Overview

- Introduction
  - Problem description
  - Current solution methods
- Concept of our approach
- Fuzzy inference system
- Advanced example
- Conclusion

Introduction

- Problem description
  - gridded data
    - data from one grid needs to be matched with another grid
    - grids are not aligned properly
  - no crisp solution in general case
  - gridded data is an approximation

Introduction

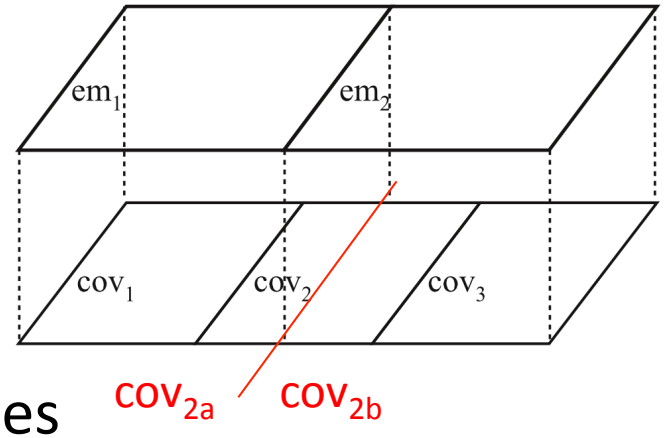
- Current solution methods
  - interpolation methods
    - aerial weighting
      - consider overlapped portion as the portion of the emission
    - spatial smoothing
      - define a smooth surface using one grid
      - divide this surface using the other grid
  - statistical methods

Overview

- Introduction
- Concept of our approach
  - Case description
  - Analyzing what happens
- Fuzzy inference system
- More advanced example
- Conclusion

Concept of our approach

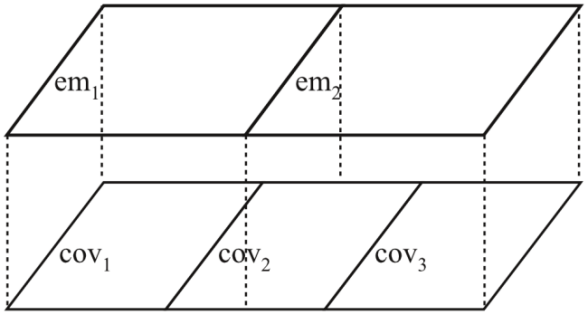
- Case description
  - abstract example
    - 2x1 grid with emission values
    - 3x1 grid with covariates
    - relationship emission – covariates



  - distribute emissions over covariates
    - distributing emission values over subsections for cov_2
      - problem is equivalent to splitting cov_2 in cov_{2a} (covered by em_1) and cov_{2b} (covered by em_2)

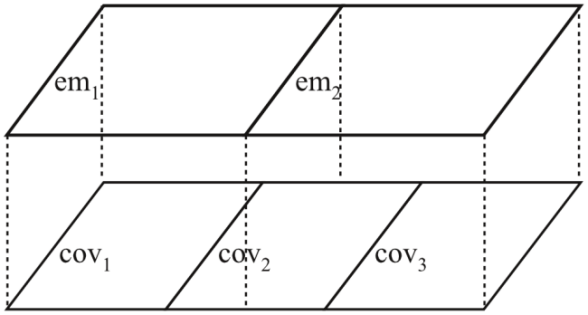
Conceptual example

- Analyzing what happens
  - consider $cov_1 = cov_3$
    - if $em_1 > em_2$ then
      - cov_2 contributes more to em_1 than to em_2 : $cov_{2a} > cov_{2b}$
    - if $em_1 < em_2$ then
      - cov_2 contributes more to em_2 than to em_1 : $cov_{2a} < cov_{2b}$
    - if $em_1 = em_2$ then
      - cov_2 contributes evenly to em_1 and em_2 : $cov_{2a} = cov_{2b}$



Conceptual example

- Analyzing what happens
  - consider $em_1 = em_2$
    - If $cov_1 > cov_3$ then
      - cov_2 contributes more to em_2 than to em_1 : $cov_{2a} < cov_{2b}$
    - If $cov_1 < cov_3$ then
      - cov_2 contributes more to em_1 than to em_2 : $cov_{2a} > cov_{2b}$
  - combination implies combination of the rules
  - output
    - Percentages for cov_{2a} and cov_{2b}



Overview

- Introduction
- Conceptual example
- Fuzzy inference system
  - fuzzy set theory
  - concept
  - examples
- More advanced example
- Conclusion

