NEURO-SYMBOLIC MODELLING FOR OPERATIONAL DECISION SUPPORT

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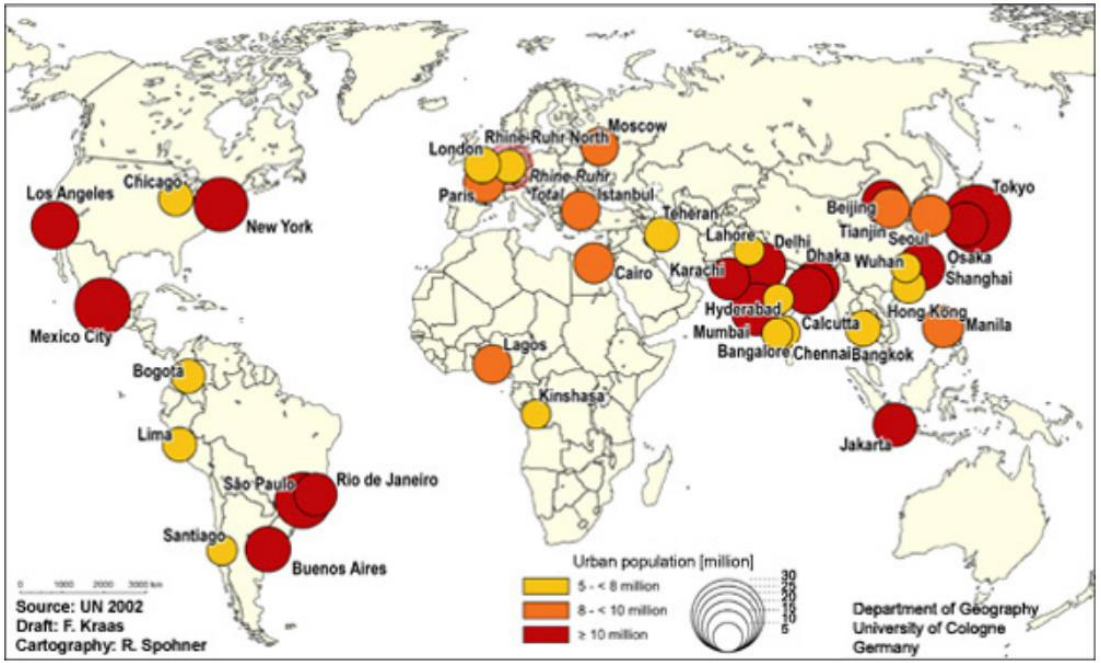
TNO innovation for life

CONTEXT

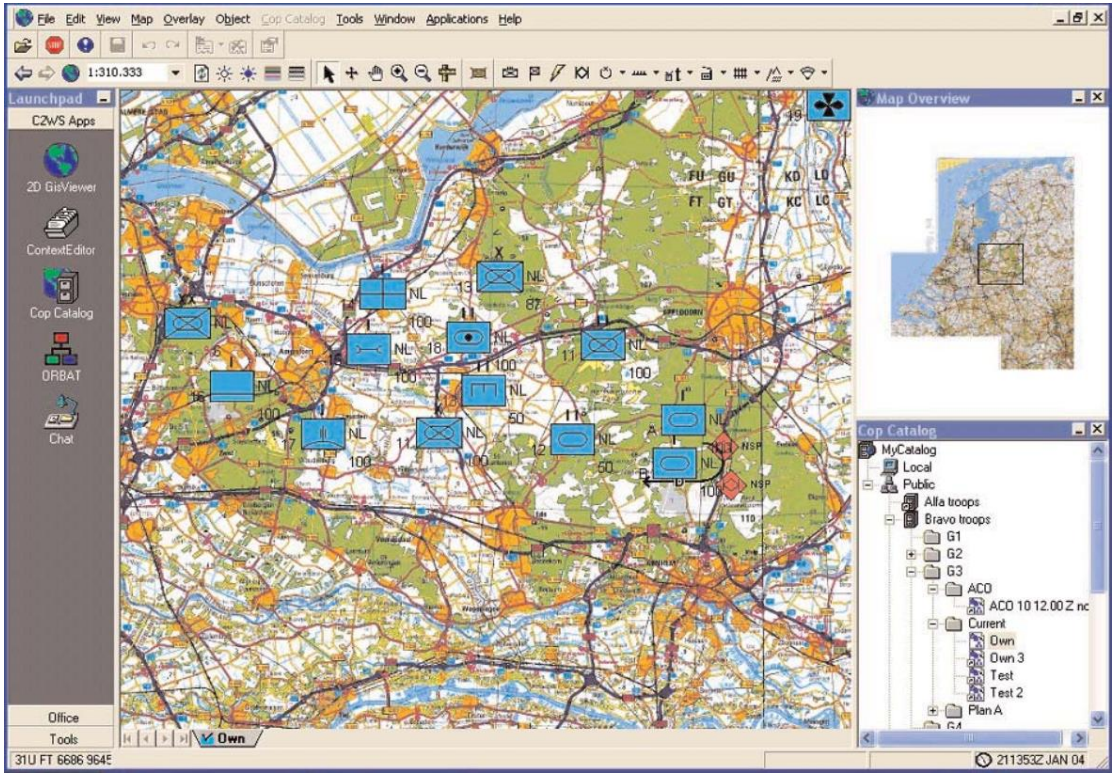
- Megacities, Littoral
- Months, weeks, days

