8th Annual Conference of IT4Innovations & CE IT4I Research and Project Evaluation

IT4Innovations national supercomputing center

RP 6 – Soft computing methods with supercomputer applications

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UNIVERSITAS OSTRAVIENSIS

Institute of Geonics ASCR

FIT

RP structure

- **Head of research programme:** prof. Ing. Vilém Novák, DrSc.
- **Responsible partners:** OU & SLU

RP structure	FTE OU	FTE SLU
Senior researchers & HRP	8,4	2,60
Researchers	19,42	2,25
Research assistants	1,50	0
Research support staff	4,50	0,40
Total	**33,82**	**5,25**

Research teams

- Theoretical Research Department (OU)
- Applied Research Department (OU)
- Software Development Department (OU)
- Multi-agent computing (SLU)
- Autonomous Agent Research Team (SLU)

No of finished publications in 2019

RP structure	OU	SLU	
Papers in journals	59	4	
Monographs	2	0	
Chapters in monographs	3	0	
Papers in proceedings	38	8	
Total	**102**	**12**	

5 most important results of RP6 in 2019

- Result #1: J. Nguyen, L. T. N. L., Perfiljeva, I. a Holčapek, M. **Boundary Value Problem: Weak Solutions Induced by Fuzzy Partitions**. Discrete and Continuous Dynamical Systems Vol. 25, No 2, 2020; doi:10.3934/dcdsb.2019263
- Result #2: Martin Štěpnička, Nhung Cao, Libor Běhounek, Michal Burda and Aleš Dolný: **Missing values and dragonfly operations in fuzzy relational compositions**, International Journal of Approximate Reasoning, Volume 113, October 2019, Pages 149-170
- Result #3: **Continuation of the development of original methods for computer vision**
- Result #4: Novák, V., Murinová, P. **A formal model of the intermediate quantifiers "A few, Several, A little"**. In: 2019 IFSA World Congress and NAFIPS Annual Conference: 2019-06-18 Lafayette, Louisiana, USA.
- Result #5: SOSÍK, P. **Morphogenetic systems: An overview** (invited talk), Procs. of 20th Int. Conf. On Membrane Computing, pp. 213-216.

Result #1

Boundary Value Problem: Weak Solutions Induced by Fuzzy Partitions

We significantly contributed to numerical analysis of differential equations (specially bounded-value problems). Our machinery is based on:

- *Sobolev spaces with weak differentiable functions,*
- *Galerkin-type methodology where test functions correspond to eigen functions of the F-transform operator*

Comparing FEM and FPP methods

Example 1: BVP with smooth coefficients

#N	FPP (Fuzzy Partition with Polynomials)		FEM (Finite Element Method)	
	Error	Convergence rate	Error	Convergence rate
8	1.8×10^{-3}	-	2.3×10^{-2}	-
16	2.2×10^{-4}	3.03	4.9×10^{-3}	2.23
32	2.8×10^{-5}	2.97	1.1×10^{-3}	2.16
64	3.3×10^{-6}	3.08	2.8×10^{-4}	1.97
128	4.5×10^{-7}	2.87	6.8×10^{-5}	2.04
256	5.1×10^{-8}	3.14	1.7×10^{-5}	2.00

Comparing FEM and FPP methods

Example 2: BVP with non-smooth coefficients

#N	FPP (Fuzzy Partition with Polynomials)		FEM (Finite Element Method)	
	Error	Convergence rate	Error	Convergence rate
8	7.3×10^{-3}	-	2.2×10^{-2}	-
16	1.6×10^{-3}	2.19	5.4×10^{-3}	2.03
32	6.2×10^{-4}	1.37	1.7×10^{-3}	1.67
64	3.0×10^{-4}	1.05	6.5×10^{-4}	1.39
128	1.5×10^{-4}	1.00	2.9×10^{-4}	1.16
256	8.6×10^{-5}	8.03	1.4×10^{-4}	1.05

Comparing FEM and FPP methods

Example 3: BVP with oscillating source function and extended domain

#N	FPP (Fuzzy Partition with Polynomials)		FEM (Finite Element Method)	
	Error	Convergence rate	Error	Convergence rate
8	0.9785	-	1.0055	-
16	0.6878	5.09	0.8559	2.32
32	0.2447	1.49	0.2764	1.63
64	3.9×10^{-2}	2.65	7.1×10^{-2}	1.96
128	5.4×10^{-3}	2.85	1.8×10^{-2}	1.98
256	6.9×10^{-4}	2.97	4.4×10^{-3}	2.03

