Colophon: The typeset of this booklet has been prepared in Microsoft Word 2003. The font Garamond was used for the headings and text throughout this document, except for the section Abstracts, where the font Tahoma was used for the session title and paper title.

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Message from local organization

Dear Participants,

It is a great pleasure to welcome you to the 16th edition of the International Conference on Information Processing and Management of Uncertainty in Knowledge-Based Systems (IPMU 2016). IPMU conference is organized every two years with the aim of bringing together scientists working on methods for the management of uncertainty and aggregation of information in intelligent systems. This year, it is being organized in Eindhoven, the Netherlands, which is one of the leading technology hotspots of Europe, and is also known by the name Brainport Eindhoven. This region is a breeding ground for innovation and the home base for many technology companies, world-class knowledge organizations and research institutes: a venue very suitable for IPMU.

Since 1986, the IPMU conference has been providing a forum for the exchange of ideas between theoreticians and practitioners working in information processing, management of uncertainty and related fields. In addition to the many contributed scientific papers, the conference has in the past attracted prominent plenary speakers, including the Nobel Prize winners Kenneth Arrow, Daniel Kahneman and Ilya Prigogine. Another important feature of the conference is the presentation of the Kampé de Féter Award for outstanding contributions to the field of uncertainty and management of uncertainty. IPMU 2016 aims to provide a stimulating forum for scientists and students to share the excitement of disseminating the latest research findings in fundamental issues of information processing and management of uncertainty. The program is broad, consisting, again, of prominent plenary speakers, invited overview talks intended as tutorials, industry round tables, multiple parallel sessions and panel discussions. We trust that the atmosphere at IPMU 2016 will create a pleasant environment for you to meet your old friends and make new friends for expanding your network connections with possible future collaborations.

Organizing a conference like IPMU 2016 is not possible without the assistance, dedication and support of many people and institutions. Special thanks go to our Program Chairs Marie-Jeanne Lesot and João Paulo Carvalho, who steered the review process and the composition of the program excellently in order to provide a varied and interesting program. We also thank IPMU Executive Directors Bernadette Bouchon-Meunier and Ron Yager for their guidance in organizing the conference. We are particularly grateful to the organizers of special sessions on dedicated topics that took place during the conference. Special thanks go to Joao Sousa, who helped evaluate and select the special session proposals and to Susana Vieira for the realisation of the conference proceedings. The Local Organizing Committee is also very grateful for the efforts of multiple student volunteers, who provide practical support during the conference.

We also want to thank our industry sponsors, the institutional sponsors and the material sponsors. Our sponsor chair Paul Grefen did an excellent job in attracting the interest and the support from the industry for the success of IPMU 2016. Finally, we gratefully acknowledge the technical support of several organizations and institutions, notably the IEEE Computational Intelligence Society, IEEE CIS Benelux Chapter, the European Society for Fuzzy Logic and Technology (EUSFLAT), the Netherlands Research School for Information and Knowledge Systems (SIKS) and the Netherlands Organization for Scientific Research (NWO). Last, but not least, our greatest gratitude goes to the authors who have submitted their work and present them at the conference. We hope your time in Eindhoven will be an exciting one!

June 2016,

Uzay Kaymak Anna Wilbik Rui J. Almeida Caro Fuchs.
Dear Participants,

On behalf of the Program Committee, it is a great honor to welcome you to Eindhoven, The Netherlands, to the 16th edition of the International Conference on Information Processing and Management of Uncertainty in Knowledge-Based Systems (IPMU 2016). As you well know, IPMU conference is organized every two years with the aim of bringing together scientists working on methods for the management of uncertainty and aggregation of information in intelligent systems, and it has been our pleasure as Program Committee Co-Chairs to help organize this meeting and prepare its technical program.

IPMU 2016 has a rich scientific program:

- Four invited overview talks will be given on the first day, offering tutorials, identifying the challenges and discussing the various methods in the field of information processing and the management of uncertainty;
- Five invited plenary talks, given by the distinguished researchers Chris Dyer (Carnegie Mellon University, USA), Joseph Y. Halpern (Cornell University, USA), Katharina Morik (Technische Universität Dortmund, Germany), Peter P. Wakker (Erasmus University Rotterdam, The Netherlands) and Ronald R. Yager (Iona College, USA);
- 13 special sessions and 15 regular sessions consisting of 127 papers authored by researchers from 34 different countries;
- Several panels discussing topical issues in computational intelligence research;
- One industry round table bringing forward the cross-fertilization of academic and industry domains in data sciences.

The number of strong submissions to IPMU 2016 was very high, resulting in a relatively high acceptance rate despite the strict reviewing process. All submitted papers were reviewed by at least 3 independent reviewers with a score ranging from -3 to 3 (strong reject, reject, weak reject, borderline paper, weak accept, accept, and strong accept). Only papers with a global positive recommendation were accepted. In the cases where there was a dissident review, the papers were further reviewed by the Program Chairs. In addition, a second review turn guaranteed that the most critical comments were addressed before the final version was accepted. The review process also respected the usual conflict-of-interest standards, guaranteeing that all papers received blind, independent evaluations.

The resulting technical program brings together an outstanding diversity of papers that we are sure will make for an exciting conference, so we hope you will enjoy the program as well as the location.

All this would not be possible without the help of many individuals, including the General Chair, Uzay Kaymak, the Special Session Chair, João M. C. Sousa, all the organizers and co-organizers of the 13 accepted Special Sessions, the members of program committee, the local organizing committee, the reviewers and, above all, the authors! Without their contribution, this year’s conference would not exist. We thank them all for their help and hope everyone will appreciate the result of their combined effort.

June 2016,

Marie-Jeanne Lesot  João Paulo Carvalho.
Venue

Conference location

The conference will take place at the Eindhoven University of Technology (TU/e) campus, in Eindhoven, The Netherlands. The campus of TU/e (Den Dolech 2, 5612 AZ Eindhoven) is located right in the center of the city of Eindhoven, next to the railway station. Sessions will take place in the Blauwe Zaal, Collegezaal 12 and Collegezaal 13 of the Auditorium (indicated as AUD on the map of the campus) and the Filmzaal in De Zwarte Doos.

Map of the TU/e campus.

Level 1 Auditorium
Level 2 Auditorium

Conference banquet

The conference banquet will be held at the Philips Stadion (Frederiklaan 10, 5616 NH Eindhoven). This stadium is the home of the football team PSV (originally meaning Philips Sport Vereniging), also known as PSV Eindhoven. With a capacity of 35,000, it is the third-largest football stadium in the country.

The entrance is main entrance, indicated as number 8 on the map.
Practicalities

About Eindhoven

Eindhoven is located in the southeast of the Netherlands, within 50 km of both the German and Belgian borders. The closest large cities are Düsseldorf (Germany) and Antwerp (Belgium). The Dutch capital Amsterdam is 125 km away. With a population of 215,000, the city of Eindhoven is the fifth largest city in the Netherlands and the largest in the southern Netherlands. Around 700,000 people live in the region of Eindhoven.

The Eindhoven region has become one of the leading technology hotspots in Europe, which is also known by the name Brainport Eindhoven. This region is a breeding ground for innovation and the home base for companies, and world-class knowledge and research institutes. Many top international high-tech companies are located in Eindhoven, such as Philips, DAF Trucks and ASML. Eindhoven offers good social and cultural facilities and plenty of facilities for concerts or theatre performances and a museum of modern art. Numerous cafés and restaurants lend the town center the pleasant and lively air of the big city.

Health

It is unlikely that you will encounter unusual health problems in the Netherlands, and if you do, standards of care are world-class. The emergency phone number for police, ambulance and the fire department is 112.

If you are an EU citizen, a European Health Insurance Card (EHIC) covers you for most medical care. It will not cover you for non-emergencies or emergency repatriation. Citizens from other countries should find out if there is a reciprocal arrangement for free medical care between their country and the Netherlands. No vaccinations are necessary for travelling to the Netherlands.

Money

In the Netherlands the Euro is used as currency. There are six coins; 5, 10, 20 and 50 cents, and 1 and 2 Euro coins. There are the bills of 5, 10, 20 and 50, 100, 200 and 500 Euro. However, not many places will accept the 200 and 500 euro note.

Language

The official language of The Netherlands is Dutch. However, most of Dutch people speak at least one foreign language, mostly English since this language is taught at school during basic education. Many Dutch people also speak German, which is in many aspects similar to the Dutch language, and some of them speak French.

Electricity

The electrical current in The Netherlands is 230 volts with a frequency of 50 Hz. Round two-pin plugs are used (type-F).

Transportation

The Netherlands has excellent public transport links, and the swipe-card payment system (OV-chipkaart) is the official transport payment system for all the public transport throughout the Netherlands. Paper train tickets were abolished mid-2014, and infrequent train travelers can buy a single-use chipkaart at EUR 1 extra per trip. The website www.9292ov.nl/en provides door-to-door itineraries for national travel and is available in the English language.

To travel between Eindhoven airport and the city center of Eindhoven, one can take bus line 400 and 401. Line 400 is a direct connection that runs four times an hour. Line 401 makes multiple stops and is therefore a little slower, but runs six times per hour. Both bus lines run only during daytime. For exact departure times, visit the website www.9292ov.nl/en. The journey by bus line 400 takes 18 minutes by bus line 401 takes 21 minutes. A one-way ticket costs € 3.70 and can be bought at the ticket machine in the bus (cash payment), the ticket machines at the airport and at the counter at the central station.

Travelers wishing to travel between Schiphol Airport (Amsterdam) and Eindhoven can make use of the train. A one-way ticket costs €19.80 with the journey taking about 90 minutes.

Taxis are expensive and not allowed to pick up people on the street except by reservation or at a taxi stand. Therefore, look for the 'standplaats taxis' sign. In the larger cities, at bar closing times, you can sometimes flag one down. Look for one with the taxi sign lit.

Weather

Eindhoven is located in an area with a temperate climate. This climate is dominated by a cold front throughout the year resulting in changeable and cloudy weather. The average daily temperature is in the winter period between five and ten degrees Celsius. In the summer months, the average daily temperature is just slightly above twenty degrees Celsius. In the evenings and nights, the temperature might drop around ten degrees Celsius.

Safety

Eindhoven, along with the rest of the Netherlands, has a relatively low crime rate, and you should not run into any problems whilst traveling throughout the area. As with any locale you are unfamiliar with, it pays to be alert while traveling within large crowds, especially during the high season. Pickpockets can quickly pick you clean of your money or passport.

Don't get hit by a bike! Always look before crossing. Visitors who are not used to having lots of bikes in their home town traffic, often have almost-accidents or even serious clashes with oncoming bikes. Bikes are one of the main means of transportation for the Dutch, and they ride fast. There are designated bike lanes (often pink/red or marked with bike symbols), and failing those, bikes will ride on the main road. World’s only suspended cycle path roundabout is even located in Eindhoven!
Organizing committee

General Chair: Uzay Kaymak (Technische Universiteit Eindhoven, The Netherlands)

Program Chairs:
- Marie-Jeanne Lesot (Université Pierre et Marie Curie, France)
- João Paulo Carvalho (INESC-ID, Instituto Superior Técnico, Universidade de Lisboa, Portugal)

Finance Chair: Anna Wilbik (Technische Universiteit Eindhoven, The Netherlands)

Publicity Chair: Rui Jorge Almeida (Technische Universiteit Eindhoven, The Netherlands)

Special Session Chair: João M. C. Sousa (IDMEC, Instituto Superior Técnico, Universidade de Lisboa, Portugal)

Publication Chair: Susana Vieira (IDMEC, Instituto Superior Técnico, Universidade de Lisboa, Portugal)

Sponsor Chair: Paul W.P.J. Grefen (Technische Universiteit Eindhoven, The Netherlands)

Executive Directors:
- Bernadette Bouchon-Meunier (Université Pierre et Marie Curie, France)
- Ronald R. Yager (Iona College, USA)

Local organizing committee:
- Uzay Kaymak (Technische Universiteit Eindhoven, The Netherlands)
- Anna Wilbik (Technische Universiteit Eindhoven, The Netherlands)
- Rui Jorge Almeida (Technische Universiteit Eindhoven, The Netherlands)
- Annemarie van der Aa (Technische Universiteit Eindhoven, The Netherlands)
- Caro Fuchs (Technische Universiteit Eindhoven, The Netherlands)

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Steve Grossberg
PrzemyslawGrzegorzewski
LawrenceHall
FranciscoHerrera
EnriqueHerrera-Viedma
VilemNovak
HannuNurmi
NikhilPal
EndrePap
SimonParsons
GabriellaPasi
WitoldPedrycz
IrinaPerfilieva
ThomasVetterlein
SusanaVieira
AnnaWilbik
SławomirZadrożny
Hans-JürgenZimmermann
JacekZurada
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Matej Bartoszuk
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Chiheb-Eddine Ben N'Cir
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Gracian Trivino
Esko Turunen
Lev Utkin
Lionel Valet
Llorenc Valverde
Francisco J. Valverde Albacete
Jan Van den Berg
Amanda Vidal Wandemmer
Zdenek Wagner
Gero Walter
## Special session organizers

<table>
<thead>
<tr>
<th>Session Title</th>
<th>Organizers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computational Aspects of Data Aggregation and Complex Data Fusion</td>
<td>M. Gagolewski, B. De Baets and G. Beliakov</td>
</tr>
<tr>
<td>Soft Computing for Image Processing</td>
<td>H. Bustince, J. Montero and I. Perfilieva</td>
</tr>
<tr>
<td>Handling Uncertainties in Health and Food Sciences</td>
<td>A. Samet, Y. Bouzembrak and T. T. Dao</td>
</tr>
<tr>
<td>Graded and Many-Valued Modal Logics</td>
<td>L. Godo and B. Teheux</td>
</tr>
<tr>
<td>Fuzzy Measures and Integrals</td>
<td>C. Labreuche and M. Grabisch</td>
</tr>
<tr>
<td>Generating Linguistic Descriptions of Data</td>
<td>A. Bugarin, N. Marin, D. Sanchez and G. Trivino</td>
</tr>
<tr>
<td>Fuzzy Implication Functions</td>
<td>M. Baczynski and S. Massanet</td>
</tr>
<tr>
<td>Uncertainty Quantification with Imprecise Probability</td>
<td>G. Walter</td>
</tr>
<tr>
<td>Advanced Information Analysis Based on Mathematical Gnostics</td>
<td>Z. Wagner, P. Kovanic and T. Ocelka</td>
</tr>
<tr>
<td>Imperfect Databases</td>
<td>M. Chebbah, M-A. Bach Tobji and B. Yaghlane</td>
</tr>
<tr>
<td>Fuzzy Logic, Formal Concept Analysis and Rough Sets</td>
<td>J. Medina and M. Aciego</td>
</tr>
<tr>
<td>Fuzzy methods in Data Mining and Knowledge Discovery</td>
<td>M. D. Ruiz, J. Romero, M. Martin-Bautista and D. Sánchez</td>
</tr>
<tr>
<td>Belief Function Theory and Its Applications</td>
<td>Didier Coquin and Sébastien Destercke</td>
</tr>
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## Panel session organizers

<table>
<thead>
<tr>
<th>Session Title</th>
<th>Organizers</th>
</tr>
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<tbody>
<tr>
<td>Women in Engineering</td>
<td>A. Wilbik, M. Razavian and R. J. Almeida</td>
</tr>
<tr>
<td>Open Access publishing</td>
<td>U. Kaymak</td>
</tr>
<tr>
<td>Industrial round table</td>
<td>H. Eshuis</td>
</tr>
</tbody>
</table>
# Program overview

## Registration

<table>
<thead>
<tr>
<th>Day</th>
<th>Date</th>
<th>Time</th>
<th>Location</th>
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<tbody>
<tr>
<td>Registration</td>
<td>Monday, June 20</td>
<td>08:00-18:00</td>
<td>Registration Desk</td>
</tr>
<tr>
<td></td>
<td>Tuesday, June 21</td>
<td>08:00-17:30</td>
<td>Registration Desk</td>
</tr>
<tr>
<td></td>
<td>Wednesday, June 22</td>
<td>08:30-17:30</td>
<td>Registration Desk</td>
</tr>
<tr>
<td></td>
<td>Thursday, June 23</td>
<td>09:00-17:30</td>
<td>Registration Desk</td>
</tr>
<tr>
<td></td>
<td>Friday, June 24</td>
<td>08:30-11:30</td>
<td>Filmzaal</td>
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## Social events

<table>
<thead>
<tr>
<th>Event</th>
<th>Day</th>
<th>Date</th>
<th>Time</th>
<th>Location</th>
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</thead>
<tbody>
<tr>
<td>Welcome Reception</td>
<td>Monday, June 20</td>
<td>17:45-19:30</td>
<td>Senaatszaal</td>
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<tr>
<td>Banquet</td>
<td>Wednesday, June 22</td>
<td>18:30-22:00</td>
<td>Philips Stadion</td>
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<tr>
<td>Closing Reception</td>
<td>Friday, June 24</td>
<td>12:30-13:30</td>
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## Technical program

### Opening Session
<table>
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<tr>
<th>Date</th>
<th>Time</th>
<th>Location</th>
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<tbody>
<tr>
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<td>Blauwe zaal</td>
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### Parallel Sessions

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<thead>
<tr>
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<th>Time</th>
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<tbody>
<tr>
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<td>Blauwe zaal, Collegezaal 12, Collegezaal 13 &amp; Filmzaal</td>
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<tr>
<td></td>
<td>15:00-16:00</td>
<td>Blauwe zaal, Collegezaal 12, Collegezaal 13 &amp; Filmzaal</td>
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<tr>
<td></td>
<td>16:20-17:40</td>
<td>Blauwe zaal, Collegezaal 12, Collegezaal 13 &amp; Filmzaal</td>
</tr>
<tr>
<td>Wednesday, June 22</td>
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<td>Blauwe zaal, Collegezaal 12, Collegezaal 13 &amp; Filmzaal</td>
</tr>
<tr>
<td></td>
<td>15:00-16:00</td>
<td>Blauwe zaal, Collegezaal 12, Collegezaal 13 &amp; Filmzaal</td>
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<tr>
<td></td>
<td>16:20-17:20</td>
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<tr>
<td>Thursday, June 23</td>
<td>10:50-12:10</td>
<td>Blauwe zaal, Collegezaal 12 &amp; Collegezaal 13</td>
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<tr>
<td></td>
<td>15:00-16:00</td>
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<tr>
<td></td>
<td>15:41-18:00</td>
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### Invited Overview Talks

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
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<tbody>
<tr>
<td>Monday, June 20</td>
<td>09:00-10:30</td>
<td>Filmzaal</td>
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<tr>
<td>Monday, June 20</td>
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<td>Monday, June 20</td>
<td>13:50-15:20</td>
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<tr>
<td>Monday, June 20</td>
<td>15:50-17:20</td>
<td>Filmzaal</td>
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### Industrial round table
<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Location</th>
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<tbody>
<tr>
<td>Friday, June 24</td>
<td>09:00-12:00</td>
<td>Filmzaal</td>
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### Plenary Talks

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<tr>
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<tbody>
<tr>
<td>Tuesday, June 21</td>
<td>09:20-10:20</td>
<td>Blauwe zaal</td>
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<tr>
<td>Tuesday, June 21</td>
<td>14:00-15:00</td>
<td>Blauwe zaal</td>
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<tr>
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<td>09:00-10:00</td>
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<td>17:40-20:00</td>
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<tr>
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<tr>
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### EUSFLAT Meeting
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<tr>
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<tbody>
<tr>
<td>Tuesday, June 21</td>
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### IEEE CIS Benelux Chapter Meeting
<table>
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<tr>
<td>Thursday, June 23</td>
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### Kampé de Feriet award ceremony
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<tbody>
<tr>
<td>Tuesday, June 21</td>
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<td>Blauwe zaal</td>
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### Panel Session: Women in Engineering
<table>
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<tbody>
<tr>
<td>Wednesday, June 22</td>
<td>12:00-14:00</td>
<td>Blauwe zaal</td>
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### Panel Session: Open Access Publishing
<table>
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<tr>
<th>Date</th>
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<th>Location</th>
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<tbody>
<tr>
<td>Thursday, June 23</td>
<td>13:30-15:00</td>
<td>Blauwe zaal</td>
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### Closing Session
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<th>Date</th>
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<tbody>
<tr>
<td>Friday, June 24</td>
<td>12:00-12:30</td>
<td>Filmzaal</td>
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</table>
Program at-a-glance