- Intelligence
  - Too much, too little
  - Uncertain
  - False

- Decision support
  - Simulation
  - AI-technology



SIMULATION ON THE BATTLEFIELD



Planning
- what-if's
- optimize

Rehearsal

Monitoring and warning
- Check execution against plan

Little time available
Trustworthy results

REQUIREMENT: SUITABLE MODELS

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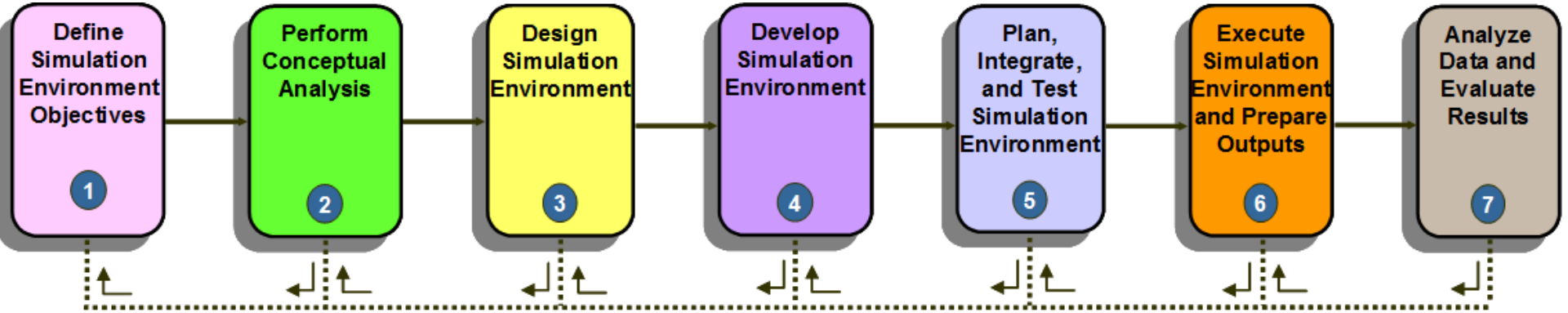
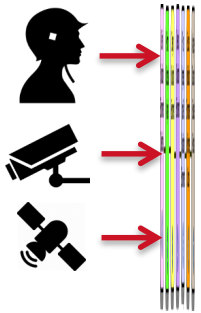
GOOD MODELS IN LITTLE TIME



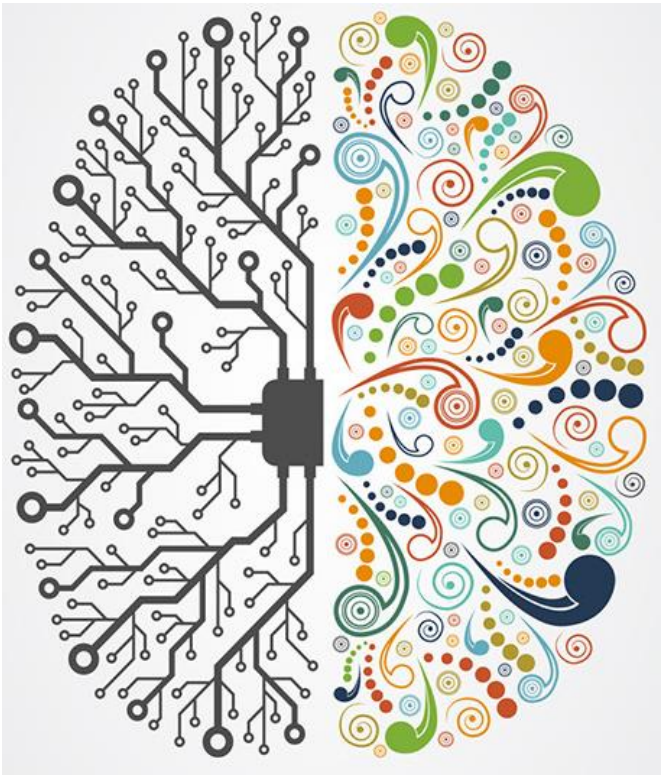


AI-TECHNOLOGY IS NEEDED

- Data + expert knowledge -> Situational Understanding (SU)
- SU + commander's intent -> valid model

- Too much data for human processing
- Too little / uncertain data:
  - combine with expert knowledge
- False information

- E.g. Neural Networks
- And ... what about trust?