Fuzzy inference system

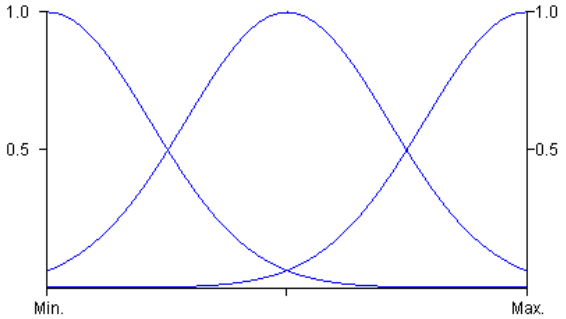
- Fuzzy set theory
  - extension of classic set theory
    - elements are assigned membership grade (in [0,1])
  - fuzzy numbers
    - fuzzy set over domain of real numbers
      - possibilistic interpretation: each element of is possible candidate
    - calculations possible using extension principle
  - representation of linguistic terms
    - linguist term is matched with fuzzy set
      - inclusive: „very tall” implies „tall”
      - exclusive

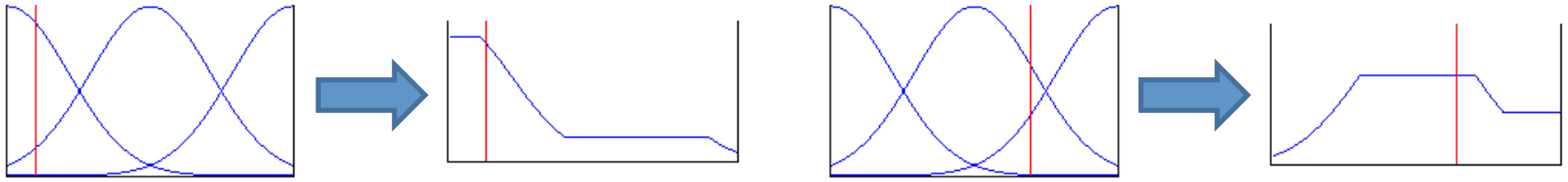
Fuzzy inference system

- Concept
  - Rules of the form: if x is A then y is B
    - x is A premise, matches a value x to a fuzzy set A
    - y is B: conclusion, assigns y a fuzzy set
    - A and B are commonly linguistic terms
      - if temperature is high then fan speed is high
    - x is an input value (can be fuzzy or crisp)
      - x can match multiple premises, thus multiple rules apply
      - the output value is a weighted aggregation of the output values of all the matching rules

Fuzzy inference system

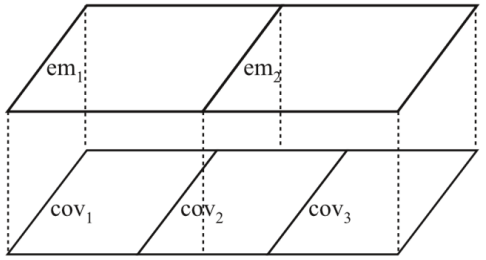
- Simple example
  - Fan controller
    - three fuzzy sets low/normal/high
    - three rules
      - if temperature is high then fanspeed is high
      - if temperature is normal then fanspeed is normal
      - if temperature is low then fanspeed is low
    - examples





Fuzzy inference system

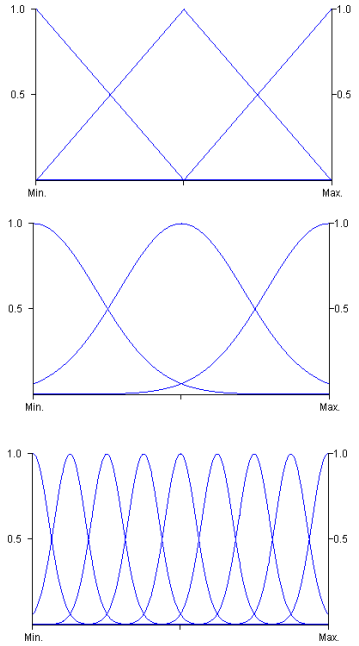
- Conceptual example
  - consider $cov_1 = cov_3$
    - if $em_1 > em_2$ then
    - cov_2 contributes more to em_1 than to em_2



  - rulebase compares values to linguistic terms
    - modified rule
      - If cov_1 is low and cov_3 is low and em_1 is high and em_2 is low then cov_{2a} is high and cov_{2b} is low
    - combining rules
      - If cov_1 is low and cov_3 is high and em_1 is high and em_2 is low then cov_{2a} is very high and cov_{2b} is very low