Monday, 20th of June

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
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<tbody>
<tr>
<td>8:00-18:00</td>
<td>Registration (Registration Desk)</td>
</tr>
<tr>
<td>9:00-10:30</td>
<td>Invited Overview Talk - Joseph Halpern, Cornell University, USA (Film Zaal)</td>
</tr>
<tr>
<td>10:30-10:50</td>
<td>Coffee Break</td>
</tr>
<tr>
<td>10:50-12:20</td>
<td>Invited Overview Talk - James Keller, University of Missouri, USA (Film Zaal)</td>
</tr>
<tr>
<td>12:20-13:50</td>
<td>Lunch (Lounge/Zwarte Doos)</td>
</tr>
<tr>
<td>13:50-15:50</td>
<td>Coffee Break</td>
</tr>
<tr>
<td>15:50-17:20</td>
<td>Invited Overview Talk - Arthur ter Hofstede, Queensland University of Technology, Australia (Film Zaal)</td>
</tr>
<tr>
<td>17:45-19:30</td>
<td>Welcome Reception (Senaatzaal)</td>
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Tuesday, 21st of June

<table>
<thead>
<tr>
<th>Room</th>
<th>Blauwe zaal</th>
<th>Collegezaal 12</th>
<th>Collegezaal 13</th>
<th>Filmzaal</th>
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<tr>
<td>8:00-17:30</td>
<td>Registration (Registration Desk)</td>
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<tr>
<td>9:00-9:20</td>
<td>Opening Session (Blauwe zaal)</td>
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<tr>
<td>9:20-10:20</td>
<td>Plenary Talk - Joseph Halpern, Cornell University, USA (Blauwe zaal)</td>
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<td>10:20-10:30</td>
<td>Lunch (Lounge/Zwarte Doos)</td>
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<td>10:30-10:50</td>
<td>Coffee Break</td>
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<tr>
<td>10:50-12:30</td>
<td>SS05 Fuzzy Measures and Integrals I</td>
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<tr>
<td>10:50-12:30</td>
<td>SS08 Uncertainty Quantification with Imprecise Probability</td>
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<td>10:50-12:30</td>
<td>Textual Data Processing</td>
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<td>10:50-12:30</td>
<td>SS13 Belief Function Theory Its Applications</td>
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<tr>
<td>12:30-14:00</td>
<td>Lunch (Senaatzaal)</td>
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<tr>
<td>14:00-15:00</td>
<td>Plenary Talk - Peter P. Wakker, Erasmus University Rotterdam, The Netherlands (Blauwe zaal)</td>
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<tr>
<td>15:00-16:00</td>
<td>SS05 Fuzzy Measures and Integrals II</td>
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<tr>
<td>15:00-16:00</td>
<td>Graphical Models</td>
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<td>15:00-16:00</td>
<td>SS07 Fuzzy Implication Functions I</td>
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<tr>
<td>16:00-16:20</td>
<td>Applications in Medicine and Bioinformatics</td>
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<td>16:00-16:20</td>
<td>Coffee Break</td>
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<tr>
<td>16:20-17:40</td>
<td>SS05 Fuzzy Measures and Integrals III</td>
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<tr>
<td>16:20-17:40</td>
<td>Real World Applications</td>
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<tr>
<td>16:20-17:40</td>
<td>SS07 Fuzzy Implication Functions II</td>
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<tr>
<td>16:20-17:40</td>
<td>SS12 Fuzzy methods in Data Mining and Knowledge Discovery</td>
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<tr>
<td>17:40-20:00</td>
<td>EUSFLAT Meeting (Film Zaal)</td>
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### Wednesday, 22nd of June

<table>
<thead>
<tr>
<th>Time</th>
<th>Room</th>
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<td>8:30-17:30</td>
<td>Registration (Registration Desk)</td>
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<tr>
<td>9:00-10:00</td>
<td>Plenary Talk - Chris Dyer, CMU, USA (Blauwe zaal)</td>
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<tr>
<td>10:00-10:20</td>
<td>Coffee Break</td>
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<tr>
<td>10:20-12:00</td>
<td>SS02 Soft Computing for Image Processing I</td>
<td>Blauwe zaal</td>
<td>Clustering</td>
<td>SS11 Fuzzy Logic, Formal Concept Analysis and Rough Sets I</td>
<td>Temporal data processing</td>
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<tr>
<td>12:00-14:00</td>
<td>Panel Session: Women in Engineering (Blauwe Zaal), including Lunch (Senaatzaal)</td>
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<tr>
<td>14:00-15:00</td>
<td>Plenary Talk - Katharina Morik, University of Dortmund, Germany (Blauwe Zaal)</td>
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<tr>
<td>15:00-16:00</td>
<td>SS02 Soft Computing for Image Processing II</td>
<td>Blauwe zaal</td>
<td>SS04 Graded and Many-Valued Modal Logics I</td>
<td>SS11 Fuzzy Logic, Formal Concept Analysis and Rough Sets II</td>
<td>Multiple Criteria Decision Methods</td>
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<td>16:00-16:20</td>
<td>Coffee Break</td>
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<tr>
<td>16:20-17:20</td>
<td>SS10 Imperfect Databases</td>
<td>Blauwe zaal</td>
<td>SS04 Graded and Many-Valued Modal Logics II</td>
<td>Comparison Measures</td>
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<td>18:30-22:00</td>
<td>Banquet - Philips Stadion</td>
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### Thursday, 23rd of June

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<tr>
<td>9:30-10:30</td>
<td>Plenary Talk - Ron Yager, Iona College, USA (Blauwe zaal)</td>
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<td>10:30-10:50</td>
<td>Coffee Break</td>
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<tr>
<td>10:50-12:10</td>
<td>Fuzzy Sets and Fuzzy Logic I</td>
<td>Blauwe zaal</td>
<td>Databases and Information Systems I</td>
<td>SS01 Computational Aspects of Data Aggregation and Complex</td>
<td>Argumentation and Belief Revision</td>
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<td>12:10-13:30</td>
<td>Lunch (Senaatzaal)</td>
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<tr>
<td>13:30-15:00</td>
<td>Panel Session: Open Access Publishing (Blauwe zaal)</td>
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<tr>
<td>15:00-16:00</td>
<td>Social Data Processing</td>
<td>Blauwe zaal</td>
<td>Machine learning</td>
<td>Decision support</td>
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<tr>
<td>16:00-16:20</td>
<td>Coffee Break</td>
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<tr>
<td>16:20-18:00</td>
<td>Fuzzy Sets and Fuzzy Logic II</td>
<td>Blauwe zaal</td>
<td>Databases and Information Systems II</td>
<td>Aggregation</td>
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<tr>
<td>18:00-19:00</td>
<td>IEEE CIS Benelux Chapter Meeting (Filmzaal)</td>
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### Friday, 24th of June

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<th>Time</th>
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<tr>
<td>8:30-11:30</td>
<td>Registration (Film zaal)</td>
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<tr>
<td>9:00-10:30</td>
<td>Industrial Round Table - Data Science for Smart Industry (Presentations)</td>
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<td>Coffee Break</td>
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<td>Industrial Round Table - Data Science for Smart Industry (Panel)</td>
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<tr>
<td>12:00-12:30</td>
<td>Closing Session</td>
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<tr>
<td>12:30-13:30</td>
<td>Lunch &amp; Closing Reception (Senaatzaal)</td>
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## Technical program

### Invited Overview Talk: Plausibility measures: a uniform approach to counterfactual reasoning, default reasoning, and belief change
**Monday 20th of June, 09:00-10:30, Filmzaal**  
*Speaker: Joseph Halpern, Cornell University, USA*

### Invited Overview Talk: Fuzzy and possibilistic clustering and the curious case of coincident clusters
**Monday 20th of June, 10:50-12:20, Filmzaal**  
*Speaker: James Keller, University of Missouri, USA*

### Invited Overview Talk: Process Query Language: A Tutorial
**Monday 20th of June, 13:50-15:20, Filmzaal**  
*Speaker: Arthur ter Hofstede, Queensland University of Technology, Australia*

### Invited Overview Talk: Data science in the enterprise
**Monday 20th of June, 15:50-17:20, Filmzaal**  
*Speaker: Gijs Wobben, Marianne Faro, Olaf Klooster, Itility, The Netherlands*

### Welcome reception
**Monday 20th of June, 17:45-19:30, Senaatszaal**

### Plenary Talk: Actual Causality: A Survey
**Tuesday 21st of June, 09:20-10:20, Blauwe zaal**  
*Speaker: Joseph Halpern, Cornell University, USA*  
*Chair: Ronald Yager*

### SS05: Fuzzy Measures and Integrals I
**Tuesday 21st of June, 10:50-12:30, Blauwe zaal**  
*Chair: Christophe Labreuche*

<table>
<thead>
<tr>
<th>Time</th>
<th>Talk</th>
<th>Authors/Institutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tu 21, 10:50</td>
<td>Decomposition integral based generalizations of OWA operators</td>
<td>Radko Mesiar and Andrea Stupnanova</td>
</tr>
<tr>
<td>Tu 21, 11:10</td>
<td>Finding the set of k-additive dominating measures viewed as a flux problem</td>
<td>Pedro Miranda and Michel Grabisch</td>
</tr>
<tr>
<td>Tu 21, 11:30</td>
<td>On capacities characterized by two weight vectors</td>
<td>Christophe Labreuche</td>
</tr>
<tr>
<td>Tu 21, 11:50</td>
<td>Computing Superdifferentials of Lovász Extension With Application to Coalitional Games</td>
<td>Lukáš Adam and Tomas Kroupa</td>
</tr>
<tr>
<td>Tu 21, 12:10</td>
<td>Conjoint axiomatization of the Choquet integral for heterogeneous product sets</td>
<td>Mikhail Timonin</td>
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</table>

### SS08: Uncertainty Quantification with Imprecise Probability
**Tuesday 21st of June, 10:50-12:30, Collegezaal 12**  
*Chair: Gero Walter*

<table>
<thead>
<tr>
<th>Time</th>
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<tbody>
<tr>
<td>Tu 21, 10:50</td>
<td>Efficient Simulation approaches for Reliability Analysis of Large Systems</td>
<td>Edoardo Patelli and Geng Feng</td>
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<tr>
<td>Tu 21, 11:10</td>
<td>Bivariate p-boxes and maxitive functions</td>
<td>Ignacio Montes and Enrique Miranda</td>
</tr>
<tr>
<td>Tu 21, 11:30</td>
<td>Sets of Prior Distributions for Reflecting Prior-Data Conflict and Strong Prior-Data Agreement</td>
<td>Gero Walter and Frank Coolen</td>
</tr>
<tr>
<td>Tu 21, 11:50</td>
<td>On imprecise statistical inference for accelerated life testing</td>
<td>Frank Coolen, Yi-Chao Yin and Tahani Coolen-Maturi</td>
</tr>
<tr>
<td>Tu 21, 12:10</td>
<td>The Mathematical Gnostics - Advanced Data Analysis</td>
<td>Pavel Kovanic</td>
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### Textual Data Processing
**Tuesday 21st of June, 10:50-12:30, Collegezaal 13**  
*Chair: Anna Wilbik*

<table>
<thead>
<tr>
<th>Time</th>
<th>Talk</th>
<th>Authors/Institutions</th>
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<tbody>
<tr>
<td>Tu 21, 10:50</td>
<td>The role of graduality for referring expression generation in visual scenes</td>
<td>Albert Gatt, Nicolás Marín, François Portet and Daniel Sanchéz</td>
</tr>
<tr>
<td>Time</td>
<td>Title</td>
<td>Authors</td>
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<tr>
<td>Tu 21, 11:10</td>
<td>Impact of the Shape of Membership Functions on the Truth Values of Linguistic Protoform Summaries</td>
<td>Akshay Jain, Tianqi Jiang and Jim Keller</td>
</tr>
<tr>
<td>Tu 21, 11:30</td>
<td>A Solution of the Multiaspect Text Categorization Problem by a Hybrid HMM and LDA Based Technique</td>
<td>Slawomir Zadrozny, Janusz Kąpczyk and Marek Gąjewski</td>
</tr>
<tr>
<td>Tu 21, 11:50</td>
<td>How much is “about?” Fuzzy interpretation of approximate numerical expressions</td>
<td>Sébastien Lefort, Marie-Joanne Lesot, Elisabetta Zibelli, Charles Tijms and Marcin Dęźniecki</td>
</tr>
<tr>
<td>Tu 21, 12:10</td>
<td>Scenario Query based on Association Rules (SQAR)</td>
<td>Carlos Medina, Belen Prudencio-Suarez and Daniel Sanchez</td>
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**SS13 - Belief Function Theory and Its Applications**

**Tuesday 21st of June, 10:50-12:30, Filmzaal**

**Chair: Didier Coquin**

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<thead>
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<th>Time</th>
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<tbody>
<tr>
<td>Tu 21, 10:50</td>
<td>Joint Feature Transformation and Selection based on Dempster-Shafer Theory</td>
<td>Chunfeng Lian, Su Ruan and Thierry Denoeux</td>
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<tr>
<td>Tu 21, 11:10</td>
<td>Recognition of confusing objects for NAO robot</td>
<td>Thanh-Long Nguyen, Didier Coquin and Ruda Boukeczkula</td>
</tr>
<tr>
<td>Tu 21, 11:30</td>
<td>Evidential Missing Link Prediction in Uncertain Social Networks</td>
<td>Sabrine Mallek, Imen Boukhrit, Zied Elouedi and Eric Lefèvre</td>
</tr>
<tr>
<td>Tu 21, 11:50</td>
<td>An evidential filter for indoor navigation of a mobile robot in dynamic environment</td>
<td>Quentin Labourey, Olivier Ayard, Denis Pelletin, Midcole Rambaut and Catherine Garbay</td>
</tr>
<tr>
<td>Tu 21, 12:10</td>
<td>A solution for the learning problem in Evidential (Partially) Hidden Markov Models based on Conditional Belief Functions and EM</td>
<td>Emmanuel Ramasso</td>
</tr>
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</table>

**Plenary Talk: The Present State of the Art of Modeling Uncertainty in Decision Theory, Resulting from an Interaction between Mathematical Economists and Empirical Psychologists**

**Tuesday 21st of June, 14:00-15:00, Blauwe zaal**

**Speaker: Peter Wakker, Erasmus University Rotterdam, The Netherlands**

**Chair: Uzay Kaymak**

**SS05: Fuzzy Measures and Integrals II**

**Tuesday 21st of June, 15:00-16:00, Blauwe zaal**

**Chair: Christophe Labreuche**

<table>
<thead>
<tr>
<th>Time</th>
<th>Title</th>
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<tbody>
<tr>
<td>Tu 21, 15:00</td>
<td>Aggregation of Choquet integrals</td>
<td>Ladislav Šipeky, Aleksandra Šipošová and Radko Mesiar</td>
</tr>
<tr>
<td>Tu 21, 15:20</td>
<td>Inclusion-exclusion integral and t-norm based data analysis model construction</td>
<td>Aoi Honda and Yoshiaki Okazaki</td>
</tr>
<tr>
<td>Tu 21, 15:40</td>
<td>Fuzzy Integral for Rule Aggregation in Fuzzy Inference Systems</td>
<td>Leary Tomlin, Derek Anderson, Christian Wagner, Timothy Havens and James Keller</td>
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**Graphical Models**

**Tuesday 21st of June, 15:00-16:00, Collegezaal 12**

**Chair: Davide Petruiti**

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<tr>
<td>Tu 21, 15:00</td>
<td>Determination of Variables for a Bayesian Network and the Most Precious One</td>
<td>Esma Nur Cinciglio and Taylan Yenişer</td>
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<td>Tu 21, 15:20</td>
<td>Incremental Junction Tree Inference</td>
<td>Hanza Agli, Philippe Bonnard, Christophe Gonzales and Pierre-Henri Willemin</td>
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<td>Tu 21, 15:40</td>
<td>Real time learning of non-stationary processes with dynamic Bayesian Networks</td>
<td>Matthias Hennemar, Christophe Gonzales, Pierre-Henri Willemin and Philippe Bonnard</td>
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**SS07: Fuzzy Implication Functions I**

**Tuesday 21st of June, 15:00-16:00, Collegezaal 13**

**Chair: Michal Baczynski**

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<td>Tu 21, 15:00</td>
<td>About the use of admissible order for defining implication operators</td>
<td>Maria Jose Asiain, Humberto Batucina, Benjamin Bedregal, Zdenká Takáč, Michal Baczynski, Daniel Paternain and Grażyna Dimuro</td>
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<td>Tu 21, 15:20</td>
<td>Generalized Sugeno Integrals</td>
<td>Didier Dubois, Henri Prade, Agnes Rico and Bruno Teheux</td>
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<tr>
<td>Tu 21, 15:40</td>
<td>A new look on fuzzy implication functions: FNI-implications</td>
<td>Isabel Aguiló, Jaume Sári and Joan Torrens</td>
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### Applications in Medicine and Bioinformatics  
**Tuesday 21st of June, 15:00-16:00, Filmzaal**  
**Chair: João Sousa**

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<tr>
<td>Tu 21, 15:00</td>
<td>Non-commutative quantales for many-valuedness in applications</td>
<td>Patrik Eklund, Ulrich Höhle and Jari Kortelainen</td>
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<td>Tu 21, 15:20</td>
<td>Evaluating Tests in Medical Diagnosis: Combining Machine Learning with Game-Theoretical Concepts</td>
<td>Karlton Pfannschmidt, Eyke Hüllemeyer, Susanne Held and Reto Neiger</td>
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<td>Tu 21, 15:40</td>
<td>Fuzzy modeling for vitamin B12 deficiency</td>
<td>Anna Wilbik, Saskia van Loon, Arjen-Kars Boer, Uzay Kaymak and Volker Schornhorst</td>
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### SS05: Fuzzy Measures and Integrals III  
**Tuesday 21st of June, 16:20-17:40, Blauwe zaal**  
**Chair: Christophe Labreuche**

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<tr>
<td>Tu 21, 16:20</td>
<td>On a fuzzy integral as the product-sum calculation between a set function and a fuzzy measure</td>
<td>Eiichiro Takahagi</td>
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<tr>
<td>Tu 21, 16:40</td>
<td>A 2-additive Choquet integral model for French hospitals rankings in weight loss surgery</td>
<td>Brice Mayag</td>
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<td>Tu 21, 17:00</td>
<td>Benchmarking over distributive lattices</td>
<td>Marta Cardin</td>
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### Real world applications  
**Tuesday 21st of June, 16:20-17:40, Collegezaal 12**  
**Chair: Sławomir Zadrozny**

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<tr>
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<td>Using geographic information systems and smartphone-based vibration data to Support decision making on pavement rehabilitation</td>
<td>Chun-Hsing Ho, David Lai and Anas Almoneisy</td>
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<td>Tu 21, 16:40</td>
<td>Automatic synthesis of fuzzy inference systems for classification</td>
<td>Jorge Parredo, Ricardo Tanscheit, Markey Vellasco and Adriano Soares Kashyama</td>
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<td>Tu 21, 17:00</td>
<td>A proposal for modelling agrifood chains as multi agent systems</td>
<td>Madalina Cretoiu, Patrice Buche, Brigitte Charnomordic, Jerome Fortin, Hazael Jones, Pascal Neven, Danai Symeonidou and Ralou Thomopoulos</td>
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<td>Tu 21, 17:20</td>
<td>Predictive model based on the evidence theory for assessing Critical Micelle Concentration property</td>
<td>Ahmed Samet, Tien Tuan Dan, Theophile Gaudin, Huiling Lu, Anne Wadouachi, Guillaume Poussen, Elisabeth Van Hecke, Isabelle Peyrun and Karim El Kirat</td>
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### SS07: Fuzzy Implication Functions II  
**Tuesday 21st of June, 16:20-17:40, Collegezaal 13**  
**Chair: Michał Baczynski**