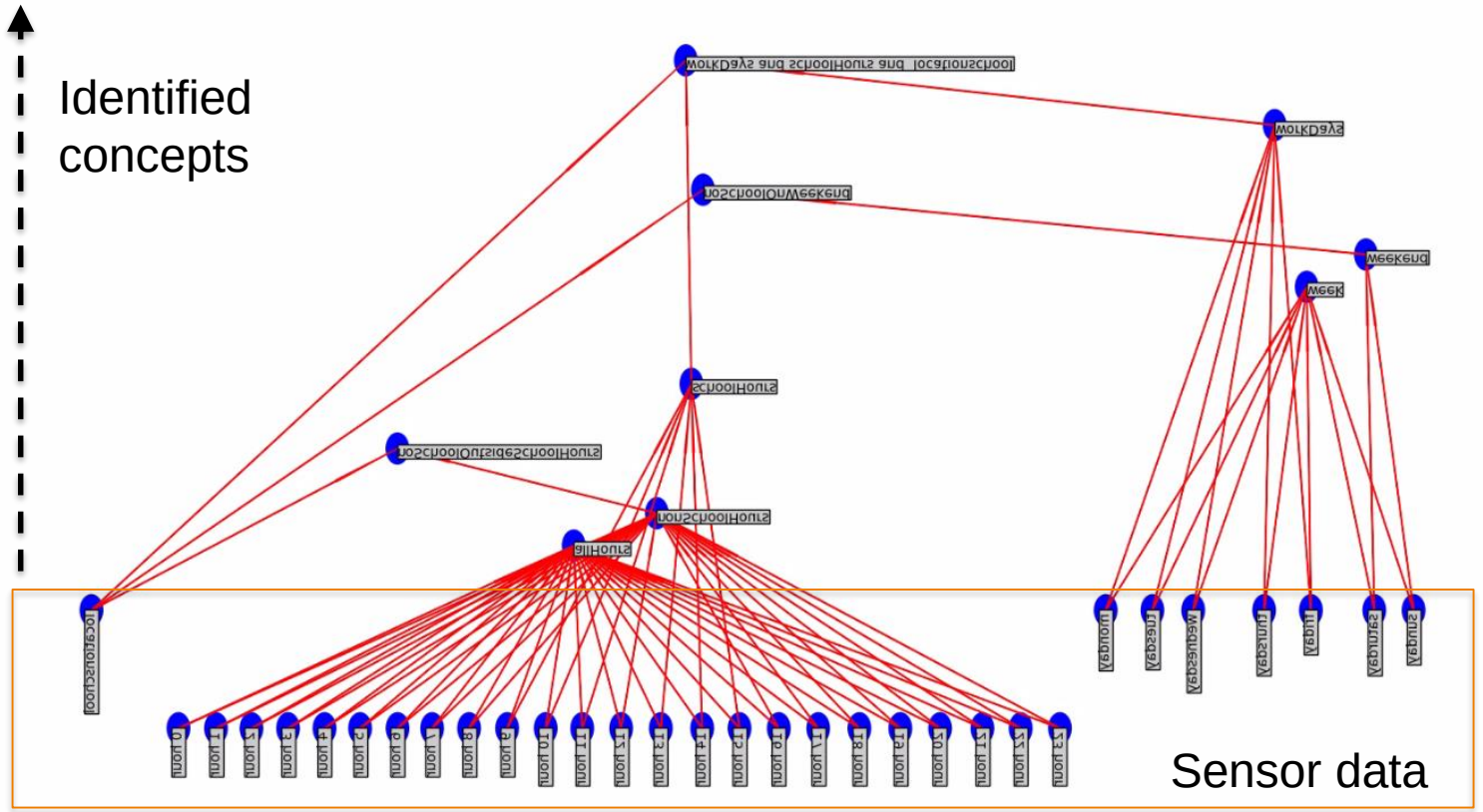
NEURO-SYMBOLIC MODELLING

- Neuro, Neural, sub-symbolic
  - Information items have little or no meaning, e.g. pixels in an image
  - Good at recognizing patterns, e.g. it is an image of a cat
  - Typically requires a lot of data, no explainability
- Symbolic
  - Information items have meaning: concepts and relations
  - Logic can be performed, explainable
  - Typically requires human input such as rules
- Neuro-symbolic
  - Flexible network that requires reasonable data for training
  - Using low level data but still have explainable results
  - High level knowledge and corrections made by expert