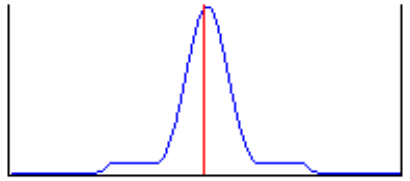
Fuzzy inference system

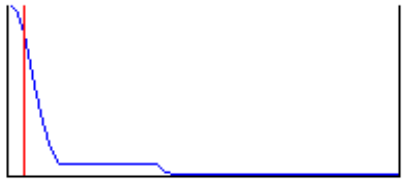
- Rulebase for conceptual example
  - Fuzzy sets used
    - emissions: triangular; mf0, mf1, mf2
    - covariates: bell shaped; mf0, mf1, mf2
    - percentages: bell shaped; mf0 .. mf9
  - General form of the rules
    - if cov_1 is mf_{x1} and cov_2 is mf_{x2} and em_1 is mf_{x3} and em_2 is mf_{x4} then cov_{2a} is mf_{x5}
      - for all combinations of x_i



Conceptual example

- Results
  - $em_1=em_2$, $cov_1=cov_3$
    - expected: even spread of cov_2
    - output: 50 % / 50 %
  - $em_2=0$, $cov_1=0$
    - expected: most output on cov_{2a}
    - output: 95.78 % / 4.22 %
  - $em_1=0$, $cov_3=0$
    - expected: least output on cov_{2a}
    - output: 4.22 % / 95.78%





Conceptual example

- Results
  - For intermediate values, the results are also well within expectations
  - Some extreme cases are suboptimal
    - the system treats values of 0 as low values
      - they match with other rules
      - this can be solved by initial testing for specific values and opting for a different rulebase
    - inconsistent input gives unpredictable output
      - could be solved by checking the input beforehand

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  - Description
  - Rulebase
  - Results
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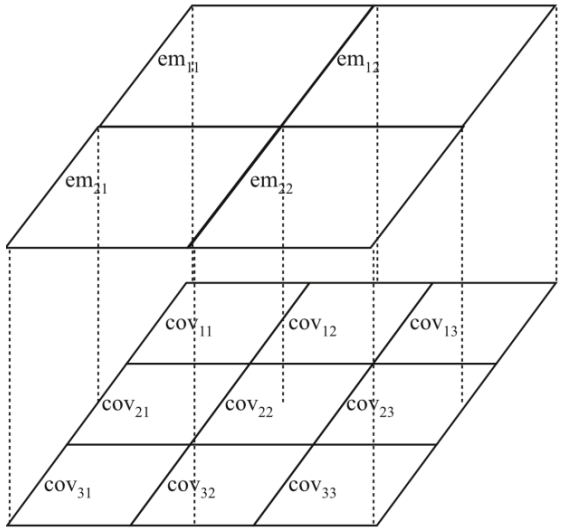
Advanced example

- Description
  - abstract example
    - 2x2 grid with emission values
    - 3x3 grid with covariates
    - relationship emission – covariates



  - distribute emissions over covariates
    - covariates covered by 2 emission tiles
      - » cov_{12}, cov_{21}, cov_{23}, cov_{32}
    - covariates covered by 4 emission tiles
      - » cov_{22}

Advanced example

- Rulebase
  - all possible combinations yields far too many rules
  - use of ratios for each covariate tile
    - R_1: proportional relation to considered part
    - R_2: inverse proportional relation to considered part
    - R: reference relation to determine low/high R_i

$$R = \frac{\sum_{i=0,1,j=0,1} \mathrm{em}_{ij}}{\sum_{k=0,1,2,l=0,1,2} \mathrm{cov}_{kl}}$$

Advanced example

- Rulebase
  - Determining the ratios
    - cov_{12}, cov_{21}, cov_{23}, cov_{32} :

$$R_1 = \frac{em_{11} + em_{21}}{cov_{11} + cov_{21} + cov_{31}} \qquad R_2 = \frac{em_{12} + em_{22}}{cov_{13} + cov_{23} + cov_{33}}$$

    - cov_{22} :

$$R_1 = \frac{em_{11}}{cov_{11}} \qquad R_2 = \frac{em_{12} + em_{21} + em_{22}}{cov_{13} + cov_{23} + cov_{33} + cov_{31} + cov_{32}}$$

  - Rules
    - if $R_1=mf_{x1}$ and $R_2=mf_{x2}$ then $cov_a = mf_{x3}$
      - for all combinations of x_i
    - 5 fuzzy sets for the possible ratios, 9 for the outputs

Advanced example

- Results
  - fuzzy inference system performs as expected
    - errors in extreme cases, but as before these could be dealt with beforehand
    - the use of the ratios makes the system less optimal, so results tend to be more averaged out
  - remarks
    - ratios limit the number of cases, but maybe too much
    - more data could be used (e.g. partly overlapped tiles)

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Conclusion

- Conclusion
  - novel approach for the map overlay problem
    - very early stage, more research required
  - works independently of data, grids or alignment
- Future work
  - improve input to obtain better rulebase in large cases
    - use of different or more ratios, other inputs, …
  - derive better rulebase
    - automatic determination using neural networks
  - verification on real world examples