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<th>Time</th>
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<th>Speaker(s)</th>
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<tr>
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<td>On a generalization of the Modus Ponens: U-conditionality</td>
<td>Margalida Mas, Miguel Monterrat, Daniel Ruiz-Aguilera and Juan Torrens</td>
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<td>Tu 21, 16:40</td>
<td>A new look on the ordinal sum of fuzzy implication functions</td>
<td>Sebastia Massanet, Juan Vicente Riera and Juan Torrens</td>
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<td>Tu 21, 17:00</td>
<td>Distributivity of implication functions over decomposable uninorms generated from representable uninorms in interval-valued fuzzy sets theory</td>
<td>Michał Baczynski and Wanda Nienyska</td>
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<td>Tu 21, 17:20</td>
<td>On functions derived from fuzzy implications</td>
<td>Prewyszlaw Grzygorynski</td>
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### SS12: Fuzzy Methods in Data Mining and Knowledge Discovery  
**Tuesday 21st of June, 16:20-17:40, Filmzaal**  
**Chair: María Dolores Ruiz Jiménez**

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<td>Tu 21, 16:20</td>
<td>An Incremental Fuzzy Approach to Categorising Event Sequences</td>
<td>Trevor Martin and Ben Ayine</td>
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<td>Tu 21, 16:40</td>
<td>Towards a non-Oriented Approach for the Evaluation of Odor Quality</td>
<td>Maxisatilia Medikum, Sebastian Harrip, Jacky Montmain, Stéphane Carion, Jean-Louis Flandre and Nicolas Fiorini</td>
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<td>Tu 21, 17:00</td>
<td>POSGRAMI: Possibilistic Frequent Subgraph Mining in a Single Large Graph</td>
<td>Montacour Zaghdoud, Mohamed Moussad and Jadel Akaichi</td>
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<td>Tu 21, 17:20</td>
<td>Mining consumer characteristics from smart metering data through fuzzy modelling</td>
<td>Joaquim Viegas, Susana Vieira and João Sousa</td>
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### Plenary Talk: Learning Representations of Complex Structures in Natural Language with Neural Networks

**Speaker:** Chris Dyer  
**Chair:** João Paulo Carvalho

### SS02: Soft Computing for Image Processing I

**Wednesday 22nd of June, 10:20-12:00, Blauwe zaal**  
**Chair:** IrinaPerfilieva

- **Wed 22, 10:20** Approximate Pattern Matching Algorithm  
  Petr Hurtík, Petra Hodakova and Irina Perfilieva
- **Wed 22, 10:40** Image Reconstruction by the Patch Based Inpainting  
  Pavel Vlašánek and Irina Perfilieva
- **Wed 22, 11:00** Similarity measures for radial data  
  Carlos López-Molina, Cedric Maron-Detchart, Javier Fernandez, Juan Cerron, Michel Galar and Humberto Bustince
- **Wed 22, 11:20** Application of a Mamdani-Type Fuzzy Rule-Based System to Segment Periventricular Cerebral Veins in Susceptibility-Weighted Images  
  F. Xavier Aymerich, Pilar Sobrevilla, Eduard Montseny and Alex Barreira
- **Wed 22, 11:40** On the use of lattice OWA operators in image reduction and the importance of the orness measure  
  Daniel Paternain, Gustavo Oehna, Inmaculada Lézgoaín, Edurne Barrenchea, Humberto Bustince and Radko Mesiar

### Clustering

**Wednesday 22nd of June, 10:20-12:00, Collegezaal 12**  
**Chair:** Sébastien Destercke

- **Wed 22, 10:20** Seasonal clustering of residential natural gas consumers  
  Marta Fernandes, Joaquim Viegas, Susana Vieira and João Sousa
- **Wed 22, 10:40** Participatory learning fuzzy clustering for interval-valued data  
  Leandro Maricé, Rasangela Ballini, Fernando Comide and Ronald Yager
- **Wed 22, 11:00** Fuzzy c-Means Clustering of Incomplete Data using Dimension-wise Fuzzy Variance of Clusters  
  Ludmila Himmelspach and Stefan Conrad
- **Wed 22, 11:20** On a generalized objective function for possibilistic fuzzy clustering  
  Jozef Mezei and Peter Sarlin
- **Wed 22, 11:40** Proximal optimization for fuzzy subspace clustering  
  Arthur Guillon, Marie-Jeanne Lenz, Christophe Marsala and Nikhil R. Pal

### SS11: Fuzzy Logic, Formal Concept Analysis and Rough Sets I

**Wednesday 22nd of June, 10:20-12:00, Collegezaal 13**  
**Chair:** Jesús Medina

- **Wed 22, 10:20** (Ir)relevant T-norm joint distributions in the arithmetic of fuzzy quantities  
  Andrea Sgarro and Laura Franzoi
- **Wed 22, 10:40** Knowledge extraction from L-fuzzy hypercontexts  
  Cristina Alcalde and Ana Burusco
- **Wed 22, 11:00** A semantical approach to rough sets and dominance-based rough sets  
  Lynn D'Een, Chris Cornelis and Yiyou Yran
- **Wed 22, 11:20** Graded generalized hexagon in fuzzy natural logic  
  Petra Manusova and Vítěz Norek
- **Wed 22, 11:40** On a category of extensional fuzzy rough approximation L-valued spaces  
  Aleksandra Elkins, Alexander Šustak and Ingrida Ujane

### Temporal Data Processing

**Wednesday 22nd of June, 10:20-12:00, Filmzaal**  
**Chair:** Trevor Martin

- **Wed 22, 10:20** Suppression of high frequencies in time series using fuzzy transform of higher degree  
  Michal Holcapek and Linh Nguyen
- **Wed 22, 10:40** A Modern Fuzzy Expert System Architecture For Data and Event Streams Processing  
  Jean-Philippe Poli and Laurence Boudet
- **Wed 22, 11:00** Estimation and Characterization of Activity Duration in Business Processes  
  Rodrigo M.T. Gonzalez, Rui Jorge Almeida, João M.C. Sousa and Remco M. Dijkman
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<tr>
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<td>Fuzzy modeling based on mixed fuzzy clustering for multivariate time series of unequal lengths</td>
<td>Cátila Salgado, Susana Vieira and João M.C. Sousa</td>
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<td>Wed 22, 11:40</td>
<td>Time varying correlation estimation using PFS</td>
<td>Rui Jorge Almeida and Nalan Basturk</td>
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<td>Rui Jorge Almeida</td>
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<td>Speaker: Katharina Morik, University of Dortmund, Germany</td>
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<td>Chair: Marie-Jeanne Lesot</td>
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<td>Panelists: Jannie Minnema, Bernadette Bouchon-Meunier, Marianne Faro &amp; Maryam Razavian</td>
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<td>Wed 22, 15:00</td>
<td>A Methodology for Hierarchical Image Segmentation Evaluation</td>
<td>J. Tinguaro Rodríguez, Carely Guada, Daniel Gómez, Javier Yáñez and Javier Monter</td>
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<td>Wed 22, 15:20</td>
<td>Higher Degree F-transforms Based on B-splines of Two Variables</td>
<td>Martins Kokainis and Svetlana Asmuss</td>
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<td>SS03: Soft Computing for Image Processing II</td>
<td>Humberto Bustince</td>
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<td>SS04: Graded and Many-Valued Modal Logics I</td>
<td>Jesús Medina</td>
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<td>Multiple Criteria Decision Methods</td>
<td>Henri Prade</td>
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<td>SS10: Imperfect Databases</td>
<td>Moura Chebbah and Mohamed Anis Bach Tobji</td>
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**SS04: Graded and Many-Valued Modal Logics II**  
**Wednesday 22nd of June, 16:20-17:40, Collegezaal 12**  
**Chair: Lluís Godo**

- **We 22, 16:20**  
  A Calculus for Rational Łukasiewicz Logic and Related Systems  
  **Paolo Baldi**

- **We 22, 16:40**  
  Negation of Graded Beliefs  
  **Bénédicte Legastelois, Marie-Jeanne Lesot and Adrien Renault d’Allonnes**

- **We 22, 17:00**  
  Comparing some Substructural Strategies Dealing with Vagueness  
  **Robert van Rooij, Pablo Colmenar, Dave Ripley and Paul Eggen**

**Comparison Measures**  
**Wednesday 22nd of June, 16:20-17:20, Collegezaal 13**  
**Chair: Janusz Kacprzyk**

- **We 22, 16:20**  
  A distance between points and intervals  
  **Hugo Saulnier, Olivier Strauss and Inés Couso**

- **We 22, 16:40**  
  On different ways to be (dis)similar to elements in a set. A Boolean analysis and its graded extension  
  **Henri Prade and Gilles Richard**

- **We 22, 17:00**  
  Comparing system reliabilities with ill-known probabilities  
  **Lanting Yu, Sébastien Destercke, Mohamed Sallak and Walter Schon**

**Conference Banquet**  
**Wednesday 22nd of June, 18:30-22:00, Philips Stadion**

**Plenary Talk: Decision Making with Multi-Criteria**  
**Thursday 23rd of June, 09:30-10:30, Blauwe zaal**  
**Speaker: Ronald Yager, Iona College, USA**  
**Chair: Bernadette Bouchon-Meunier**

**Fuzzy Sets and Fuzzy Logic I**  
**Thursday 23rd of June, 10:50-12:10, Blauwe zaal**  
**Chair: Vilém Novák**

- **Th 23, 10:50**  
  Adjoint Fuzzy Partition and Generalized Sampling Theorem  
  **IrinaPerfilieva, Michal Holcapek and Vladik Kreinovich**

- **Th 23, 11:10**  
  How to incorporate excluding features in fuzzy relational compositions and what for  
  **Nhung Cao and Martin Stepnicka**

- **Th 23, 11:20**  
  Towards Fuzzy Partial Set Theory  
  **Martina Dankova and Libor Babuska**

- **Th 23, 11:50**  
  On Perception-based Logical Deduction with Fuzzy Inputs  
  **Antonin Dvorak and Martin Stepnicka**

**Databases and Information Systems I**  
**Thursday 23rd of June, 10:50-12:10, Collegezaal 12**  
**Chair: Alfredo Cuzzocrea**

- **Th 23, 10:50**  
  Indexing Possibilistic Numerical Data: The Interval B+ Tree Approach  
  **Guy De Tre, Robin De Mul and Autunno Brunswick**

- **Th 23, 11:10**  
  Ordinal Assessment of Data Consistency based on Regular Expressions  
  **Autunno Brunswick, Joachim Nielandt, Robin De Mul and Guy De Tre**

- **Th 23, 11:30**  
  A Fuzzy Approach to the Characterization of Database Query Answers  
  **Aurélien Morvan, Olivier Pivert and Grégory Smitz**

- **Th 23, 11:50**  
  Making the Skyline Larger: A Fuzzy-Neighborhood-Based Approach  
  **DjamalBelkasmi, AikdHafjali andHandalAzzoune**

**SS01: Computational Aspects of Data Aggregation and Complex Data Fusion**  
**Thursday 23rd of June, 10:50-12:10, Collegezaal 13**  
**Chair: Marek Gabolewski**

- **Th 23, 10:50**  
  Linear Optimization for Ecological Indices Based on Aggregation Functions  
  **Gleb Beliakov, Andrew Gleich, Simon James and Dale Nimmo**

- **Th 23, 11:10**  
  A qualitative approach to set achievable goals during the design phase of complex systems  
  **DidierSon, AbdelbakImoussaten, Pierre Couturier and JackyMontmain**
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<td>Unbalanced OWA Operators for Atanassov Intuitionistic Fuzzy Sets</td>
<td>Laura De Miguel Turullols, Ederne Barrenechea, Miguel Pajola, Aranzazu Jurio, Jose Antonio Sanz, Mikel Elikamoa and Humberto Bustince</td>
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<td>Th 23, 11:50</td>
<td>Fuzzy k-minpen clustering and k-nearest-minpen classification procedures</td>
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<td>Argumentation Framework based on Evidence Theory</td>
<td>Ahmed Samet, Badrane Radjanni, Tien Tuan Don and Aliel Hadjali</td>
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<td>Constrained Value-Based Argumentation Framework</td>
<td>Karima Sedki and Safa Yahi</td>
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<td>Belief revision and the EM algorithm</td>
<td>Inés Cousin and Didier Dubois</td>
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<td>Causal belief inference in multiply connected networks</td>
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<td>Th 23, 15:00</td>
<td>Dynamic Analysis of Participatory Learning in Linked Open Data: Certainty and Adaptation</td>
<td>Marek Z. Reformat, Ronald R. Yager and Jesse Xi Chen</td>
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<td>Th 23, 15:20</td>
<td>Online Fuzzy Community Detection by Using Nearest Hubs</td>
<td>Pascal Held and Rudolf Kruse</td>
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<td>Th 23, 15:40</td>
<td>Creating Extended Gender Labelled Datasets of Twitter Users</td>
<td>Marco Visente, Fernando Batista and Juan Pablo Carvallo</td>
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<td><strong>Chair: Christophe Marsala</strong></td>
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<td>Th 23, 15:00</td>
<td>Visualization of Individual Ensemble Classifier Contributions</td>
<td>Catarina Silva and Bernardeete Ribeiro</td>
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<td>Feature Selection From Partially Uncertain Data Within the Belief Function Framework</td>
<td>Anna Trabelsi, Zied Elouedi and Eric Lefevre</td>
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<td>On the Suitability of Type-1 Fuzzy Regression Tree Forests for Complex Datasets</td>
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<td>Th 23, 15:00</td>
<td>Constructing Preference Relations from Utilities and Vice versa</td>
<td>Thomas A. Rawlser</td>
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<td>A characterization of the performance of ordering methods in TTRP with fuzzy coefficients in the capacity constraints</td>
<td>Luis Torres-Pérez, Carlos Cruz, Alejandro Rauste-Suárez and José Luis Verdegay</td>
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<td>Preferences on gambles representable by a Choquet expected value with respect to conditional belief and plausibility functions</td>
<td>Giudanna Coletti, Davide Petrinelli, Barbara Vantaggi and Letizia Caldari</td>
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<td><strong>Fuzzy Sets and Fuzzy Logic II</strong></td>
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<td><strong>Chair: Martin Štěpnička</strong></td>
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<td>Th 23, 16:20</td>
<td>Fuzzy block-pulse functions and its application to solve linear fuzzy Fredholm integral equations of the second kind</td>
<td>Shokrollah Ziari and Reza Ezati</td>
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<td>Th 23, 16:40</td>
<td>Graded dominance and Cantor-Bernstein equipollence of fuzzy sets</td>
<td>Michal Holcapek</td>
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<td>Th 23, 17:00</td>
<td>Uninorms on interval-valued fuzzy sets</td>
<td>Martin Kadina and Pavol Katf</td>
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<td>Algorithm to generate finite negative tomonoids</td>
<td>Milan Petrík and Thomas Vetterlein</td>
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<td>Some Results on Extension of Lattice-valued XOR, XOR-Implications and E-Implications</td>
<td>Eduardo Palmeira and Benjamin Bedregal</td>
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**Databases and Information Systems II**

**Thursday 23rd of June, 16:20-18:00, Collegezaal 12**

**Chair: Guy De Tré**

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<td>Th 23, 16:20</td>
<td>Describing Rough Approximations by Indiscernibility Relations in Information Tables with Incomplete Information</td>
<td>Michinori Nakata and Hiroshi Sakai</td>
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<td>Th 23, 16:40</td>
<td>A possibleistic treatment of data quality measurement</td>
<td>Antoni Brouwer and Guy De Tré</td>
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<td>Th 23, 17:00</td>
<td>Computing Theoretically-Sound Upper Bounds to Expected Support for Frequent Itemset Mining Problems over Uncertain Big Data</td>
<td>Alfredo Casazza and Carion Leung</td>
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<td>Th 23, 17:20</td>
<td>In-Database Feature Selection Using Rough Set Theory</td>
<td>Frank Beer and Ulrich Bühler</td>
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**Aggregation**

**Thursday 23rd of June, 16:20-18:00, Collegezaal 13**

**Chair: Radko Mesiar**

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<tr>
<td>Th 23, 16:20</td>
<td>Fitting aggregation functions to data: Part I - Linearization and regularization</td>
<td>Maciej Bartoszuk, Gleb Beliakov, Marek Gagolewski and Simon James</td>
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<tr>
<td>Th 23, 16:40</td>
<td>Fitting aggregation functions to data: Part II - Idempotentization</td>
<td>Maciej Bartoszuk, Gleb Beliakov, Marek Gagolewski and Simon James</td>
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<td>Th 23, 17:00</td>
<td>On the Sensitivity of the Weighted Relevance Aggregation Operator and its Application to Fuzzy Signatures</td>
<td>Istvan Harmati and Laszlo T. Koczy</td>
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<td>Th 23, 17:20</td>
<td>A new vision of Zadeh’s Z-numbers</td>
<td>Sebastia Massanet, Juan Vicente Riera and Joan Torrens</td>
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<td>Th 23, 17:40</td>
<td>Mean Estimation Based on FWA using Ranked Set Sampling with Multiple Rankers</td>
<td>Bekir Çetintav, Gözde Ulutagay, Selma Gürler and Neslihan Demirel</td>
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**IEEE CIS Benelux Chapter Meeting**

**Thursday 23rd of June, 18:00-19:00, Filmzaal**

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<td>Friday 24th of June, 09:00-10:30, Filmzaal</td>
<td>Industrial Round Table: Data Science for Smart Industry (Presentations)</td>
<td>Marianne Faro, Itility and Jan Eite Bullema, TNO and Joris van Agtmaal, Wärtsilä</td>
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**Chair: Rik Eshuis**

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<tr>
<td>Friday 24th of June, 11:00-12:00, Filmzaal</td>
<td>Industrial Round Table: Data Science for Smart Industry (Panel)</td>
<td>Marianne Faro, Itility and Jan Eite Bullema, TNO and Joris van Agtmaal, Wärtsilä</td>
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**Chair: Rik Eshuis**

**Closing Session**

**Friday 24th of June, 12:00-12:30, Filmzaal**

**Lunch & Closing Reception**

**Friday 24th of June, 12:30-13:30, Senaatszaal**
Invited overview talks

Plausibility measures: a uniform approach to counterfactual reasoning, default reasoning, and belief change

Abstract: Counterfactual reasoning involves reasoning about events that are counter to fact, as in 'If my brakes weren't defective, I wouldn't have had the accident'. Default reasoning involves reasoning about typicality, as in 'Drunk drivers typically have accidents'. Belief change involves characterizing how beliefs should change, particularly when you discover that something that you believed was false is actually true. While these may seem to be very different notions, they are in fact closely related. I discuss the three notions, and present one uniform approach to modeling all three. Central to the approach is a new formalism for reasoning about uncertainty called a plausibility measure. Plausibility is a generalization of probability: the plausibility of a set is just an element of some arbitrary partial order (instead of being an element of [0,1], as in the case of probability). As the framework shows, plausibility is a reasonable generalization of probability that allows more qualitative reasoning.

Joseph Y. Halpern, Cornell University, USA

Joseph Halpern received a B.Sc. in mathematics from the University of Toronto in 1975 and a Ph.D. in mathematics from Harvard in 1981. In between, he spent two years as the head of the Mathematics Department at Bawku Secondary School, in Ghana. After a year as a visiting scientist at MIT, he joined the IBM Almaden Research Center in 1982, where he remained until 1996, also serving as a consulting professor at Stanford. In 1996, he joined the CS Department at Cornell, and was department chair 2010-14.

Halpern's major research interests are in reasoning about knowledge and uncertainty, security, distributed computation, decision theory, and game theory. He is a Fellow of AAAI, AAAS (American Association for the Advancement of Science), the American Academy of Arts and Sciences, ACM, IEEE, and SEAT (Society for the Advancement of Economic Theory). Among other awards, he received the ACM SIGART Autonomous Agents Research Award in 2011, the Dijkstra Prize in 2009, the ACM/AAAI Newell Award in 2008, the Gödel Prize in 1997, was a Guggenheim Fellow in 2001-02, and a Fulbright Fellow in 2001-02 and 2009-10. Two of his papers have won best-paper prizes at IJCAI (1985 and 1991), and another two received best-paper awards at the Knowledge Representation and Reasoning Conference (2006 and 2012). He was editor-in-chief of the Journal of the ACM (1997-2003) and has been program chair of a number of conferences.

