Geography 5113
Special Topics in GIScience: "Fuzzy Set Theory in GIScience"

Time and location: Fr 9-12 GUGG 201E

Instructor: Stefan Leyk , GUGG 201 F, stefan.leyk@colorado.edu
Office hours: Wed 11am-12pm & Fr 2-3pm

Overview:

Where is the mountain? What is a forest? In our world we find many phenomena, which are difficult to locate or delineate because their meaning is not well defined. Fuzzy set theory represents an alternative approach to classic set theory. Problems that arise from subjectivity, vagueness or ambiguity in linguistic terms require such alternative approaches to model our real imperfect world. This seminar introduces fuzzy set theory in the context of soft computing for spatial decision-making and modeling in GIS and Remote Sensing. We will discuss different examples where the use of fuzzy sets and fuzzy logic operators allows for an extension of the analysis by incorporating concepts of partial and multi-memberships of spatial objects. These examples focus on spatial decision-making, spatial uncertainty assessment, and classification procedures to solve problems in ecological, environmental and socio-economic studies.
Class meetings consist of lectures, student presentations, discussions and in-class exercises based on the readings announced. Each pair of students will give two ***presentations*** on particular reading topics and ***lead the discussions*** during the class sessions. At the end of the semester students will work on a small ***project*** that can be connected to their own research, give a final presentation at the end of the semester, and write a ***term paper***. Different options exist for this term paper. Students can write a complete literature review of methodological issues and conceptual approaches of fuzzy sets in their field. Students can also work on a concrete analysis with real data at hand and develop (implement) a solution that incorporates fuzzy set theory. The course is designed for graduate students from Geography, Environmental Sciences, Geology, Ecology or Information Sciences with experience in GIScience or Remote Sensing and an interest in exploring alternative concepts for spatial modeling and decision-making.

PREREQUISITES: Experience in GIScience, spatial statistics or Remote Sensing. Familiarity with basic concepts of spatial analysis and modeling. A grasp of set theories...

READINGS: We will mainly rely on research papers and book chapters from different sources. A preliminary list of references is given below. All required readings will be available as pdf documents on the class homepage. One introductory textbook that I can recommend is:

Klir G J, St.Clair U. and Yuan B. 1997. Fuzzy Set Theory. Prentice Hall. Upper Saddle River, NJ, pp. 245.

TERM PROJECT: You will choose one topic for your final project and write a proposal of ca. 300 words, to be submitted by **Oct 09, 2009**. You should have data prepared if you choose the data analysis option by the same date. It might be useful to look through the literature ahead to find ideas for your project. I will comment on your proposals and require some revision if necessary. The project period is anticipated from **week 9** to week **16**. At the end of the semester each student will give a final presentation about the work done. Final papers are due **Dec 11, 2009**.

GRADING: The class grade is based on 200 points in total.

- Reading presentations and **discussion leads** (70 points)
- Class **participation** and attendance (20 points)
- T**erm paper** and presentation (proposal 20, presentation 30, final paper 60; to be submitted Dec 11, 8pm; 120 points).

Schedule Fall 2009

	DATE	LECTURE	READING
1	28 A	Introduction: Uncertainty & Sets theory; Why Fuzzy Sets? Why in Geography?	Klir et al., 1997; Dubois & Prade, 2000; Zadeh, 1965
2	4 S	Vagueness, Fuzziness & Sorites paradox in Geography	Varzi, 2001; Fisher, 1999 & 2000
3	11	Setting the scene: Fuzzy sets in GIS & Remote Sensing	Robinson, 2003; Burrough, 1998
4	18	Fuzzy GIS – Fuzzy Objects	Yanar & Akyürek, 2006, Cheng et al, 2001
5	25	Soil mapping	McBratney et al., 1997; Zhu et al, 2001
6	02 O	Risk evaluation	Vadrevu et al, 2009, Fleming et al., 2007
7	09	Classification accuracy - **Proposals due!!!**	Brown, 1998; Gopal & Woodcock, 1994
8	16	Mapping the landscape	Fritz & See, 2005; Arnot et al., 2004
9	23	Landcover change and map comparison	Ahlqvist, 2008; Fisher et al., 2006
10	30	Terrain and Morphometry	Deng & Wilson, 2008; Fisher et al, 2004
11	06 N	Ecological Modeling, disturbance and conservation	Wood & Dragicevic, 2007; Bone et al., 2005
12	13	Evaluation of places and views	Oh & Jeong, 2002; Fisher 1992
13	20	Areas of fuzzy entities & classes	Lewis & Brown, 2001; Woodcock & Gopal, 2000
14	27	FALL BREAK – NO CLASS	
15	04 D	Final presentations & Discussion	
16	11	Final presentations & Discussion **Final papers due Fri 12/11 8pm**	

Readings (* indicates reading material required for this seminar)

Books and edited volumes

*Klir G J, St.Clair U. and Yuan B. 1997. Fuzzy Set Theory. Prentice Hall. Upper Saddle River, NJ, pp. 245.