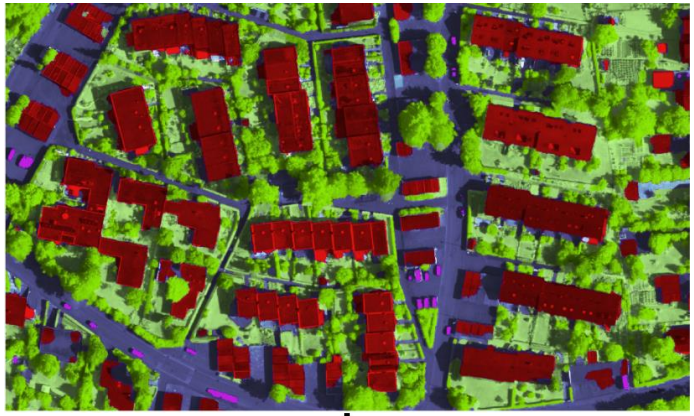
PATTERNS FROM DATA

- Deriving pattern-of-life information from sensor data

- Data without meaning (for the algorithm)
- Patterns are derived automatically by searching for XOR, AND, etc.
- Human adds meaning, i.e. the symbols


Identified concepts
Sensor data

AUGMENT NEURAL WITH SYMBOLIC



Neighbourhood info:
- # households
- # cars per household

Rules, e.g.
- Factory -> Factory + low(# households)

Building info:
- Area
- Shape
- Distance to neighbour

+ actually identified buildings

Sub-symbolic

House

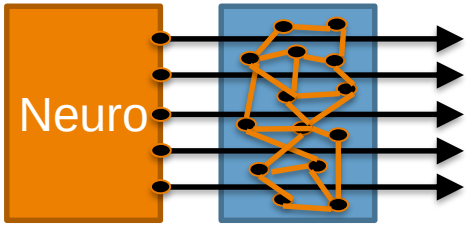
Shop

Factory

Church

Villa

AUGMENT NEURAL WITH SYMBOLIC



- Neuro part (random forest) is hard to improve upon, even with little learning
- Experts can express relations such as:

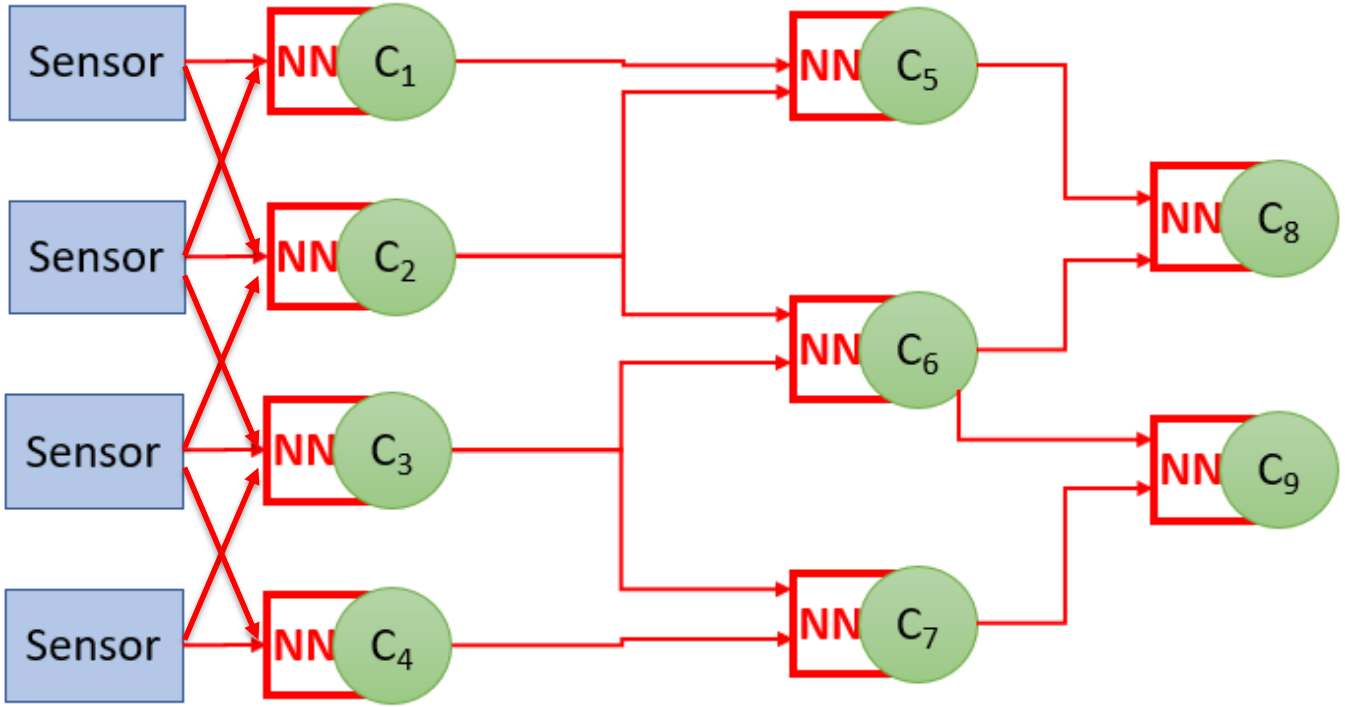
  "Factory -> Factory + low(# households)"