Fuzzy and possibilistic clustering and the curious case of coincident clusters

Abstract: The first part of this tutorial will cover the development and application of fuzzy and possibilistic clustering with emphasis on the Fuzzy C-Means (FCM) and Possibilistic C-Means (PCM) along with several of their variations and generalizations. Then we will analyze the often reported curious tendency of the PCM to produce coincident clusters, i.e., more than one cluster whose cluster centers are essentially identical. Is this a demon or angel (defect or benefit)?

James M. Keller, University of Missouri, USA

James M. Keller received the Ph.D. in Mathematics in 1978. He holds the University of Missouri Curators' Professorship in the Electrical and Computer Engineering and Computer Science Departments on the Columbia campus. He is also the R. L. Tatum Professor in the College of Engineering. 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 Leonard Wood Institute, and the Army Night Vision and Electronic Sensors Directorate. Professor Keller has coauthored over 400 technical publications.
Process Query Language: A Tutorial

Abstract: Companies that have taken up business process management in earnest may acquire hundreds if not thousands of process models over time. Managing these collections of process models can be challenging and a process query language that can facilitate the search for models with certain characteristics can be of assistance. In this tutorial PQL (Process Query Language) is introduced, a language that can be used to search for process models that exhibit certain semantic (as opposed to syntactic) features. Dealing with execution semantics is nontrivial and untangling is explained as a technique for deriving semantic properties of tasks and relationships between tasks. A number of illustrative queries will be discussed.

Arthur ter Hofstede, Queensland University of Technology, Australia

Arthur ter Hofstede is a Professor in the Information Systems School in the Science and Engineering Faculty, Queensland University of Technology, Brisbane, Australia, and he is also a Professor in the Information Systems Group of the School of Industrial Engineering of Eindhoven University of Technology, Eindhoven, The Netherlands. His research interests are in the areas of business process automation and process mining.

Data science in the enterprise

Abstract: “The interesting aspects of Data Science”: that is the main subject during the 16th edition of the International Conference on Information processing and Management of Uncertainty in Knowledge-Based systems (IPMU). Bringing together scientists, and exchanging ideas between theoreticians and practitioners in Data Science – that is Itility’s focus. Based on our practical experience, we will discuss the practice of data science for the enterprise. The session bridges theory and practice of Data Science. The underlying question is that we develop many methods, but how do we make them used on a daily basis?

Gijs Wobben, Itility, the Netherlands

Gijs Wobben is a Chief Data Scientist at Itility. Wobben graduated in 2012 at the TU/e, where he studied Industrial Design, Bachelor of Science. He graduated his Master of Science, Science and Innovation Management, in 2014. Gijs Wobben’s specialties are business analytics, Big Data, and Data Science using Splunk in projects such as: designing the architecture for the Itility Managed Analytics Platform (IMAP, a Big Data SaaS solution), implementing a capacity management environment to manage a 4000+ server platform, creating algorithms for auto scaling, designing an ‘R’ app to incorporate R in Splunk.

Marianne Faro, Itility, the Netherlands

Marianne Faro is principal consultant and Analytics competence lead at Itility. Faro graduated in 1991, Bachelor of Science in Business Informatics, and 1995, Master of Science, Business Studies. Before joining the Itility team in 2008, Marianne Faro worked as European Information Manager at Nike, and as Project Manager at various companies. Her focus is on Smart Factories, Analytics as a Service, Big Data, Data Science, Machine Learning and Internet of Things.

Olaf Klooster, Itility, the Netherlands

Olaf Klooster is a graduate intern at Itility. Klooster finished his Bachelor of Science in 2013 at the TU/e, where he studied Industrial Engineering & Management. At the moment Klooster is writing his Master Thesis at Itility to acquire a Master of Science degree in Operations Management & Logistics at the TU/e. Topic of his Master Thesis is to implement agility in big data analytics.
Plenary talks

Actual Causality: A Survey
Speaker: Joseph Y. Halpern, Cornell University, USA

What does it mean that an event C “actually caused” event E? The problem of defining actual causation goes beyond mere philo- sophical speculation. For example, in many legal arguments, it is pre- cisely what needs to be established in order to determine responsibility. (What exactly was the actual cause of the car accident or the medical problem?) The philosophy literature has been struggling with the prob- lem of defining causality since the days of Hume, in the 1700s. Many of the definitions have been couched in terms of counterfac- tuals. (C is a cause of E if, had C not happened, then E would not have happened.) In 2001, Judea Pearl and I introduced a new defini- tion of actual cause, using Pearl's notion of structural equations to model counterfactuals. The definition has been revised twice since then, extended to deal with notions like "responsibility" and "blame", and applied in databases and program verification. I survey the last 15 years of work here, including joint work with Judea Pearl, Hana Chockler, and Chris Hitchcock. The talk will be completely self-con- tained.

Joseph Y. Halpern, Cornell University, USA

Joseph Halpern received a B.Sc. in mathematics from the University of Toronto in 1975 and a Ph.D. in mathematics from Harvard in 1981. In between, he spent two years as the head of the Mathematics Depart- ment at Bawku Secondary School, in Ghana. After a year as a visiting scientist at MIT, he joined the IBM Almaden Research Center in 1982, where he remained until 1996, also serving as a consulting professor at Stanford. In 1996, he joined the CS Department at Cornell, and was department chair 2010-14. Halpern's major research interests are in reasoning about knowledge and uncertainty, security, distributed computa- tion, decision theory, and game theory. He is a Fellow of AAAI, AAAS (American Association for the Advancement of Science), the American Academy of Arts and Sciences, ACM, IEEE, and SEAT (Society for the Advancement of Economic Theory). Among other awards, he received the ACM SIGART Auton- omous Agents Research Award in 2011, the Dijkstra Prize in 2009, the ACM/AAAI Newell Award in 2008, the Godel Prize in 1997, was a Guggenheim Fellow in 2001-02, and a Fulbright Fellow in 2001-02 and 2009-10. Two of his papers have won best-paper prizes at IJCAI (1985 and 1991), and another two received best- paper awards at the Knowledge Representation and Reasoning Conference (2006 and 2012). He was editor- in-chief of the Journal of the ACM (1997-2003) and has been program chair of a number of conferences.

The Present State of the Art of Modeling Uncertainty in Decision Theory, Resulting from an Iteration between Mathematical Economists and Empirical Psychologists
Speaker: Peter P. Wakker, Erasmus University Rotterdam, The Netherlands

In decision theory, more than in other fields of IPMU, the modeling of uncertainty is driven by empirical findings about human behavior. Decision theorists are strict in the requirement that for every mathematical detail the empirical meaning must be exactly specified. For example, taking the lower bound of possible probabilities of an event, while accepted uncritically in most information management theories, is meaningless to a decision theorist until it has been specified whether the event in question yields good or bad outcomes.

This lecture describes how the current state of the art in uncertainty- decision theory could only come about from interactions between empiri- cally oriented psychologists and mathematically oriented economists. At several stages in history, the next step forward could be made only by empirical intuitions from psychologists. Following up on that, the next step forward could be made only by theoretical inputs from economists with advanced technical skills. Modern views on the proper modeling of uncertainty attitudes could only arise from the merger of ideas from all the fields mentioned. It, for instance, led to a measure of information- insensitivity that is more refined than just taking supremums or infimums of uncertainty measures.

Peter P. Wakker, Erasmus University Rotterdam, The Netherlands

Peter Wakker is a professor of decisions under uncertainty at the Department of Econometrics of the Erasmus School of Economics (ESE). He works in behavioral economics, primarily on the differences between norma- tive and descriptive decisions, and on decisions under risk and uncertainty. Wakker has published in leading journals in economics, business, medicine, psychology, statistics, and mathematics. He was nominated the best-publishing Dutch economist in the years 1994, 1998, 2003, and 2007, and was ranked 90th in the world in the ISI's most cited scientists in economics and business in 2003. He received a Frank P. Ramsey Medal in 2013 and Medical Decision Making Career Achievement Award in 2007. Wakker regularly gives advices on insurance in the media. Wakker is director, jointly with Professor Han Bleichrodt, of the research group Behavioral Eco- nomics.
Learning Representations of Complex Structures in Natural Language with Neural Networks

Speaker: Chris Dyer, Carnegie Mellon University, USA

Effective processing of natural language requires integrating information from a variety of sources: an individual word's meaning depends on the context it is used in; the proper interpretation of a sentence depends on understanding the discursive context it occurs in; and, reasoning about the truth of a linguistically encoded proposition requires drawing on world knowledge. However, if we take stock of what progress has been made in language processing applications to date, it is precisely those that depend on a narrow view of context rather than those that require significant integration of contextual information where we find the most success.

In this talk I argue that the challenge of developing next-generation models that are sensitive to broader contextual information can be helpfully cast as a representation learning problem. Given a basic representation of the input signal and relevant contextual information, a unified representation suitable for making predictions needs to be computed. I discuss work from my group on using neural networks to integrate basic representations of component linguistic elements and combining them recursively to obtain composite representations of complex objects. Our work has demonstrated that taking inspiration from the linguistic structures when designing architectures is more effective than task-agnostic architectures. Applications ranging from text categorization, to language modeling, to machine translation will be discussed.

Chris Dyer, Carnegie Mellon University, USA

Chris Dyer is an assistant professor at Carnegie Mellon University. Dyer graduated from the Duke University in 2000, where he studied computer science. He went on to obtain a Ph.D. in linguistics in 2010 from University of Maryland under the supervision of Prof. Philip Resnik. Chris Dyer's research interests lie in the intersection of statistical machine translation, unsupervised learning, computational morphology and phonology, large-scale data processing, probabilistic models of natural language processing, Bayesian techniques and machine learning. He is currently supported by grants from The National Science Foundation (Lexical Borrowing), DARPA (LORELEI), Google (A Hybrid Neural–Phrase-Based Model for Machine Translation) and The Army Research Office (MT/NLP for Low-Resource Languages).

Resource-constrained Data Analysis and Exploration

Speaker: Katharina Morik, Technische Universität Dortmund, Germany

Computer science has always taken into account some resources needed for the execution of algorithms, namely runtime and memory space. Since the triumph of very large data centers, energy has become a resource of importance, additionally. In 2008, Google had its millionth server. Google’s estimated yearly energy consumption is about 2024 watt hours (Wh). A search request consumes 0.3 Wh, asking and reading the result at a home computer consumes about the same, so that each query costs about 0.6 Wh.

Where data centers challenge resources at a global scale, the energy of cyber-physical systems and smartphones is restricted at the local device. The battery of a smartphone has a capacity of about 8 Wh. The user wants a long battery duration together with a high quality of service. Regarding machine learning, there are two ways, in which energy may be saved. On the one hand, a learning algorithm may learn from compiler logs or from user behavior how to enhance the heuristics of the system’s software. On the other hand, the learning algorithm itself has to become energy-efficient. This can be achieved through approximations which reduce the operations that cost the most energy. Cyber-physical systems populate diverse parts of our everyday life, they are the nodes of the Internet of Things and they produce big data.

If we focus again on smartphones, each user generates about 60 GB of data per year. Learning a personal model of app usage could allow early warnings when to recharge the battery.

However, the analysis of such data is not easy: data may be missing, their incompleteness is not easy to recognize, and they may be wrong due to several reasons. Labels, which are needed for classifier training, are missing; Data exploration is an important, though often underestimated first part of data analysis. In the talk, several probabilistic graphical models will be presented together with their applications.

Katharina Morik, Technische Universität Dortmund, Germany

Katharina Morik is a professor at Technische Universität Dortmund. She received her PhD at the University of Hamburg 1981 and worked in the well-known natural language project HAM-ANS at Hamburg from 1982 to 1984. Then, she moved to the technical university Berlin and became the project leader of the first German machine learning project, KIT-Lerner. From 1989 to 1991 she was leading a research group for machine learning at the German National Research Center for Computer Science at Bonn. This team developed the MOBAL system within the ESPRIT project Machine Learning Toolboxes (P2154). In 1991, she became full professor at the University of Dortmund. Until 1994 she was the leader of the German special interest group in machine learning of the German Society for Computer Science. Together with Xindong Wu, she started the IEEE International Conference on Data Mining. Katharina Morik is speaker of the collaborative research center SFB876, member of the Scientific Advisory Board of Rapid-I, part of the Scientific Council of The European Institute for Participatory Media. Interests are in all kinds of applications of machine learning, including cognitive modeling of theory acquisition and revision.
The construction of multi-criteria decision functions is strongly dependent upon the use of aggregation operators. Here if \( D(x) = \text{Agg}(C_1(x), C_2(x), ..., C_n(x)) \) represents the satisfaction of alternative \( x \) to the collection of criteria a central problem becomes the formulation of the decision function \( D \). The structure of the function \( \text{Agg} \) must be a reflection of the decision makers perceived relationship between the different criteria. We must provide some approaches that can used to help in the construction of these decision functions. One approach is to allow the decision-maker to express their perceived relationship between the criteria in a linguistic like manner and then try to model this relationship using fuzzy logic formalisms. Another approach is the use of set measures for the representation of the relationship between criteria. Once having a formal representation of the decision function \( D \) we must evaluate it for each alternative. In many real world environments the values of the \( C_i(x) \) can only be provided with some uncertainty. Among the different types of imprecise valuations are intervals, probability distributions, D-S belief structures, fuzzy sets, intuitionistic, Pythagorean and generalized orthopair fuzzy sets as well ordinal linguistic valuations. Finally we must choose among these alternatives based their values for \( D(x) \). In the case of uncertainty in the \( C_i(x) \) the value of \( D(x) \) also manifests uncertainty. Choosing requires that we provide an ordering of these uncertain values. In our talk we shall discuss various topics from the above.

Ronald Yager, Iona College, USA

Ronald R. Yager is Director of the Machine Intelligence Institute and Professor of Information Systems at Iona College. He is editor and chief of the International Journal of Intelligent Systems. He has published over 500 papers and edited over 30 books in areas related to fuzzy sets, human behavioral modeling, decision-making under uncertainty and the fusion of information. He is among the world’s top 1% most highly cited researchers with over 45,000 citations in Google Scholar. He was the recipient of the IEEE Computational Intelligence Society Pioneer award in Fuzzy Systems. He received the special honorary medal of the 50-th Anniversary of the Polish Academy of Sciences. He received the Lifetime Outstanding Achievement Award from International the Fuzzy Systems Association. He recently received honorary doctorate degrees, honoris causa, from the Azerbaijan Technical University and the State University of Information Technologies, Sofia Bulgaria. Dr. Yager is a fellow of the IEEE, the New York Academy of Sciences and the Fuzzy Systems Association. He has served at the National Science Foundation as program director in the Information Sciences program. He was a NASA/Stanford visiting fellow and a research associate at the University of California, Berkeley. He has been a lecturer at NATO Advanced Study Institutes. He was a program director at the National Science Foundation. He is a visiting distinguished scientist at King Saud University, Riyadh Saudi Arabia. He was an adjunct professor at Aalborg University in Denmark. He received his undergraduate degree from the City College of New York and his Ph. D. from the Polytechnic Institute New York University. He is the 2016 recipient of the IEEE Frank Rosenblatt Award the most prestigious honor given out by the IEEE Computational Intelligent Society.
Panel sessions

Women in Engineering
Chair: Rui Jorge Almeida, Eindhoven University of Technology, The Netherlands

A well-known adage says “diversity brings innovation”. Diversity can be in culture, in thinking, in discipline, in gender, and in many more aspects. The result is the same: the chances for creating innovation in a given context increase when diversity is involved. We have been investing for decades in achieving gender balance in fields related to Engineering and Computer Science. We complain that too few women choose a technology-related career. But is it really true that gender diversity contributes to innovation, or more in general, brings concrete, technical advantages to the engineering outcomes? How to defeat the stereotypes about genders? In the Women in Engineering Panel we will explore these questions.

Panelists:
- Jannie Minnema, Senior Director Business Operations, Oracle, The Netherlands
- Bernadette Bouchon-Meunier, Director of research emeritus, National Center for Scientific Research, France
- Marianne Faro, Principal consultant at Itility, The Netherlands
- Maryam Razavian, Assistant Professor in Information Systems, Eindhoven University of Technology, The Netherlands

Open Access Publishing
Chair: Uzay Kaymak, Eindhoven University of Technology, The Netherlands

Open Access (OA) publishing is high on the agenda of researchers and research funding agencies. European Union is expecting more and more that the research it funds is published in Open Access journals. Although the need for OA publications is generally acknowledged amongst the scientific community of IPMU, many researchers prefer more established non-OA journals for publishing. In this session, we will highlight the status of OA publishing amongst the journals related to the IPMU field of research. The session brings together a number of editor-in-chiefs (EIC) of journals. The discussion will consider which challenges OA publishing brings to our community and how these challenges are being dealt with.

Panelists:
- Bernadette Bouchon-Meunier, EIC International Journal of Uncertainty, Fuzziness and Knowledge-Based Systems
- Humberto Bustince, EIC Mathware & Soft Computing Magazine
- Didier Dubois, EIC Fuzzy Sets and Systems
- Janusz Kacprzyk, EIC Journal of Automation, Mobile Robotics & Intelligent Systems
- James Keller, Chair IEEE TAB Transactions Committee
- Ronald Yager, EIC International Journal of Intelligent Systems

This panel is organized under the auspices of the Netherlands Organization for Scientific Research (NWO).
Industry round table – Data Science for Smart Industry (Presentations and Panel)

Smart industry - manage uncertainties via smart analytics
Speaker & panelist: Marianne Faro, Itility, The Netherlands

Itility is an IT consultancy firm, serving enterprise customers in high tech and manufacturing. What does Smart Industry mean to them? How to make Big Data in a Semiconductor Manufacturing environment productive?

Speaker & panelist: Jan Eite Bullema, TNO, The Netherlands

In the ENIAC project Integrate an architecture has been developed that is meant to enable fab-wide implementation of advanced process control methods.

Koenig estimated in 2004 that a typical semiconductor manufacturing line produces in excess of 1 Terabyte per day. In the Big Data section of the ITRS 2013 data volumes are shown in the unit “Terabyte per day” (TBD). Mariano expected in 2014 that in future FABS will have to deal with multiple Petabytes of data on a daily basis. According to Mariano, this data is not fully used. Routine reports are extracted for common purposes like maintenance, documentation, process control and optimization and quality management.

Much data that are stored, whether in the equipment or in a database, are kept only for a limited time or in a rolling log file subject to the storage requirements. The infamous data graveyard.

According to the 2013 ITRS roadmap fab wide solutions to make big data streams productive are required. But: “The current state of the art is that fab-wide implementation of Advanced Manufacturing Technology remains an aspiration”

In this presentation I will present an Agent Based Control architecture -more specific a holarchy- for Semiconductor Manufacturing that will enable the productive use of all available data. The elegance of the presented architecture is that it (a) uses already existing industrial standards (b) building a fab-wide solution can be done from simple to increasing complexity. The system can be built into an existing system. Starting with autonomous entities, towards cooperative entities, thus gradually creating fab-wide integration.

An example of autonomous entity would be an agent that performs the function of a statistical process control chart (i.e. in control or out of control decision) or an agent that performs a predictive maintenance function (i.e. prediction of remaining useful life of a tool). A cooperative entity could be a dispatching agent that uses the statistical control chart agent and the predictive maintenance agent to decide whether a specific production batch can be dispatched to a specific tool.

By building upon existing SEMI standards (i.e. SEMI E133) and data mining/ machine learning standards (i.e. PMML) implementation costs are expected to be comparable to the cost of running traditional process control methods (e.g. SPC). An advantage of the use of PMML is that the standard is applicable in Big Data environments (e.g. Hadoop, Spark) and can be used for massive parallel scoring of machine learning models. The concept of holonic manufacturing system already exists for several decades. At the current moment – emergence of Big Data analytics – the holonic approach has become more relevant, as the holonic approach can be put into practice to maintain control in inherent complex Big Data environments.