Klir G.J. and Wierman M.J. 1999. Uncertainty-Based Information- Elements of Generalized Information Theory. Springer. Physica-Verlag.

Petry F., Robinson V. and Cobb M. (eds.) 2005. Fuzzy Modeling with Spatial Information for Geographic Problems. Springer, pp. 337.

Lodwick W. 2008. Fuzzy Surfaces in GIS and Geographical Analysis. CRC Press, pp. 167.

Dubois D. and Prade H. 2000. Fundamentals of Fuzzy Sets. The Handbook of Fuzzy Sets Series. Kluwer Academic, Dordrecht, The Netherlands.

Articles and book chapters

*Ahlqvist O. 2008. Extending post-classification change detection using semantic similarity metrics to overcome class heterogeneity: A study of 1992 and 2001 U.S. National Land Cover Database changes. Remote Sensing of Environment 112 (2008) 1226–1241.

Ahlqvist O., Keukelaar J. and Oukbir K. 2003. Rough and fuzzy geographical data integration. International Journal of Geographical Information Science 17(3): 223-234.

Amo A., Montero J., Biging G., Cutello V. Computing, Artificial Intelligence and Information Technology - Fuzzy classification systems. European Journal of Operational Research 156 (2004) 495–507.

Andréfouët S., Roux L.,Chancerelle Y. and Bonneville A. 2000. A fuzzy-possibilistic scheme of study for objects with indeterminate boundaries: Application to French Polynesian reefscapes. IEEE Transactions on Geoscience and Remote Sensing 38(1): 257-270.

*Arnot C., Fisher P.F., Wadsworth R. and Wellens J. Landscape metrics with ecotones: pattern under uncertainty. *Landscape Ecology* 19: 181–195, 2004.

Binaghi E., Brivio P.A., Ghezzi P. and Rampini A. 1999. A fuzzy set-based accuracy assessment of soft classification. Pattern Recognition Letters 20: 935-948.

Bolliger J, Mladenoff D.J. 2005. Quantifying spatial classification uncertainties of the historical Wisconsin landscape (USA). Ecography 28: 141-156.

*Bone ., Dragicevic S. and Roberts A. 2005. Integrating high resolution remote sensing, GIS and fuzzy set theory for identifying susceptibility areas of forest insect infestations. International Journal of Remote Sensing 26(21), pp. 4809 — 4828

*Brown D.G. 1998. Classification and boundary vagueness in mapping pre-settlement forest types. International Journal of Geographical Information Science 12(2): 105-129.

Burrough P A 1996 Natural objects with indeterminate boundaries. In Burrough P A and Frank A U (eds) *Geographic Objects with Indeterminate Boundaries*. London, Taylor and Francis: 3–28

*Burrough P. and McDonnell R. 1998. Fuzzy Sets and Fuzzy Geographical Objects. Chapter eleven in: Principles of Geographical Information Systems. Oxford University Press.

Burrough P.A. 1989. Fuzzy mathematical methods for soil survey and land evaluation. Journal of Soil Science 40: 477-492.

*Cheng T., Molenaar M. and Lin H. 2001. Formalizing fuzzy objects from uncertain classification results. International Journal of Geographical Information Science 15(1):27-42.

*Deng, Y. and Wilson, J. P. 2008. Multi-scale and multi-criteria mapping of mountain peaks as fuzzy entities. International Journal of Geographical Information Science,22:2,205 — 218

Ergin A., Karaesmen E., Micallef A. and Williams A.T. 2004. A new methodology for evaluating coastal scenery: fuzzy logic systems. Area 36.4, 367–386.