Result #2

Missing values and dragonfly operations in fuzzy relational compositions. Application of the theory of compositions of fuzzy relations (representation of expert knowledge)

- The logical/algebraic approaches deal with truth-values different from the standard True and False

  "Graded truth"; "Irrelevant"; "Non-applicable"; "Indeterminable"; "Inconsistent"; "Unknown"
- We suggested a special algebra incorporating missing values in the compositions of fuzzy relations: **Dragonfly algebra**

Result #2

- Real example: taxonomical classification of dragonflies

- Expert knowledge-based classification is mathematically formulated using fuzzy relational compositions
- It is very reliable even if a high number of missing values occurs

Result #2

- Unambiguous feature-based classification is hardly possible but we can significantly narrow the class of most similar ones (guess-set). The presence of missing values does not have fatal influence on the result.

- Example: testing 52940 objects

  Non-missing values give guess-set 20.42 (average) dragonflies candidates; precision 98.85 %

  Missing values (randomly distributed) give guess-set 20.96 dragonflies candidates; precision 93.71 %

Different species

same distinguishable features

Result #3

Continuation of the development of original methods for computer vision

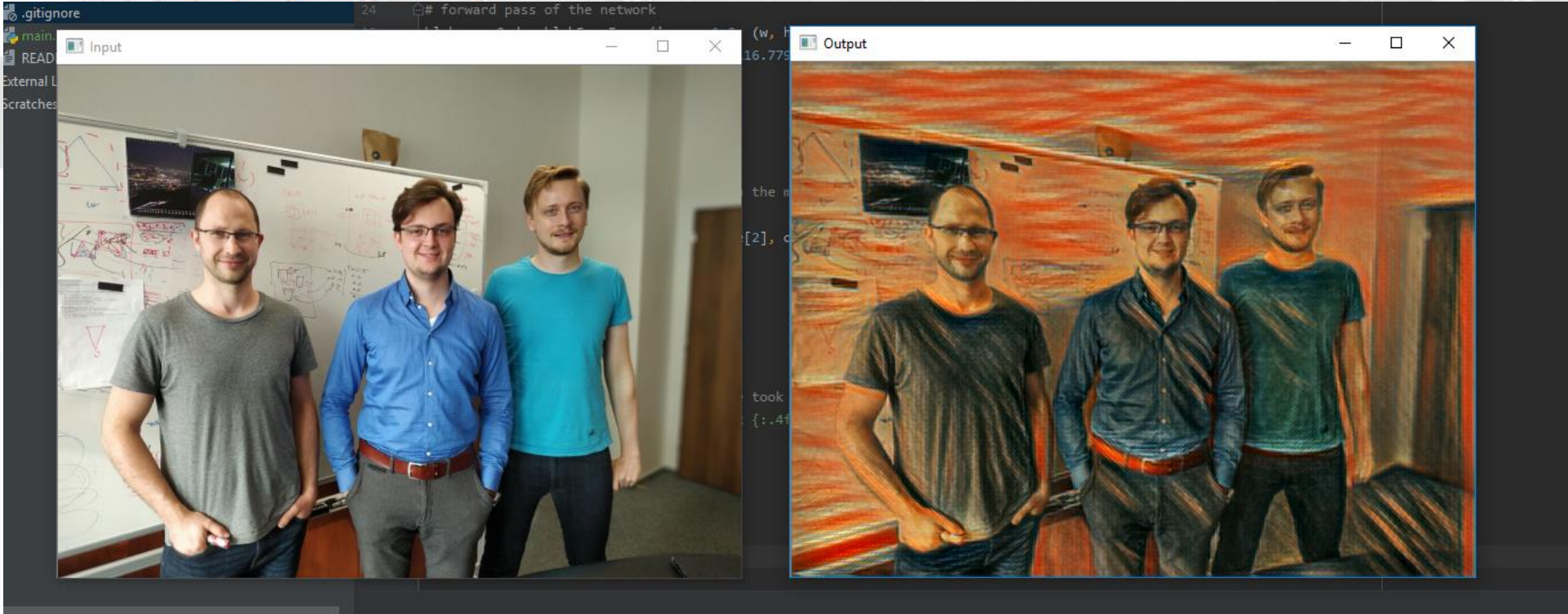
The methods are based on the application of F-transform and some special methods including deep neural nets

1. **Classification of images:** Preprocessing Technique for Neural Networks Based on Image Represented by a Fuzzy Function (motivated by human perception of images)
   Significant decrease of the classification error