How to make Big Data in a Semiconductor Manufacturing environment productive?
Speaker & panelist: Jan Eite Bullema, TNO, The Netherlands

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Jan Eite Bullema, TNO, The Netherlands

Jan Eite Bullema (1959) received an M.Sc in Inorganic Chemistry and Physics from the University of Groningen (NL) in 1987, after obtaining a B.Eng. in Chemical Technology. Before graduating from University, he worked as process engineer for AKZO, starting in 1984. After graduating from the University, he started working for Royal Philips Electronics Philips in the field of Process Control/ Quality Improvement at the Centre for Manufacturing Technologies (CFT), eventually as a Six Sigma Master Black Belt.

In 1999 he joined TNO, as Senior Scientist in the field of Micro and Nano Technology mainly for development of micro systems technology. Mr. Bullema has been a parttime professor (lector) at the University for Applied Sciences in Utrecht in the field of micro systems technology. Mr. Bullema holds several patents in the field of micro systems technology. At TNO Mr. Bullema has contributed to development of various micro devices (e.g. MEMS oscillator, micro Gas chromatograph, RF Switch, Autonomous Sensors), currently with a focus on 3D Printed microfluidic devices.

Mr. Bullema is certified by the American Productivity and Inventory Control Society (APICS) in Production and Inventory Management (CPIM) and Integrated Resource Management (CIRM) and is certified by ASQ (American Society for Quality) as Certified Six Sigma Black Belt.
Belt (CSSBB) and Certified Reliability Engineer (CRE). Besides manufacturing and process control expertise, Mr. Bullema has a demonstrated track record in application of advanced process control and machine learning, with an interest in big data based deep learning for complex manufacturing control.

**Smart industry - Smart analytics in practice**  
*Speaker & panelist: Joris van Agtmaal, Wärtsilä, The Netherlands*

Wärtsilä is a global leader in power solutions for the marine and energy markets. Their huge engines contain ever more sensors, generating lots of data that can be repurposed for smart analytics. The new digital services they deliver to their customers use the insights extracted from this data to generate new value for their customers. The latest developments in data science, like the latest tools, advanced algorithms and cloud computing make it possible to automate more and more of the steps in the process of turning this pile of data into money.

Sounds great, right? Let’s look at a case and see what we can learn.

Joris van Agtmaal, Wärtsilä, The Netherlands

Joris van Agtmaal finished a master degree in technology management at the TU/e, after which he decided being a fulltime DJ and playing records all night seemed like a more appealing option. After various other weird and wonderful side jobs he ended up with ASML reporting and analysing the reliability of complex Lithography equipment and this is where the interest in data analysis got sparked. Now, about 10 years later he is working as the product owner of the data science team in the digitalization department of Wärtsilä.
Abstracts
SS05 – Fuzzy Measures and Integrals I
Tuesday 21st of June, 10:50-12:30, Blauwe zaal
Chair: Christophe Labreuche

Decomposition integral based generalizations of OWA operators
Radko Mesiar and Andrea Stupnanova
Based on the representation of OWA operators as Choquet integrals with respect to symmetric capacities, a new kind of OWA generalizations based on decomposition integrals is proposed and discussed. The symmetry of the underlying capacity is not sufficient to guarantee the symmetry of the resulting operator, and thus we deal with symmetric saturated decomposition systems only. All possible generalized OWA operators on $X = \{1, 2\}$ are introduced. Similarly, when considering the maximal decomposition system on $X = \{1, 2, 3\}$, all generalized OWA operators are shown, based on the ordinal structure of the normed weighting vector $w = (w_1, w_2, w_3)$.

Finding the set of k-additive dominating measures viewed as a flux problem
Pedro Miranda and Michel Grabisch
In this paper we deal with the problem of obtaining the set of k-additive measures dominating a fuzzy measure. This problem extends the problem of deriving the set of probabilities dominating a fuzzy measure, an important problem appearing in Decision Making and Game Theory. The solution proposed in the paper follows the line developed by Chateauneuf and Jaffray for dominating probabilities and continued by Miranda et al. for dominating k-additive belief functions. Here, we address the general case transforming the problem into a similar one such that the involved set functions have non-negative Möbius transform; this simplifies the problem and allows a result similar to the one developed for belief functions. Although the set obtained is very large, we show that the conditions cannot be sharpened. On the other hand, we also show that it is possible to derive a more natural extension of the result for probabilities, such that it is possible to derive any k-additive dominating measure from it.

On capacities characterized by two weight vectors
Christophe Labreuche
We are interested in aggregation function based on two weights vectors: the criteria weights $p$ and the order weights $w$. The main drawback of the existing proposals based on $p$ and $w$ (in particular the Weighted OWA (WOWA) and the Semi-Uninorm OWA (SUOWA) operators) is that their expression is rather complex and the contribution of the weights $p$ and $w$ in the aggregation is obscure. There is no clear interpretation of these weights. We propose a new approach to define aggregation functions based on the weights $p$ and $w$. We consider the class of capacities (which subsumes the WOWA and SUOWA). We start by providing clear interpretations of these weights. They are seen as constraints on the capacity. We consider thus the whole class of capacities fulfilling these constraints. A simulation shows that the WOWA and SUOWA almost never satisfy these constraints in a strict sense.

Computing superdifferentials of Lovász extension with application to coalitional games
Lukáš Adam and Tomas Kroupa
Every coalitional game can be extended from the powerset onto the real unit cube. One of possible approaches is the Lovász extension, which is a piecewise affine interpolation of the coalitional game among the canonical simplices of the cube. We will study some solution concepts for coalitional games (core, Weber set) using various notions of superdifferential developed in non-smooth analysis. It has been shown that the core coincides with Fréchet superdifferential and the Weber set with Clarke superdifferential for the Lovász extension, respectively. We introduce the intermediate set as the limiting superdifferential and show that it always lies between the core and the Weber set. From the game-theoretic point of view, the intermediate set is a non-convex solution containing the Pareto optimal payoff vectors, which depend on some ordered partition of the players and the marginal coalitional contributions with respect to the order.

Conjoint axiomatization of the Choquet integral for heterogeneous product sets
Mikhail Timonin
We propose an axiomatization of the Choquet integral model for the general case of a heterogeneous product set $X = X_1 \times \ldots \times X_n$. In MCDA elements of $X$ are interpreted as alternatives, characterized by criteria taking values from the sets $X_i$. Previous axiomatizations of the Choquet integral have been given for particular cases $X = Y^n$ and $X = \mathbb{R}^n$. However, within multicriteria context such indenticalness, hence commensurateness, of criteria cannot be assumed a priori. This constitutes the major difference of this paper from the earlier axiomatizations. In particular, the notion of "comonotonicity" cannot be used in a heterogeneous structure, as there does not exist a "built-in" order between elements of sets $X_i$ and $X_i$. However, such an order is implied by the representation model. Our approach does not assume commensurateness of criteria. We construct the representation and study its uniqueness properties.

SS08 – Uncertainty Quantification with Imprecise Probability
Tuesday 21st of June, 10:50-12:30, Collegezaal 12
Chair: Gero Walter

Efficient simulation approaches for reliability analysis of large systems
Edoardo Patelli and Geng Feng
Survival signature has been presented recently to quantify the system reliability. However, survival signature-based analytical methods are generally intractable for the analysis of realistic systems with multi-state components and imprecisions on the transition time. The availability of numerical simulation methods for the analysis of such systems is required. In this paper, novel simulation methods for computing system reliability are presented. These allow to estimate the reliability of realistic and large-scale systems based on survival signature including parameter uncertainties and imprecisions. The simulation approaches are generally applicable and efficient since only one estimation of the survival signature is needed while Monte Carlo simulation is used to generate component transition times. Numerical examples are presented to show the applicability of the proposed methods.

Bivariate p-boxes and maxitive functions
Ignacio Montes and Enrique Miranda
We investigate the properties of the upper probability associated with a bivariate p-box, that may be used as a model for the imprecise knowledge of a bivariate distribution function. We give necessary and
Sets of prior distributions for reflecting prior-data conflict and strong prior-data agreement

Gero Walter and Frank Coolen

Bayesian inference enables combination of observations with prior knowledge in the reasoning process. The choice of a particular prior distribution to represent the available prior knowledge is, however, often debatable, especially when prior knowledge is limited or data are scarce, as then posterior inferences are highly dependent on the choice of prior. Robust Bayesian analysis accounts for this issue by inquiring whether posterior inferences change substantially when the prior distribution is varied within a set of distributions that contains all `reasonable' priors. Similar, but slightly different in scope, is the imprecise probability approach, formalizing the idea that sets of probability distributions should be taken to model prior knowledge more accurately. Imprecise probability allows to model prior-data conflict sensitivity: Ranges of posterior inferences should be substantially larger when prior and data are in conflict. Here we propose a new method for generating parameter prior sets in a conjugate setting that, in addition to prior-data conflict sensitivity, allow to reflect strong prior-data agreement, i.e., the case when prior and data coincide especially well, by increased posterior precision. Although presented here for the case of binary data only, it is easily extensible to the general exponential family case.

Impact of the shape of membership functions on the truth values of linguistic protoform summaries

Akhay Jain, Tianqi Jiang and Jim Keller

In the recent past, a lot of work has been done on Linguistic Protoform Summaries (LPS). Much of this work focuses on improvement of the ways to compute truth values of LPS as well as on development of different protoforms. However, almost all of the systems using LPS use trapezoidal membership functions. This work investigates the effects of using triangular and pi shaped membership functions and compare their performance when using trapezoids. We start with an experiment using synthetic data and then compare the behavior of the three types of membership functions using real data which is obtained from an eldercare setting.
How much is “about”? Fuzzy interpretation of approximate numerical expressions

Sébastien Lefort, Marie-Jeanne Lesot, Elisabetta Zibetti, Charles Tijus and Marcin Detyniecki.

Approximate Numerical Expressions (ANEs) are linguistic expressions involving numbers and referring to imprecise ranges of values, such as "about 100". This paper proposes to interpret ANEs as fuzzy numbers. A model, taking into account the cognitive salience of numbers and based on critical points from Pareto frontiers, is proposed to characterize the support, the kernel and the 0.5-cut of the corresponding membership functions. An experimental study, based on real data, is performed to assess the quality of these estimated parameters.

Scenario Query based on Association Rules (SQAR)

Carlos Molina, Belen Prados-Suarez and Daniel Sanchez

In the last years association rules are being applied to support decision making. However, the main concern is in the precision and not in the interpretability of their results, so they produce large sets of rules difficult to understand for the user. A comprehensible system should work according to the human decision making process, which is quite based on the case study and the scenario projection. Here we propose an association rule based system for scenario query (SQAR), where the user can perform 'what if...?' queries, and get as response what usually happens under similar scenarios. Even more we enrich our proposal with a hierarchical structure that allows the definition of scenarios with different detail levels, to comply with the needs of the user.

SS13 – Belief Function Theory and its Applications

Tuesday 21st of June, 10:50-12:30, Filmzaal
Chair: Didier Coquin

Joint feature transformation and selection based on Dempster-Shafer theory

Chunfeng Lian, Su Ruan and Thierry Denoeux

In statistical pattern recognition, feature transformation attempts to change original feature space to a low-dimensional subspace, in which new created features are discriminative and non-redundant, thus improving the predictive power and generalization ability of subsequent classification models. Traditional transformation methods are not designed specifically for tackling data containing unreliable and noisy input features. To deal with these inputs, a new approach based on Dempster-Shafer Theory is proposed in this paper. A specific loss function is constructed to learn the transformation matrix, in which a sparsity term is included to realize joint feature selection during transformation, so as to limit the influence of unreliable input features on the output low-dimensional subspace. The proposed method has been evaluated by several synthetic and real datasets, showing good performance.

Recognition of confusing objects for NAO robot

Thanh-Long Nguyen, Didier Coquin and Reda Boukez-zoula

Visual processing is one of the most essential tasks in robotics systems. However, it may be affected by many unfavourable factors in the operating environment which lead to imprecisions and uncertainties. Under those circumstances, we proposed a multi-camera fusing method applied in a scenario of object recognition for a NAO robot. The cameras captured the same scene at the same time, then extracted feature points from the scene and gave their belief about the classes of the detected object. Dempster's rule of combination was then used to fuse information from the cameras and provide a better decision. In order to take advantages of heterogeneous sensors fusion, we combined information from 2D and 3D cameras, and the results of experimentation proved the efficiency of the proposed approach.

Evidential missing link prediction in uncertain social networks


Link prediction is the problem of determining future or missing associations between social entities. Most of the methods have focused on social networks under a certain framework neglecting some of the inherent properties of data from real applications. These latter are usually noisy, missing or partially observed. Therefore, uncertainty is an important feature to be taken into account. In this paper, proposals for handling the problem of missing link prediction while being attentive to uncertainty are presented along with a technique for uncertain social networks generation. Uncertainty is not only handled in the graph model but also in the method itself using the assets of the belief function theory as a general framework for reasoning under uncertainty. The approach combines sampling techniques and information fusion and returns good results in real-life settings.

An evidential filter for indoor navigation of a mobile robot in dynamic environment

Quentin Labourey, Olivier Aycard, Denis Pellerin, Michèle Rombaut and Catherine Garbay.

Robots are destined to live with humans and perform tasks for them. In order to do that, an adapted representation of the world including human detection is required. Evidential grids enable the robot to handle partial information and ignorance, which can be useful in various situations. This paper deals with an audiovisual perception scheme of a robot in indoor environment (apartment, house...). As the robot moves, it must take into account its environment and the humans in presence. This article presents the key-stages of the multimodal fusion: an evidential grid is built from each modality using a modified Dempster combination, and a temporal fusion is made using an evidential filter based on an adapted version of the generalized bayesian theorem. This enables the robot to keep track of the state of its environment. A decision can then be made on the next move of the robot depending on the robot’s mission and the extracted information. The system is tested on a simulated environment under realistic conditions.
A solution for the learning problem in evidential (partially) hidden Markov models based on conditional belief functions and EM

Emmanuel Ramasso

Evidential Hidden Markov Models (EvHMM) is a particular Evidential Temporal Graphical Model that aims at statistically representing the kinetics of a system by means of an Evidential Markov Chain and an observation model. Observation models are made of mixture of densities to represent the inherent variability of sensor measurements, whereas uncertainty on the latent structure, that is generally only partially known due to lack of knowledge, is managed by Dempster-Shafer’s theory of belief functions. This paper is dedicated to the presentation of an Expectation-Maximization procedure to learn parameters in EvHMM. Results demonstrate the high potential of this method illustrated on complex datasets originating from turbofan engines where the aim is to provide early warnings of malfunction and failure.

SS05 – Fuzzy Measures and Integrals II

Tuesday 21st of June, 1500-1600, Blauwe zaal
Chair: Christophe Labreuche

Aggregation of Choquet integrals

Ladislav Šipeky, Alexandra Šipošová and Radko Mesiar

Aggregation functions acting on the lattice of all Choquet integrals on a fixed measurable space \((X,A)\) is discussed. The only direct aggregation of Choquet integrals resulting into a Choquet integral is linked to the convex sums, i.e., to the weighted arithmetic means. We introduce and discuss several other approaches, for example one based on compatible aggregation systems. For \(X\) finite, the related aggregation of OWA operators is obtained as a corollary. The only exception, with richer structure of aggregation functions, is the case card \(X = 2\), when the lattice of all OWA operators forms a chain.

Inclusion-exclusion integral and t-norm based data analysis model construction

Aoi Honda and Yoshiaki Okazaki

A mathematical model using the inclusion-exclusion integral and a construction method of the model utilizing t-norms are proposed. This model is based on the integral with respect to non-additive measure and have high flexibility and description power. The construction method is shown by dividing to three process. In addition, applying this model to a data set of multiple criteria decision making problem, the validity of this model is shown comparing to the classical linear regression model and the Choquet integral model.

Fuzzy integral for rule aggregation in fuzzy inference systems

Leary Tomlin, Derek Anderson, Christian Wagner, Timothy Havens and James Keller

The fuzzy inference system (FIS) has been tuned and revamped many times over and applied to numerous domains. New and improved techniques have been presented for fuzzification, implication, rule composition and defuzzification, leaving one key component relatively underrepresented, rule aggregation. Current FIS aggregation operators are relatively simple and have remained more-or-less unchanged over the years. For many problems, these simple aggregation operators produce intuitive, useful and meaningful results. However, there exists a wide class of problems for which quality aggregation requires non-additivity and exploitation of interactions between rules. Herein, we show how the fuzzy integral, a parametric non-linear aggregation operator, can be used to fill this gap. Specifically, recent advancements in extensions of the fuzzy integral to unrestricted fuzzy sets, i.e., subnormal and non-convex, makes this now possible. We explore the role of two extensions, the gFI and the NDFI, discuss when and where to apply these aggregations, and present efficient algorithms to approximate their solutions.

Graphical models

Tuesday 21st of June, 1500-1600, Collegezaal 12
Chair: Davide Petturiti

Determination of variables for a Bayesian network and the most precious one

Esma Nur Cinicioglu and Taylan Yenilmez

To ensure the quality of a learned Bayesian network out of limited data sets, evaluation and selection process of variables becomes necessary. With this purpose, two new variable selection criteria N2Sj and N3Sj are proposed in this research which show superior performance on limited data sets. These newly developed variable selection criteria with the existing ones from prior research are employed to create Bayesian networks from three different limited data sets. On each step of variable elimination, the performance of the resulting BNs are evaluated in terms of different network performance metrics. Furthermore, a new variable evaluation criterion, IHj, is proposed which measures the impact of a variable to all the other variables in the network. IHj serves as an indicator of the most important variables in the network which has a special importance for the use of BNs in social science research, where it is crucial to identify the most important factors in a setting.

Incremental Junction Tree Inference

Hamza Agli, Philippe Bonnard, Christophe Gonzales and Pierre-Henri Wullemain

Performing probabilistic inference in multi-target dynamic systems is a challenging task. When the system, its evidence and/or its targets evolve, most of the inference algorithms either recompute everything from scratch, even though incremental changes do not invalidate all the previous computations, or do not fully exploit incrementality to minimize computations. This incurs strong unnecessary overheads when the system under study is large. To alleviate this problem, we propose in this paper a new junction tree-based message-passing inference algorithm that, given a new query, minimizes computations by identifying precisely the set of messages that differ from the preceding computations. Experimental results highlight the efficiency of our approach.

Real time learning of non-stationary processes with dynamic Bayesian Networks

Mathieu Hourbraq, Christophe Gonzales, Pierre-Henri Wullemain and Philippe Baumard

Dynamic Bayesian Networks (DBNs) provide a principled scheme for modeling and learning conditional dependencies from complex multivariate time-series data and have been used in a wide scope. However, in most cases, the underlying generative Markov model is assumed to be homogeneous, meaning that neither its topology nor its parameters evolve over time. Therefore, learning a DBN to model a non-stationary process under this assumption will amount to poor predictions capabilities. To account for non-stationary processes, we build on a framework to identify, in a streamed manner, transition times between underlying models and a framework to learn them in
real time, without assumptions about their evolution. We show the method performances on simulated datasets. The goal of the system is to model and predict incongruities for an Intrusion Detection System (IDS) in near real-time, so great care is attached to the ability to correctly identify transitions times. Our preliminary results reveal the precision of our algorithm in the choice of transitions and consequently the quality of the discovered networks. We finally suggest future works.

SS07 – Fuzzy Implication Functions I

Tuesday 21st of June, 15:00-16:00, Collegezaal 13
Chair: Michal Baczynski

About the use of admissible order for defining implication operators

Maria Jose Asiain, Humberto Bustince, Benjamin Bedregal, Zdenko Takač, Michal Baczynski, Daniel Paternain and Graçaliz Dimuro.

Implication functions are crucial operators for many fuzzy logic applications. In this work, we consider the definition of implication functions in the interval-valued setting using admissible orders and we use these interval-valued implications for building comparison measures.