*Fisher P 1999 Models of uncertainty in spatial data. In Longley P, Goodchild M F, Maguire D J, and Rhind D W (eds) *Geographical Information Systems: Principles, Techniques, Management and Applications (Volume 1)*. New York, John Wiley and Sons: 191–205

*Fisher P. 1992. First Experiments in Viewshed Uncertainty: Simulating Fuzzy Viewsheds. Photogrammetric Engineering & Remote Sensing, 58(3), March 1992, pp. 345-352

Fisher P 2001 Alternative set theories for uncertainty in spatial information. In Hunsaker C T, Goodchild M F, Friedl M A, and Case T G (eds) *Spatial Uncertainty in Ecology*. Berlin, Springer: 351–62

*Fisher P. 2000. Sorites paradox and Vague Geographies. Fuzzy Sets and Systems 113(1): 7-18.

*Fisher P., Arnot C., Wadsworth R., Wellens J. 2006. Detecting change in vague interpretations of landscapes. Ecological Informatics 1, pp. 63 – 178.

*Fisher P., Wood J. and Cheng T. 2004. Where is Helvellyn? Fuzziness of multi-scale landscape morphometry. *Trans Inst Br Geogr* NS 29 106–128.

*Fleming G., van der Merwe M. and McFerren G. 2007. Fuzzy expert systems and GIS for cholera health risk prediction in southern Africa. Environmental Modelling & Software 22, pp. 442-448.

Fonte C.C. and Lodwick W.A. 2004. Areas of fuzzy geographical entities. International Journal of Geographical Information Science 18(2): 127-150.

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*Fritz S. and See L. 2005. Comparison of land cover maps using fuzzy agreement. International Journal of Geographical Information Science,19:7,787 — 807

*Gopal S. and Woodcock C. 1994. Theory and methods for accuracy assessment of thematic maps using fuzzy sets. Photogrammetric Engineering and Remote Sensing 60 (2): 181-188.

Hagen A 2003 Fuzzy set approach to assessing similarity of categorical maps. *International Journal of*

Geographical Information Science 17: 235–249

Jäger G. and Benz U. 2000. Measures of classification accuracy based on fuzzy similarity. IEEE Transactions on GeoScience and Remote Sensing 38:1462-1467.

Krishnapuram R. and Keller J. M. 1993. A possibilistic approach to clustering. IEEE Transactions on Fuzzy Systems 1:98–110.

Lagacherie et al., 1996

Leung Y. 1983. Fuzzy Sets Approach to Spatial Analysis and Planning, a Nontechnical Evaluation. Geografiska Annaler. Series B, Human Geography, Vol. 65, No. 2 (1983), pp. 65-75

*Lewis H.G. and Brown M. 2001. A generalised confusion matrix for assessing area estimates from remotely sensed data. International Journal of Remote Sensing 22(16): 3223-3235.

Leyk S., Boesch R. and Weibel R. 2005: A Conceptual Framework for Uncertainty Investigation in Map-Based Land Cover Change Modelling. *Transactions in GIS*: 9(3), pp. 291-322

Li S.-P. and Will B.F. 2005. A fuzzy logic system for visual evaluation. Environment and Planning B: Planning and Design 32, pp. 293 – 304.

Matsakis P., Andréfouët S. and Capolsini P. 2000. Evaluation of fuzzy partitions. Remote Sensing of Environment 74: 516-533.

*McBratney A.B. and Odeh I.O.A. 1997 Application of fuzzy sets in soil science: fuzzy logic, fuzzy measurements and fuzzy decisions. Geoderma 77, pp. 85-113.

*Oh K. and Jeong Y. 2002. The usefulness of the GIS - fuzzy set approach in evaluating the urban residential environment. Environment and Planning B: Planning and Design 29, pp. 589 - 606

*Power C., Simms A. and White R. 2001. Hierarchical fuzzy pattern matching for the regional comparison of land use maps. International Journal of Geographical Information Science 15(1): 77-100.

Rashed T. and Weeks J. 2003. Assessing vulnerability to earthquake hazards through spatial multicriteria analysis of urban areas. International Journal of Geographical Information Science,17:6,547 — 576.

Robinson V B 1988 Some implications of fuzzy set theory applied to geographic databases. Computers, Environment and Urban Systems 12: 89-97

Robinson V. 2007. ISSUES AND CHALLENGES OF INCORPORATING FUZZY SETS IN ECOLOGICAL MODELING. In *A. Morris and S. Kokhan (eds.), Geographic Uncertainty in Environmental Security, Springer, pp.* 33–51.