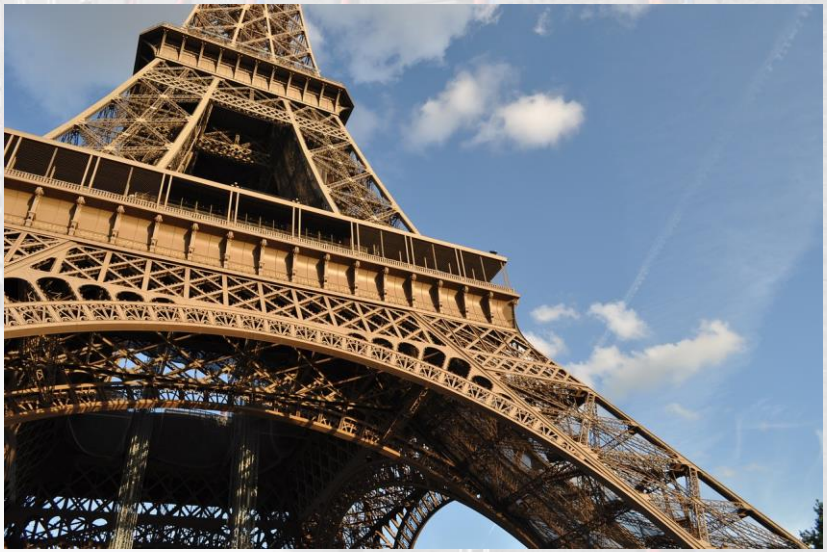
2. Style transfer

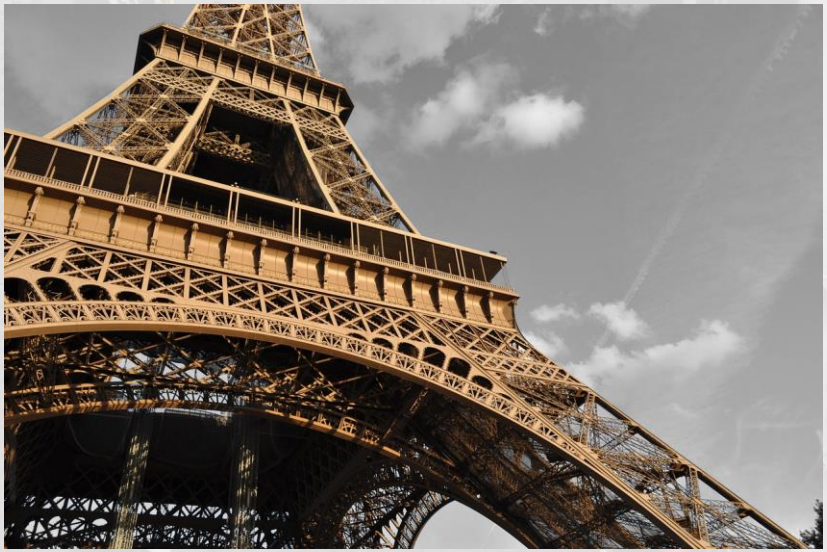
Original

Edvard Munch style



3. Automatic color segmentation method





Result #4

A formal model of the intermediate quantifiers
"A few, Several, A little"

The result is related to models of natural human reasoning

Quantifiers: *words or expressions of natural language characterizing quantity of specimens in a given domain having a specified property*

Intermediate quantifiers: their meaning lays between "all" and "exists"

A formal model of the intermediate quantifiers
"A few, Several, A little"

Examples of intermediate quantifiers: "**most, almost all, many, a lot of**"