Generalized Sugeno integrals

Didier Dubois, Henri Prade, Agnes Rico and Bruno Tcheyu

Sugeno integrals are aggregation functions defined on a qualitative scale where only minimum, maximum and order-reversing maps are allowed. Recently, variants Sugeno integrals based on Gödel implication and its contraposition were defined and axiomatized in the setting of bounded chain with an involutive negation. This paper proposes a more general approach. We consider totally ordered scale[s], multi-valued conjunction operations not necessarily commutative, and implication operations induced from them by means of an involutive negation. In such a context, different Sugeno-like integrals are defined and axiomatized.

A new look on fuzzy implication functions: FNI-implications

Isabel Aguiló, Jaume Suñer and Joan Torrens

Fuzzy implication functions are used to model fuzzy conditional and consequently they are essential in fuzzy logic and approximate reasoning. From the theoretical point of view, the study of how to construct new implication functions from old ones is one of the most important topics in this field. In this paper a construction method of implication functions from a t-conorm \( S \) (or any disjunctive aggregation function \( F_\triangleright \)) a fuzzy negation \( N \) and an implication function \( I \) is studied. Some general properties are analyzed and many illustrative examples are given. In particular, this method shows how to obtain new implications from old ones with additional properties not satisfied by the initial implication function.

Applications in Medicine and Bioinformatics

Tuesday 21st of June, 15:00-16:00, Filmzaal
Chair: João Sousa

Non-commutative quantales for many-valuedness in applications

Patrik Eklund, Ulrich Höhle and Jari Kortelainen

In this paper we show how the diversity of properties for quantales is well suited for describing multivalence in many-valued logic. Non-commutativity is important from application point of view, as will be demonstrated for a particular application area in health and social care. Tensor products of quantales will play an important role in showing how more simple valuation scales can be tensored together to provide more complex valuation scales. In health, this is typically seen for disorders and functioning. Classification of disorder is typically quite bivalent, whereas scales used in functioning classifications are multivalent. The role ‘not specified’ or ‘missing’ is shown to be of importance.

Evaluating tests in medical diagnosis: Combining machine learning with game-theoretical concepts

Karlsön Pfannschmidt, Eyke Hüllermeyer, Susanne Held and Reto Neiger

In medical diagnosis, information about the health state of a patient can often be obtained through different tests, which may perhaps be combined into an overall decision rule. Practically, this leads to several important questions. For example, which test or which subset of tests should be selected, taking into account the effectiveness of individual tests, synergies and redundancies between them, as well as their cost. How to produce an optimal decision rule on the basis of the data given, which typically consists of test results for patients with or without confirmed health condition. To address questions of this kind, we develop an approach that combines (semi-supervised) machine learning methodology with concepts from (cooperative) game theory. Roughly speaking, while the former is responsible for optimally combining single tests into decision rules, the latter is used to judge the influence and importance of individual tests as well as the interaction between them. Our approach is motivated and illustrated by a concrete case study in veterinary medicine, namely the diagnosis of a disease in cats called feline infectious peritonitis.

Fuzzy modeling for vitamin B12 deficiency

Anna Wilbik, Saskia van Loon, Arjen-Kars Boer, Uzay Kaymak and Volkher Schanzhorst

Blood vitamin B12 levels are not representative for actual vitamin B12 status in tissue. Instead plasma methylmalonic acid (MMA) levels can be measured because MMA concentrations increase relatively early in the course of vitamin B12 deficiency. However, MMA levels in plasma may also be increased due to renal failure. In this paper we estimate the influence of the kidney function on MMA levels in plasma by using fuzzy inference systems. Using this method diagnosing vitamin B12 deficiencies could be improved when kidney failure is present.
Thursday 21st of June, 16:20-17:40, Collegezaal 12
Chair: Christophe Labreuche

On a fuzzy integral as the product-sum calculation between a set function and a fuzzy measure

Eiichiro Takahagi

We propose the Choquet integral with respect set functions defined as the product-sum calculation between a set function and a fuzzy measure. The fuzzy integral is an extension of the Choquet integral. The Choquet integral assumes that the interactions among input values are interact fully but the extension assumes the values partially interact. In this paper, we define another integral expression and analyze its properties. For a input vector the optimal set function is calculated through linear programming. Lastly, we analyze coalitions among set functions that are a cooperative game using the proposed integral.

A 2-additive Choquet integral model for French hospitals rankings in weight loss surgery

Brice Mayag

In a context of Multiple Criteria Decision Aid, we present a decision model explaining some French hospitals rankings in weight loss surgery. To take into account interactions between medical indicators, we elaborated a model based on the 2-additive Choquet integral. The reference subset, defined during the elicitation process of this model, is composed by some specific alternatives called binary alternatives. To validate our approach, we showed that the proposed 2-additive Choquet integral model is able to approximate the hospitals ranking, in weight loss surgery, published by the French magazine "Le Point" in August 2013.

Benchmarking over distributive lattices

Marta Cardin

We provide an axiomatic characterization of preorders in lattices that are representable as benchmarking procedure. We show that the key axioms are related to compatibility with lattice operations. This paper proposes also a characterization and a generalization of Sugeno integral in a ordinal framework. Lattice, benchmark, congruence, compatible preorder, aggregation function, Sugeno integral.

Real world applications

Tuesday 21st of June, 16:20-17:40, Blauwe zaal
Chair: Sławomir Zadrożny

Using geographic information systems and smartphone-based vibration data to Support decision making on pavement rehabilitation

Chun-Hsing Ho, David Lai and Anas Almonnieay

This paper presents a data collecting process using smartphone-based accelerometer in association with geographic information systems (GIS) software to better manage pavement condition data and facilitate with decision making for maintenance and rehabilitation. The smartphone is equipped with an accelerometer (a mobile apps) could record 50 vibration data points per second in three directions (X, Y, and Z). The type of Traditional pavement survey is time-consuming and requires experienced technicians to travel along high-way to visualize pavement conditions and record any failures. Combining vibration intensity data with a GIS platform can help public agencies with a strategic plan to prioritize maintenance schedules for both bike trails and highway roads. The objective of this paper is to (1) discuss the processes of vibration data analysis using a smartphone based accelerometer and to (2) demonstrate how to relate vibration intensity data to locate priority areas for immediate.

Automatic synthesis of fuzzy inference systems for classification

Jorge Paredes, Ricardo Tanscheit, Marley Vellasco and Adriano Soares Koshiyama

This work introduces AutoFIS-Class, a methodology for automatic synthesis of Fuzzy Inference Systems for classification problems. It is a data-driven approach, which can be described in five steps: (i) mapping of each pattern to a membership degree to fuzzy sets; (ii) generation of a set of fuzzy rule premises, inspired on a search tree, and application of quality criteria to reduce the exponential growth; (iii) association of a given premise to a suitable consequent term; (iv) aggregation of fuzzy rules to a same class and (v) decision on which consequent class is most compatible with a given pattern. The performance of AutoFIS-Class has been compared to those of other four rule-based systems for 21 datasets. Results show that AutoFIS-Class is competitive with respect to those systems, most of them evolutionary ones.

A proposal for modelling agrifood chains as multi agent systems

Madalina Croitoru, Patrice Buche, Brigitte Charonmordic, Jerome Fortin, Hazael Jones, Pascal Neveu, Danai Symeonidou and Rallou Thomopoulos

In this paper, we introduce an uncertain data mining driven model for knowledge discovery in chemical database. We aim at discovering relationship between molecule characteristics and properties using uncertain data mining tools. In fact, we intend to predict the Critical Micelle Concentration (CMC) property based on molecule characteristics. To do so, we develop a likelihood-based belief function modeling approach to construct evidential database. Then, a mining process is developed to discover valid association rules. The prediction is performed using association rule fusion technique. Experiments were conducted using real-world chemical databases. Performance analysis showed a better prediction outcome for our proposed approach in comparison with several literature-based methods.
On a generalization of the Modus Ponens: U-conditionality

Margalida Mas, Miquel Monserrat, Daniel Ruiz-Aguilera and Joan Torrens

In fuzzy logic, the Modus Ponens property for fuzzy implication functions is usually considered with respect to a continuous t-norm T and for this reason this property is also known under the name of T-conditionality. In this paper, the t-norm T is substituted by a uninorm U leading to the property of US-conditionality. The new property is studied in detail and it is shown that usual implications derived from t-norms and t-conorms do not satisfy it, but many solutions appear among those implications derived from uninorms. In particular, the case of residual implications derived from uninorms or RU-implications is investigated in detail for some classes of uninorms.

A new look on the ordinal sum of fuzzy implication functions

Sebastia Massanet, Juan Vicente Riera and Joan Torrens

Fuzzy implication functions are logical connectives commonly used to model fuzzy conditional and consequently they are essential in fuzzy logic and approximate reasoning. From the theoretical point of view, the study of how to construct new implication functions from old ones is one of the most important topics in this field. In this paper a new ordinal sum construction methods of implication functions based on fuzzy negations is presented. Some general properties are analyzed and particular cases when the considered fuzzy negation is the classical one or any strong negation are highlighted.

Distributivity of implication functions over decomposable uninorms generated from representable uninorms in interval-valued fuzzy sets theory

Michal Baczynski and Wanda Niemyska

In this work we investigate two distributivity equations \( I_U(x, U_{1}(y,z)) = U_{1}(I_U(x,y), I_U(x,z)) \) and \( I_U(U_{1}(x,y), z) = U_{1}(I_U(x,z), I_U(y,z)) \) for implication operations and uninorms in interval-valued fuzzy sets theory. We consider decomposable (t-representable) uninorms generated from two conjunctive or disjunctive representable uninorms. Our method reduces to solve the following functional equation \( f(u_1+u_2+u_3) = f(u_1, u_2) + f(v_1, v_2) \) thus we present new solutions for this equation.

On functions derived from fuzzy implications

Przemyslaw Grzegorzewski

Recently, fuzzy implications based on copulas, i.e. probabilistic implications and probabilistic S-implications, were introduced and their properties were explored. However, the reverse problem of copulas derived from fuzzy implications, suggested by Massanet et al. (2015), are also of interest. In the paper we consider geometric properties of those fuzzy implications that generate copulas. Moreover, we consider the reverse problem for some generalizations of copulas like quasi-copulas and semi-copulas.

POSGRAMI: Possibilistic frequent subgraph mining in a single large graph

Montaceur Zaghdoud, Mohamed Moussaoui and Jalel Akaichi

The frequent subgraph mining has widespread applications in many different domains such as social network analysis and bioinformatics. Generally, the frequent subgraph mining refers to graph matching. Many research works dealt with structural graph matching, but a little attention is paid to semantic matching when graph vertices and/or edges are attributed. Therefore, the discovered frequent subgraphs should become more pruned by applying a new semantic filter instead of using only structural similarity in the graph matching process. In this paper, we present POSGRAMI, a new hybrid approach for frequent subgraph mining based principally on approximate graph
Chair: Irina Perfilieva

cially if compared to other fields like scalar or vectorial data. This work.
Radial data has become ubiquitous for many applications in computer

Carlos Lopez-Molina, Cedric Marco-Detchart, Javier Fernandez, Juan Cerron, Mikel Galar and Humberto Bustince
Radial data has become ubiquitous for many applications in computer vision. However, we still find a lack of well-grounded operators, especially if compared to other fields like scalar or vectorial data. This work studies the comparison of radial data, and proposes comparison measures for that task. As a result, we introduce the concepts of Restricted Radial Equivalence Function and Restricted Similarity Measure (RSM), which model the perceived similarity between scalar and vectorial pieces of radial data, respectively. These measures are further applied to fingerprint analysis, resulting in a singular point detection method. This method, which goes for the name of Template-based Singular Point Detection method (TSPD), has qualitative advantages over other alternatives, and proves competitive with state-of-the-art methods in well-known fingerprint dataset.

Application of a Mamdani-type fuzzy rule-based system to segment periventricular cerebral veins in susceptibility-weighted images

F. Xavier Aymerich, Pilar Sobrevilla, Eduard Montseny and Alex Rovira
This paper presents an algorithm designed to segment veins in the periventricular region of the brain in susceptibility-weighted magnetic resonance images. The proposed algorithm is based on a Mamdani-type fuzzy rule-based system that enables enhancement of veins within periventricular regions of interest as the first step. Segmentation is achieved after determining the cut-off value providing the best trade-off between sensitivity and specificity to establish the suitability of each pixel to belong to a cerebral vein. Performance of the algorithm in susceptibility-weighted images acquired in healthy volunteers showed excellent segmentation, with a small number of false positives. The results were not affected by small changes in the size and location of the regions of interest. The algorithm also enabled detection of differences in the visibility of periventricular veins between healthy subjects and multiple sclerosis patients.

On the use of lattice OWA operators in image reduction and the importance of the orness measure

Daniel Paternain, Gustavo Ochoa, Inmaculada Lizasoain, Edurne Barrenechea, Humberto Bustince and Radko Mesiar
In this work we investigate the use of OWA operators in color image processing. Since the RGB color scheme can be seen as a Cartesian product of lattices, we use the generalization of OWA operators to any complete lattice. However, the behavior of lattice OWA operators in image processing is not easy to predict. Therefore, we propose a quantitative orness measure that generalizes the orness measure given by Yager for usual OWA operators. With the aid of this new measure, we are able to classify each OWA operator and to analyze how its properties affect the results of applying OWA operators in an algorithm for reducing color images.

Clustering

Wednesday 22nd of June, 10:20-12:00, Collegezaal 12
Chair: Sébastien Destercke

Seasonal clustering of residential natural gas consumers

Marta Fernandes, Joaquim Viegas, Susana Vieira and João Sousa
This paper proposes a methodology to define the seasonal load profiles of residential gas consumers using smart metering data. A detailed clustering analysis is performed using fuzzy c-means, k-means and hierarchical clustering algorithms and multiple clustering validity indices. The analysis is based on a sample of more than one thousand
housesholds over one year. The results provide evidence that crisp algorithms present the best clustering results overall. However, the fuzzy algorithm proves to be suited when the others generate clusters which are not representative of population groups. Compact and well-defined seasonal clusters of gas consumers are obtained, where the representative profiles reflect the consumption patterns that vary according to the season of the year. The knowledge obtained with this methodology can assist decision makers in the energy utilities in order to develop demand side management programs, consumer engagement strategies, marketing, as well as in designing innovative tariff systems.

**Participatory learning fuzzy clustering for interval-valued data**
Leandro Maciel, Rosangela Ballini, Fernando Gomide and Ronald Yager

This paper suggests an interval participatory learning fuzzy clustering (iPL) method for partitioning interval-valued data. Participatory learning provides a paradigm for learning that emphasizes the pervasive role of what is already known or believed in the learning process. iPL-clustering method uses interval arithmetic, and the Hausdorff distance to compute the (dis)similarity between intervals. Computational experiments are reported using synthetic interval data sets with linearly non-separable clusters of different shapes and sizes. Comparisons include traditional hard and fuzzy clustering techniques for interval-valued data as benchmarks in terms of corrected Rand (CR) index for comparing two partitions. The results suggest that the interval participatory learning fuzzy clustering algorithm is highly effective to cluster interval-valued data and has comparable performance than alternative hard and fuzzy interval-based approaches.

**Fuzzy c-means clustering of incomplete data using dimension-wise fuzzy variance of clusters**
Ludmila Himmelspach and Stefan Conrad

Clustering is an important technique for identifying groups of similar data objects within a data set. Since problems during the data collection and data preprocessing steps often lead to missing values in the data sets, there is a need for clustering methods that can deal with such imperfect data. Approaches proposed in the literature for adapting the fuzzy c-means algorithm to incomplete data work well on data sets with equally sized and shaped clusters. In this paper we present an approach for adapting the fuzzy c-means algorithm to incomplete data that uses the dimension-wise fuzzy variances of clusters for imputation of missing values. In experiments on incomplete real and synthetic data sets with differently sized and shaped clusters, we demonstrate the benefit over the basic approach in terms of the assignment of data objects to clusters and the cluster prototype computation.

**On a generalized objective function for possibilistic fuzzy clustering**
Jozsef Mezei and Peter Sarlin

Possibilistic clustering methods have gained attention in both applied and theoretical research. In this paper, we formulate a general objective function for possibilistic clustering. The objective function can be used as the basis of a mixed clustering approach incorporating both fuzzy memberships and possibilistic typicality values to overcome various problems of previous clustering approaches. We use numerical experiments for a classification task to illustrate the usefulness of the proposal. Beyond a performance comparison with the three most widely used (mixed) possibilistic clustering methods, this also outlines the use of possibilistic clustering for descriptive classification via memberships to a variety of different class clusters. We find that possibilistic clustering using the general objective function outperforms traditional approaches in terms of various performance measures.

**Proximal optimization for fuzzy subspace clustering**
Arthur Guillon, Marie-Jeanne Lesot, Christophe Marsala and Nikhil R. Pal

This paper proposes a fuzzy partitioning subspace clustering algorithm that minimizes a variant of the FCM cost function with a weighted Euclidean distance and a penalty term. To this aim it considers the framework of proximal optimization. It establishes the expression of the proximal operator for the considered cost function, and derives PFSCM, an algorithm combining proximal descent and alternate optimization. Experiments show the relevancy of the proposed approach.

**S11 Fuzzy Logic, Formal Concept Analysis and Rough Sets I**

**A semantical approach to rough sets and dominance-based rough sets**
Lynn D'Eer, Chris Cornelis and Yiyu Yao

There exist two formulations of rough sets: the conceptual and computational one. The conceptual or semantical approach of rough set theory focuses on the meaning and interpretation of concepts, while algorithms to compute those concepts are studied in the computational formulation. However, the research on the former is rather limited. In this paper, we focus on a semantically sound approach of Pawlak's rough set model and covering-based rough set models. Furthermore, we illustrate that the dominance-based rough set model can be rephrased using this semantic approach.

**Graded generalized hexagon in fuzzy natural logic**
Petra Murinová and Vilém Novák

In our previous papers, we formally analyzed the generalized Aristotelian square of opposition using tools of fuzzy natural logic. Namely, we introduced general definitions of selected intermediate quantifiers, constructed a generalized square of opposition consisting of them and syntactically analyzed the emerged properties. The main goal of this paper is to extend the generalized square of opposition to graded generalized hexagon.
**Temporal Data Processing**

Wednesday 22nd of June, 10:20-12:00, Filmzaal
Chair: Trevor Martin

**Suppression of high frequencies in time series using fuzzy transform of higher degree**

Michal Holcapek and Linh Nguyen

In this paper, we provide a theoretical justification for the application of the higher degree fuzzy transform in time series analysis. We demonstrate that the higher degree fuzzy transform technique can be used for the suppression of high frequencies in time series, which belongs among the essential assumptions for a successful extraction of the trend (trend-cycle) of time series. More precisely, if a time series can be additively decomposed into a trend-cycle, a seasonal component and a noise, we show that high frequencies appearing in the seasonal component can be arbitrarily suppressed using the fuzzy transform of higher degree with a reasonable adjustment of parameters of a generalized uniform fuzzy partition.

**A modern fuzzy expert system architecture for data and event streams processing**

Jean-Philippe Poli and Laurence Boudet

In many decision making scenarios, expert systems have been useful to deduce a more conceptual knowledge from data. More particularly, fuzzy expert systems are able to deal with uncertainty and imprecision which are real-world challenges. They also present different advantages against Boolean logic expert systems: fuzzy rules are closer to natural language and can take into account the inherent vagueness of human language. Moreover, fuzzy logic avoids threshold effects and facilitates reasoning under uncertainty. In this paper, we present the development of a fuzzy expert system software which takes data or event streams in input and which outputs decisions on the fly. The article details an architecture which differs from fuzzy controllers, and which has been tested on synthetic data.

**Estimation and characterization of activity duration in business processes**

Rodrigo M. T. Gonçalves, Rui Jorge Almeida, João Sousa and Remco M. Dijkman

Process-aware information systems are typically used to log events in a variety of domains (e.g. commercial, logistics, healthcare) describing the execution of business processes. The analysis of such logs can provide meaningful knowledge for organizations to improve the quality of their services as well as their efficiency. The prediction of activity durations, based on historic data from execution logs, allows the creation of feasible plans for business processes. However, a problem arises when there are discrepancies between execution logs and the actual execution. When event logs are partially human-generated there is an underlying uncertainty related to the time at which events (recorded by means of user interaction) are logged. If not taken into account, this uncertainty can lead to wrong predictions of activity durations. In this paper, we focus in creating assumptions to estimate activity durations and analyze their impact in the stochastic characterization. A partially human-generated logistics database is used as example.

