography

Björn W. Schuller received his diploma, doctoral degree, habilitation, and Adjunct Teaching Professor in Machine Intelligence and Signal Processing all in EE/IT from TUM in Munich/Germany. He is Full Professor of Artificial Intelligence and the Head of GLAM at Imperial College London/UK, Full Professor and Chair of Embedded Intelligence for Health Care and Wellbeing at the University of Augsburg/Germany,

co-founding CEO and current CSO of audEERING – an Audio Intelligence company based near Munich and in Berlin/Germany, and permanent Visiting Professor at HIT/China amongst other Professorships and Affiliations. Previous stays include Full Professor at the University of Passau/Germany, and Researcher at Joanneum Research in Graz/Austria, and the CNRS-LIMSI in Orsay/France.

He is a Fellow of the IEEE, Fellow of the ISCA, Golden Core Awardee of the IEEE Computer Society, President-Emeritus of the AAAC, and Senior Member of the ACM. He (co-)authored 900+ publications (h-index = 79), is Field Chief Editor of Frontiers in Digital Health and was Editor in Chief of the IEEE Transactions on Affective Computing, General Chair of ACII 2019, ACII Asia 2018, and ACM ICMI 2014, and a Program Chair of Interspeech 2019, ACM ICMI 2019/2013, ACII 2015/2011, and IEEE SocialCom 2012 amongst manifold further commitments and service to the community. His 40+ awards include having been honoured as one of 40 extraordinary scientists under the age of 40 by the WEF in 2015. He served as Coordinator/PI in 15+ European Projects, is an ERC Starting Grantee, and consultant of companies such as Barclays, GN, Huawei, or Samsung.

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