Basic reasoning schemes with quantifiers

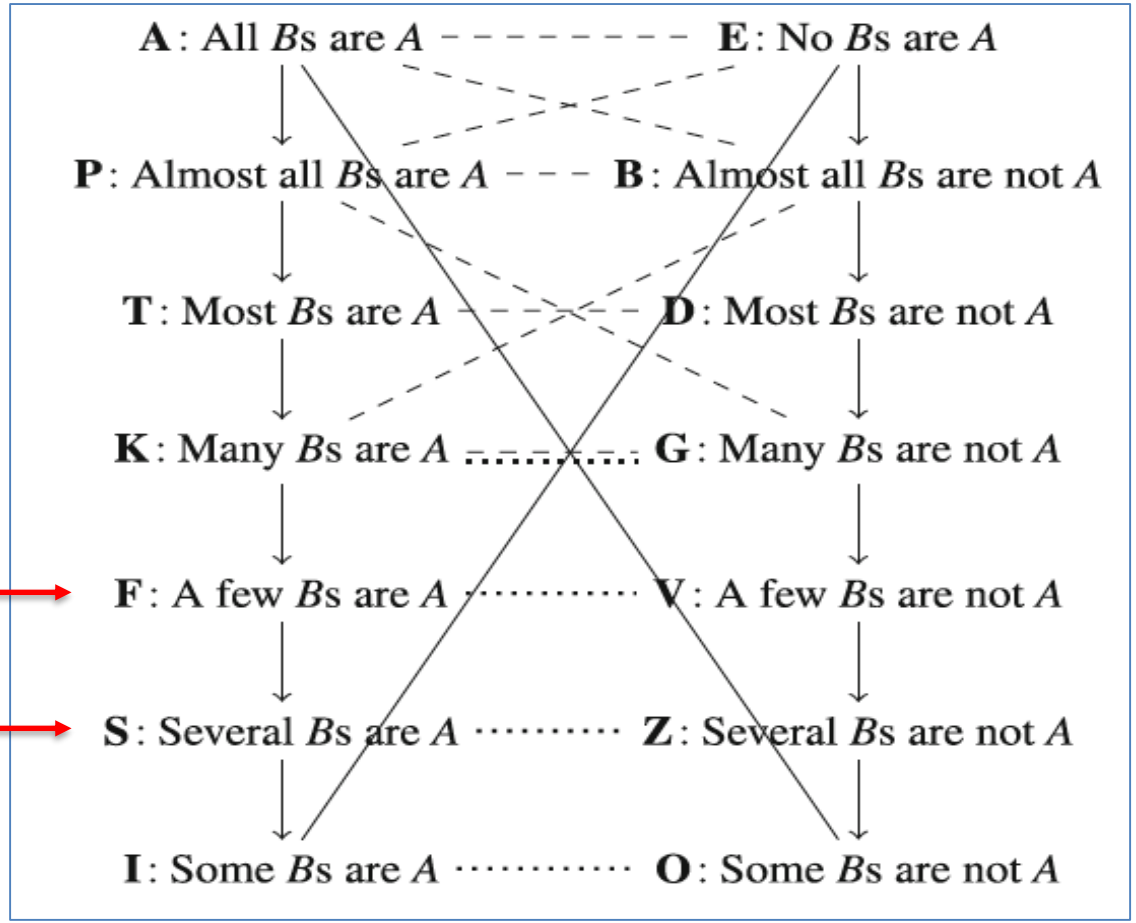
- Syllogisms (Aristotle)

P_1: ***Many American cars are heavy***
P_2: ***Many American cars are expensive***
C: ***Some expensive cars are heavy***

More than 120 generalized syllogisms are valid

- Square of opposition

Generalized square of opposition



Other valuable results in 2019 (OU)

- **General ordinal sum of t-norms and t-conorms on bounded lattices;** we obtain a broad class of new t-norms and t-conorms in a simple and elegant way
- **Dynamical systems on Cantor set**. We show that all systems that are minimal (i.e., all points travel arbitrarily close to any given location under iterations of the system) can be realized as systems with zero derivative at every point.
- **Theory of variable-domain fuzzy sets.** These are based on representation of variable domains by a dummy membership degree. We introduced variable-domain variants of the basic operations

  (*unions and intersections, kernels and supports, heights and plinths, equalities and inclusions, Cartesian products, and fuzzy relational compositions*)

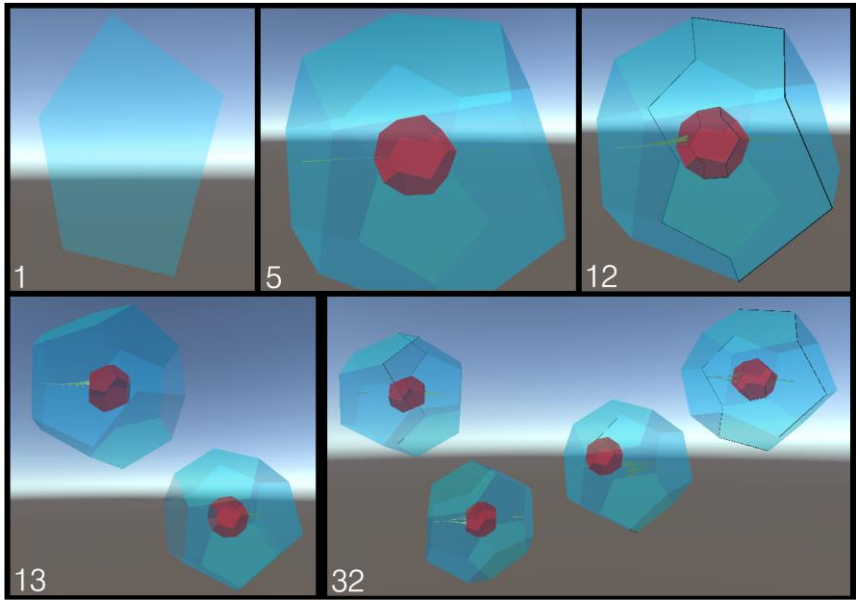
Other valuable results in 2019 (OU)