**Fuzzy modeling based on mixed fuzzy clustering for multivariate time series of unequal lengths**

Cátia Salgado, Susana Vieira and João Sousa

The sampling rate of variables collected in the hospital setting is dependent on several factors. Patients have different lengths of stay in the hospital, during which distinct physiological parameters are measured. The frequency of measurements depends ultimately in the type of variable and in the patient condition. Hence, when performing data based modeling for knowledge discovery in medical databases, one should have in consideration the heterogeneity of variables. This paper proposes an extension of a mixed fuzzy clustering algorithm in order to handle time invariant and time variant features of unequal lengths. Additionally, a novel approach for deriving Takagi-Sugeno fuzzy models, based on feature transformation using fuzzy c-means is implemented and compared with approaches based on mixed fuzzy clustering. The proposed approaches are tested on real data for mortality prediction in intensive care units of patients diagnosed with acute kidney injury and for ICU readmission prediction. Overall, the mixed fuzzy clustering yields better results than fuzzy c-means. Moreover, the proposed extension for time series of unequal lengths improves previous results. Mortality is classified with an AUC of 0.72 and readmissions with an AUC of 0.62.

**Time varying correlation estimation using PFS**

Rui Jorge Almeida and Nalan Basturk

Accurate financial risk analysis has drawn considerable attention after the recent financial crisis. Several regulatory agencies recently documented the need for proper assessment and reporting of financial risk for banks and other financial institutions. It is stressed that risk analysis should take into account changing risk properties over time. For a set of financial assets, risk analysis relies on the correlation and covariance structure among these returns from these assets. Therefore analyzing changes in the correlations and covariances of assets is essential to document changing risk properties. In this paper we show that a PFS can be used to model unobserved time-varying correlation between financial returns. The method is applied to simulated data and real data of daily NASDAQ and HSI stock returns. We show that the PFS application improves over the conventional moving window approximation of time-varying correlation by decreasing the sensitivity of the results to the selection of the window length.
SS02 – Soft computing for Image Processing II

Wednesday 22nd of June, 15:00-16:00, Blauwe zaal
Chair: Humberto Bustince

A methodology for hierarchical image segmentation evaluation

J. Tinguaro Rodríguez, Carely Guada, Daniel Gómez, Javier Yáñez and Javier Montero

This paper proposes a method to evaluate hierarchical image segmentation procedures, in order to enable comparisons between different hierarchical algorithms and of these with other (non-hierarchical) segmentation techniques (as well as with edge detectors) to be made. The proposed method builds up on the edge-based segmentation evaluation approach by considering a set of reference human segmentations as a sample drawn from the population of different levels of detail that may be used in segmenting an image. Our main point is that, since a hierarchical sequence of segmentations approximates such population, those segmentations in the sequence that best capture each human segmentation level of detail should provide the basis for the evaluation of the hierarchical sequence as a whole. A small computational experiment is carried out to show the feasibility of our approach.

Higher degree F-transforms based on B-splines of two variables

Martins Kokainis and Svetlana Asmuss

The paper deals with the higher degree fuzzy transforms (F-transforms with polynomial components) for functions of two variables in the case when two-dimensional generalized fuzzy partition is given by B-splines of two variables. We investigate properties of the direct and inverse F-transform in this case and prove that using B-splines as basic functions of fuzzy partition allows us to improve the quality of approximation.

Gaussian noise reduction using fuzzy morphological amoebas

Manuel González-Hidalgo, Sebastia Massanet, Arnau Mir and Daniel Ruiz-Aguilera

Many image processing and computer vision applications require a preprocessing of the image to remove or reduce noise. Gaussian noise is a challenging type of noise whose removal has led to the proposal of several noise filters. In this paper we present a novel version of the morphological filters based on amoebas with the aim to incorporate fuzzy logic into them to achieve a better treatment of the uncertainty. The experimental results show that the proposed algorithm outperforms the classical amoeba-based filters both from the visual point of view and the quantitative performance values for images corrupted with Gaussian noise with standard deviation from 10 to 30.

SS04 – Graded and Many-Valued Modal Logics I

Wednesday 22nd of June, 15:00-16:00, Collegezaal 12
Chair: Tomáš Kroupa

From Kripke to neighborhood semantics for modal fuzzy logics

Petr Cintula, Carles Noguera and Jonas Rogger

The majority of works on modal fuzzy logics consider Kripke-style possible worlds semantics as the principal semantics despite its well-known axiomatizability limitations when considering fuzzy accessibility relations. The present work offers the first (two) steps towards exploring a more general semantical picture, namely a fuzzified version of the classical neighborhood semantics. First we prove the fuzzy version of the classical relationship between Kripke and neighborhood semantics. Second, for any axiomatic extension of MTL (one of the main fuzzy logics), we define its modal expansion by a box-like modality, and, in the presence of some additional conditions, we prove that the resulting logic can be axiomatized by adding the (E)-rule to the corresponding Hilbert-style calculus of the starting logic.

Łukasiewicz public announcement logic

Leonardo Cabrer, Umberto Rivieccio and Ricardo Oscar Rodriguez

In this work we lay a theoretical framework for developing dynamic epistemic logics in a many-valued setting. We consider in particular the logic of Public Announcements, which is one of the most simple and most well-known dynamic epistemic systems in the literature. We show how to develop a Public Announcement Logic based on finite-valued Łukasiewicz modal logic. We define our logic through a relational semantics based on many-valued Kripke models, and also introduce an alternative but equivalent algebra-based semantics using MV-algebras with modal operators. We provide a Hilbert-style calculus for our logic and prove completeness with respect to both semantics.

Possibilistic semantics for a modal KD45 extension of Godel fuzzy logic

Felix Bou, Francesc Esteva, Lluis Godo and Ricardo Oscar Rodriguez

In this paper we provide a simplified semantics for the logic KD45(G), i.e. the many-valued Godel counterpart of the classical modal logic KD45. More precisely, we characterize KD45(G) as the set of valid formulae under the class of possibilistic Godel Kripke Frames (W, p); where W is a non-empty set of worlds and p is a normalized possibility distribution on W.
The syntax of many-valued relations
Patrik Eklund

In this paper we show how many-valued relations syntactically can be formulated using powertype constructors. This in turn enables to describe the syntax of generalized relations in the starting point sense where the category sets and relations is isomorphic to the Kleisli category of the powerset monad over the category of sets. We can then generalize to work over monoidal closed categories, and thereby description logic, formal concepts and rough sets can be viewed as depending on that powertype constructor, and within a setting of many-valued lambda-calculus. In order to achieve this, we will adopt a three-level arrangement of signatures, and demonstrate the benefits of using it.

Reduct-irreducible α-cut concept lattices: an efficient reduction procedure to multi-adjoint concept lattices
Maria Eugenia Cornejo Piñero, Jesús Medina Moreno and Eloisa Ramírez Poussa

The computation of fuzzy concept lattices is really complex. Hence, looking for mechanism in order to reduce this complexity is fundamental. This paper presents a new efficient mechanism which combines two ones. First of all, an attribute reduction is given, which removes the unnecessary attributes, and then a reduction based on a truth degree is applied, which removes the fuzzy attributes with low weight. Different interesting properties and examples of this mechanism are also introduced.

Towards Galois connections over positive semifields
Francisco José Valverde Albacete and Carmen Peláez-Moreno

In this paper we try to extend the Galois connection construction of K-Formal Concept Analysis to handle semifields which are not idempotent. Important examples of such algebras are the extended non-negative reals and the extended non-negative rationals, but we provide a construction that suggests that such semifields are much more abundant than suspected. This would broaden enormously the scope and applications of K-Formal Concept Analysis.

Multiple Criteria Decision Methods
Wednesday 22nd of June, 15:00-16:00, Filmzaal
Chair: Henri Prade

Prediction Model with Interval Data -Toward Practical Applications-
Michihiro Amagasa and Kiyoshi Nagata

The regression model is one of typical model for predicting some values by analyzing existing numerical data collected in various ways. If data are not crisp numbers, they are usually transformed into numerical crisp values by means of some methods such as quantification method. In companies' decision making process, collected and referred data usually have uncertainty which sometimes play an important roles for business performance. One of authors have proposed a model deriving predicting values with uncertainty by handling data with uncertainties. In this paper, we review some method for this purpose, then describe the model by applying it to some practical cases.

B-robustness approach for fuzzy multi-objective problems
Oumayma Bahri, Nahla Ben Amor and El-Ghazali Talbi

The paper addresses the robustness of multi-objective problems with fuzzy data expressed via triangular fuzzy numbers. We first define new concepts of B-robustness in the multi-objective fuzzy context. Then, we integrate the proposed robustness concepts into the search process of well-studied evolutionary algorithms to ensure the convergence towards robust optimal solutions. These proposals are illustrated on a multi-objective vehicle routing problem with fuzzy demands. The experimental results on different instances show the efficiency of the proposed approach.

Construction of an outranking relation based on semantic criteria with ELECTRE-III
Miriam Martínez García, Aida Valls and Antonio Moreno

ELECTRE-III is a well-known multi-criteria decision analysis method that ranks a set of alternatives in terms of a set of heterogeneous evaluation criteria. It is based on constructing and exploiting a pairwise outranking relation between alternatives, which are defined with numerical and ordinal values. However, nowadays it is very common the use of descriptive linguistic tags, which is information that requires a qualitative treatment rather than a numerical one. In this paper we propose to store the user preferences about a set of tags in an ontological structure and to use this knowledge to construct the outranking relation by means of a semantic analysis of the tags associated to the alternatives. Uncertainty is handled by means of fuzzy concordance and discordance functions. The method is illustrated with a case study related to the recommendation of touristic activities.

SS10 – Imperfect Databases
Wednesday 22nd of June, 16:20-17:20, Blauwe zaal
Chair: Mouna Chebbah & Mohamed Anis Bach Tobji

An incremental algorithm for repairing training sets with missing values
Bas van Stein and Wojtek Kowalczyk

Real-life datasets that occur in domains such as industrial process control, medical diagnosis, marketing, risk management, often contain missing values. This poses a challenge for many classification and regression algorithms which require complete training sets. In this paper we present a new approach for “repairing” such incomplete datasets by constructing a sequence of regression models that iteratively replace all missing values. Additionally, our approach uses the target attribute to estimate the values of missing data. The accuracy of our method, Incremental Attribute Regression Imputation, IARI, is compared with the accuracy of several popular and state of the art imputation methods, by applying them to five publicly available benchmark datasets. The results demonstrate the superiority of our approach.
Analysis and visualization of missing value patterns

Bas van Stein, Wojtek Kowalczyk and Thomas Bäck

Missing values in datasets form a very relevant and often overlooked problem in many fields. Most algorithms are not able to handle missing values for training a predictive model or analyzing a dataset. For this reason, records with missing values are either rejected or repaired. However, both repairing and rejecting affects the dataset and the final results, creating bias and uncertainty. Therefore, knowledge about the nature of missing values and the underlying mechanisms behind them are of vital importance. To gain more in-depth insight into the underlying structures and patterns of missing values, the concept of Monotone Mixture Patterns is introduced and used to analyze the patterns of missing values in datasets. Several visualization methods are proposed to present the “patterns of missingness” in an informative way. Finally, an algorithm to generate missing values in datasets is provided to form the basis of a benchmarking tool. This algorithm can generate a large variety of missing value patterns for testing and comparing different algorithms that handle missing values.

Efficient skyline maintenance over frequently updated evidential databases

Sayda Elmí, Mohamed Anis Bach Tobji, Allel Hadjiali and Bouthaina Ben Yaghlane

In many recent applications, data are intrinsically uncertain, noisy and error-prone. That is why, uncertain database management has attracted the attention of several researchers. Data uncertainty can be modeled in the evidence theory setting. On the other hand, skyline analysis is a powerful tool in a wide spectrum of real applications involving multi-criteria optimal decision making. It relies on Pareto dominance relationship. However, the skyline maintenance is not an easy task when the queried database is updated. This paper addresses the problem of maintenance of b-dominant skyline objects of frequently updated evidential databases. We propose algorithms for maintaining evidential skyline in the case of object insertion or deletion. Extensive experiments are conducted to demonstrate the efficiency and scalability of our proposal.

SS04 – Graded and Many-Valued Modal Logics II

Wednesday 22nd of June, 16:20-17:20, Collegezaal 12
Chair: Lluís Godo

A calculus for rational Łukasiewicz logic and related systems

Paolo Baldi

We introduce hypersequent calculi for Rational Łukasiewicz logic and for the logic \(KZ(\pi)\), an extension of Kleene-Zadeh logic, motivated by game semantic investigations.

Negation of graded beliefs

Bénédicte Legastelois, Marie-Jeanne Lesot and Adrien Revault d’Allonnes

Negation is a key element in the construction of logical systems and it plays a central role in reasoning and information manipulation tools. This paper considers the negation issue in the case of an expressive model of beliefs that allows to represent graded beliefs. Enriching formulas with belief degrees in the framework of a graded doxastic logic, it studies three interpretations of negation for these high level pieces of information, where negation is transferred to the three components of graded beliefs: the formula about which a belief is expressed, the belief modality and the belief degree. The paper discusses the choice of appropriate formal frameworks for each of them, considering % weighted modal, fuzzy and many-valued logics: it characterizes their use and underlines their relations, in particular regarding their effects on the belief degrees.

Comparing some Substructural Strategies Dealing with Vagueness

Robert van Rooij, Pablo Cobreros, Dave Ripley and Paul Egre

In this paper, we are interested in accounts of vagueness that, instead of relying on a special conditional connective, propose to capture the tolerance principle by imposing specific constraints on the consequence relation, in a way that leaves intuitively desirable properties of a conditional connective in place, and in a way suitable to deal with the sorties argument in its conjunctive form as well as its conditional one. We will focus on two structural approaches which mirror the nontransitive and non-monotone conditional to some extent, but shift those properties up one level, namely to the consequence relation. The first is the nontransitive treatment of logical consequence favored in our past work, on which the principle of tolerance comes out as valid in rule form, but cannot be iterated without risk (soft consequence as permissive consequence, see Cobreros et al (2014) for an overview). The second is the non-monotone treatment of logical consequence, on which the principle of tolerance too can come out as valid, but in a way that is sensitive to context and to the addition of further premises (soft consequence as defeasible consequence).

Comparison Measures

Wednesday 22nd of June, 16:20-17:20, Collegezaal 13
Chair: Janusz Kacprzyk

A distance between points and intervals

Hugo Saulnier, Olivier Strauss and Inés Couso

In the last decade, numerous proposals have been made to deal with imprecision in estimation problems. Those approaches, many of which involve interval-valued outputs, allow a better understanding of the difference between uncertainty and imprecision. One of the crucial points— which to our knowledge has never been addressed—is “how to compare an interval-valued method with a precise valued method?” The usual way to compare two estimation methods is to use benchmark data with ground truths and to compute a distance between the estimates of each method and the ground truth. However, most the mathematical available extensions of distances are either biased in favor of a precise approach or in favor of an imprecise approach. This paper proposes a weighted extension of the L1 distance that is more suitable to achieve this kind of comparison, dealing with imprecision with a particular semantic. After reviewing existing metrics, we introduce this weighted distance, first from an intuitive perspective, then from a more mathematical point of view. Its very satisfactory properties are highlighted through an experiment.

On different ways to be (dis)similar to elements in a set. A Boolean analysis and its graded extension

Henri Prade and Gilles Richard

What being ‘at odd’ with a subset may mean for an item, or what being ‘even’ may mean for a subset, are two questions that are addressed, in a Boolean and then in a gradual setting, in this paper. Is there a relation between oddness and evenness? Such questions emerge from recent
proposals for using tentative evenness or oddness measures in classification problems. This paper is dedicated to a formal study of the oddness and evenness indices in the case of subsets with three or four elements, which are at the basis of the associated measures. Triples are indeed the only subsets such that adding an item that does not conform to the triple majority destroys the majority. It appears that the notions of evenness and oddness are not simple dual of each other; a third notion of being ‘balanced’ interplay with the two others. This is discussed in the setting of squares and hexagons of opposition. These notions are related to the study of homogeneous or heterogeneous logical proportions that relate four Boolean variables through the conjunction of two equivalences between similarity or dissimilarity indicators pertaining to pairs of these variables. Although elementary, the analysis provides an organized view of new notions that appear to be meaningful when revisiting the old ideas of similarity and dissimilarity in a new perspective. As a side result, it is also mentioned that the logical proportion underlying the idea of being balanced corresponds to the logical encoding of Bongard problems.

Comparing system reliabilities with ill-known probabilities

Lanting Yu, Sébastien Destercke, Mohamed Sallak and Walter Schon

In reliability analysis, comparing system reliability is an essential task when designing safe systems. When the failure probabilities of the system components (assumed to be independent) are precisely known, this task is relatively simple to achieve, as system reliabilities are precise numbers. When failure probabilities are ill-known (known to lie in an interval) and we want to have guaranteed comparisons (i.e., declare a system more reliable than another when it is for any possible probability value), there are different ways to compare system reliabilities. We explore the computational problems posed by such extensions, providing first insights about their pros and cons.

Fuzzy Sets and Fuzzy Logic

Thursday 23rd of June, 10:50-12:10 Blauwe zaal
Chair: Vilém Novák

Adjoint fuzzy partition and generalized sampling theorem

IrinaPerfilieva, Michal Holčapek and Vladik Kreinovich

A new notion of adjoint fuzzy partition is introduced and the reconstruction of a function from its F-transform components is analyzed. An analogy with the Nyquist-Shannon-Kotelnikov sampling theorem is discussed.

How to incorporate `excluding symptoms' in fuzzy relational compositions and what for

Nhung Cao and Martin Stepička

The aim of this paper is, first, to recall fuzzy relational compositions (products) and, to introduce an idea, how the so-called excluding symptoms could be incorporated into the theoretical background. Apart from rather natural definitions, we provide readers with a theoretical investigation that provides and answer to a rather natural question, under which conditions, in terms of the underlying algebraic structures, the proposed incorporation of excluding symptoms preserves the same properties as the incorporation in the classical relational compositions. The positive impact of the incorporation on reducing the suspicions provided by the basic ‘circle’ composition without losing the possibly correct suspicion, as in the case of the use of the Bandler-Kohout products, is demonstrated on an example.

Towards Fuzzy Partial Set Theory

Martina Dankova and Libor Behounek

We sketch a simple theory of fuzzy partial sets, i.e., fuzzy sets that can have undefined membership degrees. The theory is developed in the semantic framework of a first-order extension of the recently proposed fuzzy partial propositional logic. We introduce a selection of basic notions of fuzzy partial set theory, discuss their variants, and present a few initial results on the properties of fuzzy partial class operations and relations.

On perception-based logical deduction with fuzzy inputs

Antonín Dvorák and Martin Stepička

We present and analyze inference method called Perception-based Logical Deduction (PhLD) aimed at the treatment of fuzzy IF-THEN rules as linguistically expressed genuine logical implications. We analyze two variants of PhLD (original and balancing) that differ in the selection of fired IF-THEN rules. We concentrate on a situation when inputs into inference are fuzzy sets (fuzzy inputs). We study the conditions under which both variants fulfill the interpolativity property.