*Robinson V.B. 2003. A perspective on the fundamentals of fuzzy sets and their use in Geographical Information Systems. Transactions in GIS 7(1): 3-30.

Ruspini E. H. 1969. A new approach to clustering. Information and Control 15: 22–23.

*Vadrevu K.P., Eaturu A. and Badarinath K.V.S. 2009. Fire risk evaluation using multicriteria analysis—a case study. Environ Monit Assess, forthcoming.

*Varzi A 2001 Vagueness in geography. *Philosophy and Geography* 4: 49–65

White R. 2006. Pattern based map comparisons. J Geograph Syst 8: 145–164.

*Wood L.J. and Dragicevic S. 2007. GIS-based multicriteria evaluation and fuzzy sets to identify priority sites for marine protection. Biodivers Conserv 16:2539–2558.

*Woodcock C. E. and Gopal S. 2000. Fuzzy set theory and thematic maps: accuracy assessment and area estimation. International Journal of Geographical Information Science 14: 153-172.

*Yanar T.A and Akyurek Z. 2006. The enhancement of the cell-based GIS analyses with fuzzy processing capabilities. Information Sciences 176 (2006) 1067–1085

Zadeh L.A. 1965. Fuzzy sets. Information and Control 8: 338-53

*Zhu A.X., Hudson B., Burt J., Lubich K. and Simonson D. 2001. Soil Mapping Using GIS, Expert Knowledge, and Fuzzy Logic. Soil Sci. Soc. Am. J. 65:1463–1472.

Department of Geography Code of Conduct

In the Department of Geography, instructors strive to create an atmosphere of mutual trust and respect in which learning, debate, and intellectual growth can thrive. Creating this atmosphere requires that instructors and students work to achieve a classroom in which learning is not disrupted. At the most basic level, this means that everyone attend class, be prepared with readings and assignments completed, and that students pay attention. This means no conversations with friends, reading the newspaper, coming late, or leaving early. Such behavior is disruptive to the instructor and to your fellow classmates.

These basics of classroom etiquette are an important means of building and showing mutual respect. Inevitably, however, disagreements will arise. Sometimes these disagreements will be about content, sometimes about grades or course procedures, and sometimes they will be about the treatment of participants in the class. In order to facilitate the resolution of these disagreements, the following guidelines should be followed by everyone:

- All interactions must be guided by mutual respect and trust.
- If you are bothered by some aspect of the class, identify what it is that is bothering you and center the discussion on that issue.
- Address issues that concern you early. Problems are easier to resolve before they fester.
- Consider whether it is best to address your concerns in class or in a separate appointment with the instructor. Remember, behavior that disrupts your fellow classmates is not acceptable.
- Abusive speech or behavior will not be tolerated in any interaction between students or between student and instructor. If an instructor feels that your speech or behavior is abusive, you will be asked to leave the room. If you believe an instructor has become abusive, you may leave the room and talk with the department chairperson. Debate and discussion can continue when all parties proceed with mutual respect.
- If mutual respect cannot be restored, either you or the instructor may take the issue to the department chairperson or the Campus Ombuds Office.

Policy on Plagiarism

The College of Arts and Sciences has an Honor Code that prohibits plagiarism, cheating, fabrication, aiding academic dishonesty, lying, bribery, and threats at the University of Colorado. A key element of this code is that CU students will not plagiarize which means you may not use someone else's words, pictures, ideas, or procedures as your own. In some instances, it is appropriate to do so when you provide proper acknowledgement. Cases of plagiarism and violations of the CU Honor Code will not be tolerated. More information can be found online at http://www.colorado.edu/academics/honorcode/, particularly under the "Student Information, What is a Violation?" section.

GEOG 5113
Fall, 2009

QUESTIONNAIRE

NAME_____ **YEAR** _____
(optional)

MAJOR_____ **CONCENTRATION** _____

WHAT OTHER COURSEWORK have you taken related to Cartography / GIS / Remote Sensing, Environmental Modeling, Information Sciences, Set theories?

1. _____ **2.** _____

3._____ **4.** _____

WHAT DO YOU EXPECT TO LEARN BY TAKING THIS SEMINAR?

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WHAT CONCERNS DO YOU HAVE ABOUT TAKING THIS SEMINAR?

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Thanks for filling this out. This will help us to understand more about you.