- **Fuzzy relational modalities of possibility and necessity** for handling propositions that can be **truth-valueless**
- A new approach to the **interval-valued Choquet integral** that takes into account every possible permutation fitting to the considered ordinal structure of data
- A new technique to **identify bull and bear phase in markets** based on the analysis of time series using the F-transform and methods of fuzzy natural logic
- A new **fuzzy clustering algorithm for processing high-dimensional data** based on distances of a particular type that are insensitive to the "concentration of norms" phenomenon
- A method for **task planning based on an intelligent expert system** that makes it possible to obtain a conclusion on the basis of linguistically characterized knowledge

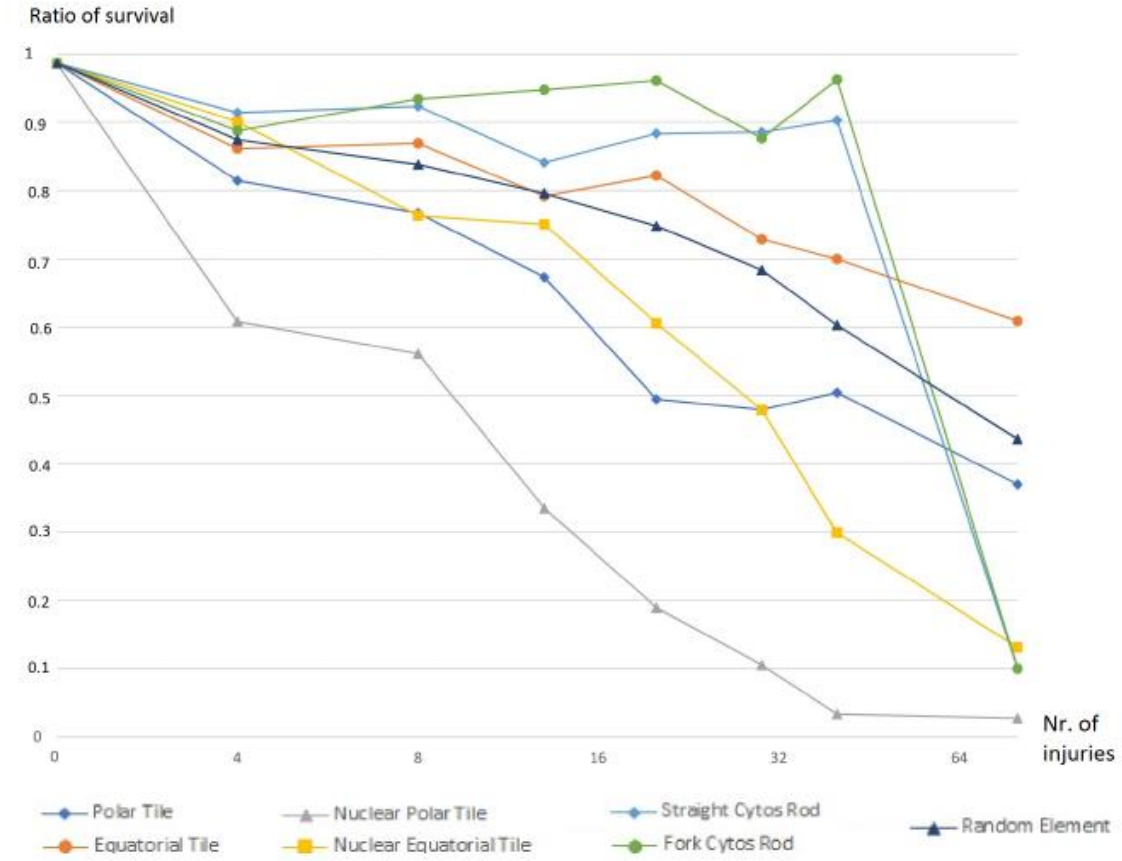
Result #5

SOSÍK, P. Morphogenetic systems: An overview (invited talk), Procs. of 20th Int. Conf. On Membrane Computing, pp. 213-216.

- M system: computational model of morphogenesis at an abstract level.
- Uses principles on membrane computing and algorithmic self-assembly.
- Computationally universal, capable of self-reproduction, strong self-healing properties
- Simple models of morphogenesis providing complex behavior



Result #5 (in 2019)



Thank you for your attention!