Databases and Information Systems I

Thursday 23rd of June, 10:50-12:10, Collegezaal 12
Chair: Alfredo Cuzzocrea

Indexing possibilistic numerical data: The interval B+tree approach

Guy De Tre, Robin De Mol and Antoon Bronselaer

When record sets become large, indexing becomes a required technique for speeding up querying. This holds for regular databases, but also for ‘fuzzy’ databases. In this paper we propose a novel indexing technique, supporting the querying of imperfect numerical data. A possibility based relational database setting is considered. Our approach is based on a novel adaptation of a B+ tree, which is currently still one of the most efficient indexing techniques for databases. The leaf nodes of a B+ tree are enriched with extra data and an extra tree pointer so that interval data can be stored and handled with them, hence the name Interval B+ Tree (IBPT). An IBPT allows to index possibility distributions using a single index structure, offering almost the same benefits as a B+ tree. We illustrate how an IBPT index can be used to index fuzzy sets and demonstrate its benefits for supporting ‘fuzzy’ querying of ‘fuzzy’ databases. More specifically, we focus on the handling of elementary query criteria that use the so-called compatibility operator IS, which checks whether stored imperfect data are compatible with user preferences (or not).

Ordinal assessment of data consistency based on regular expressions

Antoon Bronselaer, Joachim Nießhardt, Robin De Mol and Guy De Tre

In this paper, a novel assessment method for measurement of data consistency is proposed. The first novelty of this assessment method is that it allows to express a broad range of state-of-the-art consistency measurements in a simple and elegant, yet standardized way. This is obtained by constructing the framework of measurement on top of standardized regular expressions. The key advantage of such a standardized expression is that knowledge about consistency becomes portable, exchangeable and easy to access. The second novelty is that it
A qualitative approach to set achievable goals during the design phase of complex systems
Diadie Sow, Abdelhak Imoussaten, Pierre Couturier and Jacky Montmain

The problem addressed in this paper is “how to set ambitious targets when improving or designing a product while these targets remain within the reach of the manufacturer”. Thus, improvements to be focused on are those which both have a significant positive impact on product performance and correspond to operational changes properly under control by the manufacturer. While some approaches in the literature have already addressed each of the two issues of the improvement problem, few treat conjointly both of them. In this paper we investigate a qualitative approach that conciliates both points of view as an optimization problem. The notion of interaction between any two objectives to be simultaneously satisfied is central in our framework. An illustrative example related to the design phase of autonomous robot is provided.

Unbalanced OWA Operators for Atanassov Intuitionistic Fuzzy Sets
Laura De Miguel Turullolols, Edurne Barrenechea, Miguel Pagola, Aránzazu Jurío, Jose Antonio Sanz, Mikel Eklano and Humberto Bustince

In this work we introduce a new class of OWA operators for Atanassov intuitionistic fuzzy sets which distinguishes between the weights for the membership degree and the weights for the non-membership degree; we call these operators Unbalanced Atanassov Intuitionistic OWA operators. We also study under which conditions these operators are aggregation functions with respect to the Atanassov intuitionistic admissible linear orders. Finally, we apply these aggregation functions in an illustrative example of a decision making problem.

Fuzzy k-minpen clustering and k-nearest-minpen classification procedures
Anna Cena and Marek Gagolewski

We discuss a generalization of the fuzzy (weighted) k-means clustering procedure and point out its relationships with data aggregation in spaces equipped with arbitrary dissimilarity measures. In the proposed setting, unsupervised learning data set partitioning is performed based on the notion of points’ proximity to generic distance-based penalty minimizers. Moreover, a new data classification algorithm, resembling the k-nearest neighbors scheme but less computationally and memory demanding, is introduced. Rich examples in complex data domains indicate the usability of the methods and aggregation theory in general.

A Fuzzy Approach to the Characterization of Database Query Answers
Aurélien Moreau, Olivier Pivert and Grégory Smits

This paper describes an approach helping users to better understand the results of their queries. These results are structured with a clustering algorithm and described using a personal vocabulary. The goal is to find what the elements of a cluster have in common that also differentiates them from the elements of the other clusters. The originality of this work is that the data considered for characterizing each cluster of answers are not limited to attributes used in the query. Fuzzy sets and labels from the user’s vocabulary are used to personalize this characterization process.

Making the skyline larger: A fuzzy-neighborhood-based approach
Djamal Belkasmi, Allel Hadjali and Hamid Azzoune

Skyline queries have gained much attention in the last decade and are proved to be valuable for multi-criteria ranking. They are based on the concept of Pareto dominance. In many real-life applications, the skyline returns only a small number of non-dominated objects which could be insufficient for the user. In this paper, we discuss an approach to enriching the small skyline with particular points that could serve the decision makers’ needs. The idea consists in identifying the most interesting non-skyline points belonging to the fuzzy neighborhood of a skyline point and then adding them to the classical skyline. To do so, a particular fuzzy closeness relation is introduced. The relaxed skyline obtained which include the classical skyline, is a discriminated set. Furthermore, an efficient algorithm to compute the extended skyline is proposed. Extensive experiments are conducted to demonstrate the effectiveness of our approach and the performance of the proposed algorithm.

SS01 – Computational Aspects of Aggregation and Complex Data Fusion
Thursday 23rd of June, 10:50-12:10, Collegezaal 13
Chair: Marek Gagolewski

Linear Optimization for Ecological Indices Based on Aggregation Functions
Gleb Beliaev, Andrew Geschke, Simon James and Dale Nimmo

We consider an optimization problem in ecology where our objective is to maximize biodiversity with respect to different land-use allocations. As it turns out, the main problem can be framed as learning the weights of a weighted arithmetic mean where the objective is the geometric mean of its outputs. We propose methods for approximating solutions to this and similar problems, which are non-linear by nature, using linear and bilevel techniques.
Constrained value-based argumentation framework

Karima Sedki and Safa Yahi

Value-based argumentation framework (VAF) is an extension of Dung argumentation framework where arguments promote specific values. In VAF, an argument a defeats b only if the value promoted by b is not preferred than the value promoted by a according to some total ordering on values given by a specific audience. However, despite the interesting idea of considering the preference relation between arguments’ values, VAF does not offer a way to express further requirements, like “no arguments promoting expensive value” or “if we accept arguments promoting expensive value, then we accept arguments promoting healthy value”. This paper generalizes VAF by incorporating some constraints, expressed as propositional formulas on either the arguments’ values or on the arguments. We propose two inference relations for defining some acceptability semantics in such constrained arguments promoting expensive value, then we accept arguments.

Belief revision and the EM algorithm

Inés Couso and Didier Dubois

This paper tries to provide a natural interpretation of the EM algorithm as a succession of revision steps that tries to find a probability distribution in a parametric family of models in agreement with frequentist observations over a partition of a domain. Each step of the algorithm corresponds to a revision operation that respects a form of minimal change. In particular, the so-called expectation step actually applies Jeffrey’s revision rule to the current best parametric model so as to respect the frequencies in the available data. We also indicate that in the presence of incomplete data, one must be careful in the definition of the likelihood function in the maximization step, which may differ according to whether one is interested by the precise modeling of the underlying random phenomenon together with the observation process, or by the imprecise modeling of the underlying random phenomenon alone.

Causal belief inference in multiply connected networks

Oumaima Boussarsar, Imen Boukhris and Zied Elouedi.

The belief function theory is an efficient tool to represent causal knowledge under uncertainty. Therefore, causal belief inference process is important to evaluate the impact of an observation or an intervention on the system. However, existing algorithms only deal with the propagation of observational data in belief networks. This paper addresses propagation algorithms of causal knowledge in multiply connected causal belief networks. To handle this propagation, we have first to transform the initial network into a tree structure. Therefore, we propose some modifications to construct a new structure by exploiting independence relations in the initial network. This structure is called hybrid binary join tree composed of conditional distributions and non-conditional ones. Then, we develop a causal belief propagation algorithm using the belief graph mutilation or the graph augmentation methods.

Social Data Processing

Chair: Marie-Jeanne Lesot

Dynamic analysis of participatory learning in linked open data: Certainty and adaptation

Marek Z. Reformat, Ronald Yager and Jesse Xi Chen

Graph-based data formats are popular ways of representing information, while graph-processing engines and graph databases become preferable tools for handling data of different size. World Wide Web Consortium has introduced a graph-based data format called Resource Description Framework (RDF) as the part of its Semantic Web initiative. The intrinsic features of RDF, i.e., its interconnectivity and simplicity of expressing information as triples containing two entities connected by a property, provide new possibilities of analyzing and absorbing information. The participatory learning of propositional knowledge is an attractive way of integrating and updating knowledge bases built based on symbolic data equipped with uncertainty. In such context, an idea of considering RDF triples as propositions allowed us to use the principles of participatory learning for assimilating RDF triples and handling different levels of uncertainty associated with them. This paper examines the RDF-based participatory learning process from the perspective of its dynamics. The emphasis is put on aspects related to handling certainty, accepting new pieces of information, and dealing with contradicting information. The learning process is presented, and the results of analysis are provided.

Creating Extended Gender Labelled Datasets of Twitter Users

Marco Vicente, Fernando Batista and Joao Paulo Carvalho

Twitter registration does not include gender information. As such, user gender is not known a priori when analyzing Twitter data. This paper proposes an approach for creating extended labelled gender datasets of Twitter users in a semi-automatic fashion. The proposed method allows the creation of large gender labelled datasets of Twitter users in an inexpensive and reusable way. Users databases are initially created from tweets produced by Twitter active users. A supervised gender classification model is then applied to unstructured text content from these initial databases, based on smaller manually labelled datasets. Finally, the existing dataset is enriched with additional properties extracted from the profile picture and from user location. The proposed approach was successfully applied to English and Portuguese users, leading to two large datasets containing more than 57K labeled users each. These datasets constitute valuable resources that can be used either for creating gender models or to perform gender dependent analyses of Twitter content.
Machine Learning

Thursday 23rd of June, 15:00-16:00, Collegezaal 12
Chair: Christophe Marsala

Visualization of individual ensemble classifier contributions

Catarina Silva and Bernardete Ribeiro

Ensembles of classifiers are usually considered a valuable approach in different scenarios. A broad range of methods to deal with the construction, diversity and combination of multiple predictive models have been extensively studied. While the focus is often to obtain more accurate and robust predictions than single models seldom the individual contribution of classifiers which could contribute to a better understanding of the uncertainty associated with ensembles’ outputs is taken into account. In this work we look into this issue and focus on evaluating the individual ensemble classifier contributions using several scenarios. We propose a visual web model that allows for the evaluation of both individual contributions as well as their interactions. We apply the proposed approach on a benchmark dataset and show how it can visually be used to better understand the uncertainty associated with the construction of ensembles, presenting some insight on the individual contributions and interactions.

Feature selection from partially uncertain data within the belief function framework

Asma Trabelsi, Zied Elouedi and Eric Lefevre

With the rapid growth of high dimensional data, feature selection has become a substantial task for several machine learning problems. In fact, it is regarded as an important process for classification performance owing to its ability to remove redundant and inconsistent features. The rough set theory is regarded as a well-known tool allowing relevant feature selection. As the task of attribute selection using rough sets is an NP-hard problem, several heuristic algorithms have been introduced. The Johnson’s algorithm, handling data characterized by certain and precise attribute values, is one of the most known ones. In this paper, we propose to extend this latter algorithm to an uncertain context, precisely where data contain uncertain condition attribute values represented within the belief function framework. We test the performance of our belief Johnson’s algorithm through several experiments on synthetic databases.

On the suitability of type-1 fuzzy regression tree forests for complex datasets

Fathi Gasir and Keeley Crockett

One of the challenges in data mining practices is that the datasets vary in complexity and often have different characteristics such as number of attributes, dependent variables characteristics etc. In terms of regression problems, the features that describe the dataset will vary in their complexity, sparseness verses coverage in relation to the decision space, and the number of outcome classes. Fuzzy Decision trees are well-established classifiers in terms of building robust, representative models of the domain. In order to represent different perspectives of the same domain, fuzzy trees can be used to construct fuzzy decision forests to enhance the predictive ability of singular trees. This paper describes an empirical study which examines the applicability of fuzzy tree regression forests to seven different datasets which have complex properties. The relationship between dataset characteristics and the performance of fuzzy regression tree forests is debated.

Decision Support

Thursday 23rd of June, 15:00-16:00, Collegezaal 13
Chair: Didier Dubois

Constructing preference relations from utilities and vice versa

Thomas A. Runkler

In decision making, the suitability of decision options may be specified by utility values for each option or by preference values for each pair of options. This paper introduces a new approach to construct a matrix of pairwise preference values from a vector of utility values, which is called the U2P transformation. The U2P transformation satisfies reciprocity, triangle condition, weak transitivity, restricted max-min transitivity, and restricted max-max transitivity, but it violates (unrestricted) max-min transitivity, (unrestricted) max-max transitivity, multiplicative transitivity, and additive transitivity. Inversion of the U2P transformation yields the P2U transformation which can be used to construct a vector of utility values from a matrix of pairwise preference values. Numerical experiments with movie ratings illustrate the practical use of the U2P and P2U transformations.

A characterization of the performance of ordering methods in TTRP with fuzzy coefficients in the capacity constraints

Isis Torres-Pérez, Carlos Cruz, Alejandro Rosete-Suárez and José Luis Verdegay

Recently, the Truck and Trailer Routing Problem has been tackled with uncertainty in the coefficients of the constrains. To solve this problem, it is needed to use methods for comparison of fuzzy numbers. The problem of ordering fuzzy quantities has been addressed by many authors and there are a lot indices concerning the evaluation and comparison of fuzzy quantities. The performance of each method depends on the characteristics of the problems, for example, the number of vehicles, the vehicles capacities or the total number of customers. In this paper we focus our attention on a model to characterize TTRP problems. We use a data mining algorithm to derive a decision tree that determined the best method for comparison based on the characteristics of the problem to be solved.

Preferences on gambles representable by a Choquet expected value with respect to conditional belief and plausibility functions

Giulianella Coletti, Davide Petturiti, Barbara Vantaggi and Letizia Caldari

We deal with decisions under uncertainty starting from a preference relation on a finite set of (conditional) gambles. Necessary and sufficient conditions are provided for the existence of a (conditional) belief function or a (conditional) plausibility function such that the (conditional) Choquet expected value with respect to these measures represents the preference relation.
Fuzzy block-pulse functions and its application to solve linear fuzzy Fredholm integral equations of the second kind

Shokrollah Ziari and Reza Ezati

In this paper, a method of successive approximations based on the fuzzy block-pulse functions is proposed to solve linear fuzzy Fredholm integral equations of the second kind. Moreover, the error estimation of the the approximation solution is given. Finally, illustrative example is included to show the accuracy and the efficiency of the proposed method.

Graded dominance and Cantor-Bernstein equivalence of fuzzy sets

Michal Holcapek

The aim of the paper is to propose a graded dominance for fuzzy sets that assigns to each pair of fuzzy sets a degree in which one fuzzy set has less cardinality than another one or the cardinalities of both fuzzy sets are approximately equal. The graded dominance for fuzzy sets is a natural generalization of the dominance relation for sets. The graded dominance is then used for the introduction of a fuzzy class equivalence that satisfies a graded version of the Cantor-Bernstein theorem.

Uninorms on interval-valued fuzzy sets

Martin Kalina and Pavol Kráľ

This paper is a kind of continuation of the paper by G. Deschrijver 'Uninorms which are neither conjunctive nor disjunctive in interval-valued fuzzy set theory'}, which was published in Information Sciences in 2013. In that paper he constructed uninorms whose neutral element is arbitrary of the type epsilon=(e,e) and annihilator, a, is arbitrary point that is incomparable with (e,e). In the present paper we intend to show what are all possibilities of the position of the pair (epsilon,a).

Algorithm to generate finite negative tomonoids

Milan Petrič and Thomas Vetterlein

The canonical semantics of fuzzy logic is typically based on negative totally ordered monoids. This contribution describes an algorithm generating in a step-wise fashion all finite structures of this kind.

Some results on extension of lattice-valued XOR, XOR-implications and E-implications

Eduardo Palmeira and Benjamin Bedregal

The extension problem is an important and interesting issue that is addressed for many different classes of operator. For instance, one can thing who to extend a fuzzy operator from a lattice to a bigger one preserving its algebraic properties. In this paper we attempt to the extension of lattice-valued version of Xor (exclusive) operator using a special method based on retractions. Also we discuss about Xor-implications end E-implications.
In-database feature selection using rough set theory

Frank Beer and Ulrich Bühler

Despite their traditional roles, database systems increasingly became attractive as scalable analytical platforms using extensible SQL over the last decade. This methodology is coined in-database processing and provides several advantages over traditional mining attempts. In this work we bring Variable Precision Rough Sets to the domain of databases as a common framework to unlock hidden knowledge from data. Our derived model is built upon pure relational operations and thus very efficient. We further demonstrate its applicability for feature selection by introducing two in-database algorithms. Our experiments indicate, the model run at scale and is comparable to existing approaches in terms of performance but superior when applied to real-life applications.

Aggregation

Thursday 23rd of June, 16:20-18:00, Collegezaal 13
Chair: Radko Mesiar

Fitting aggregation functions to data: Part I - Linearization and regularization

Maciej Bartoszuk, Gleb Beliakov, Marek Gagolewski and Simon James

The use of supervised learning techniques for fitting weights and/or generator functions of weighted quasi-arithmetic means -- a special class of idempotent and nondecreasing aggregation functions -- to empirical data has already been considered in a number of papers. Nevertheless, there are still some important issues that have not been discussed in the literature yet. In the first part of the two-part contribution we deal with the concept of linearization, a quite standard technique from machine learning applied so as to increase the fit quality on test and validation data samples. Due to the constraints on the weighting vector, it turns out that many more methods can be used in the current framework, as compared to regression models. Moreover, it is worth noting that so far fitting weighted quasi-arithmetic means to empirical data has only been performed approximately, via the so-called linearization technique. In this paper we consider exact solutions to such special optimization tasks and indicate cases where linearization leads to much worse solutions.

Fitting aggregation functions to data: Part II - Idempotentization

Maciej Bartoszuk, Gleb Beliakov, Marek Gagolewski and Simon James

The use of supervised learning techniques for fitting weights and/or generator functions of weighted quasi-arithmetic means -- a special class of idempotent and nondecreasing aggregation functions -- to empirical data has already been considered in a number of papers. Nevertheless, there are still some important issues that have not been discussed in the literature yet. In the second part of the two-part contribution we deal with a quite common situation in which we have inputs coming from different sources, describing a similar phenomenon, but which have not been properly normalized. In such a case, idempotent and nondecreasing functions cannot be used to aggregate them unless proper pre-processing is performed. The proposed idempotentization method, based on the notion of B-splines, allows for an automatic calibration of independent variables. The introduced technique is applied in an R source code plagiarism detection system.

On the sensitivity of the weighted relevance aggregation operator and its application to fuzzy signatures

Istvan Harmati and Laszlo T. Koczy

The weighted relevance aggregation operator is a modified, flexible version of the general power mean. In this paper we discuss the sensitivity of this operator, namely we give bounds on the change of the output in terms of vector norms of the change of the input variables. We apply then these results to characterize sensitivity of fuzzy signatures which are equipped with these operators in its nodes.

A new vision of Zadeh's Z-numbers

Sebastia Massanet, Juan Vicente Riera and Joan Torrens

From their introduction Z-numbers have been deeply studied and many investigations have appeared trying to reduce the inherent complexity in their computation. In this line, this paper presents a new vision of Z-numbers based on discrete fuzzy numbers with support in a finite chain Ln. In this new approach, a Z-number associated with a variable X is a pair (A,B) of discrete fuzzy numbers, where A is interpreted as a fuzzy restriction on X, while the estimation of the reliability of A is interpreted as a linguistic valuation based on the discrete fuzzy number B. In this non-probabilistic approach an aggregation method is proposed with the aim of applying it in group decision making problems.

Mean estimation based on FWA using ranked set sampling with multiple rankers

Bekir Çetintav, Gözde Ulutagay, Selma Gürler and Neslihan Demirel

The Ranked Set Sampling (RSS) is an advanced sampling method which improves the precision and accuracy of the mean estimator. In RSS, the units in the random sets which are drawn from a population are ranked by a ranking mechanism, and one of these ranked units is sampled from each set with a specific scheme. Ranking the units (visually or by a concomitant variable) could not be perfect because there is an uncertainty in decision making about the rank of a unit. In this study, we propose a fuzzy set perspective for RSS and an estimator for the population mean based on Fuzzy Weighted Average (FWA) operator. A real data application is given to illustrate the new approach for the single and multiple rankers.
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