- But to improve upon the neuro part, experts would have to specify:

  "Factory -> Factory + 0.21 * low(# households)"

- Explainability

INTEGRATED NEURO AND SYMBOLIC



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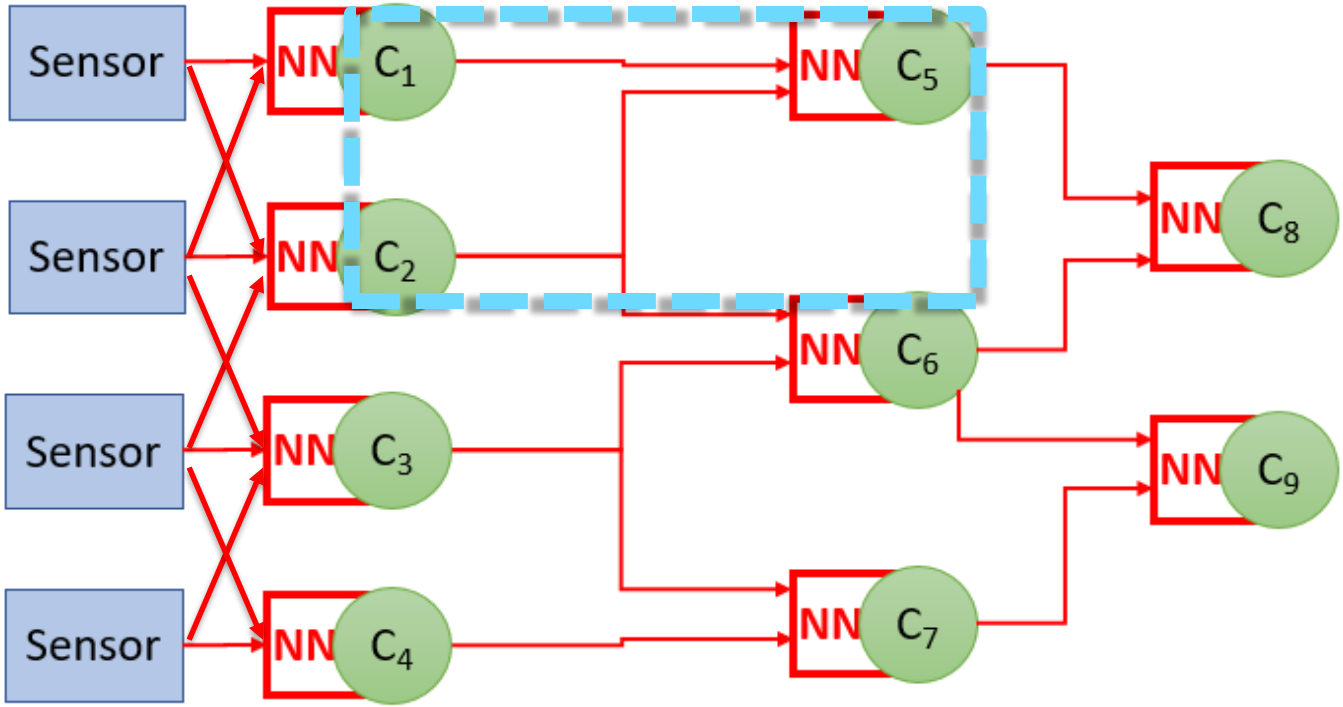


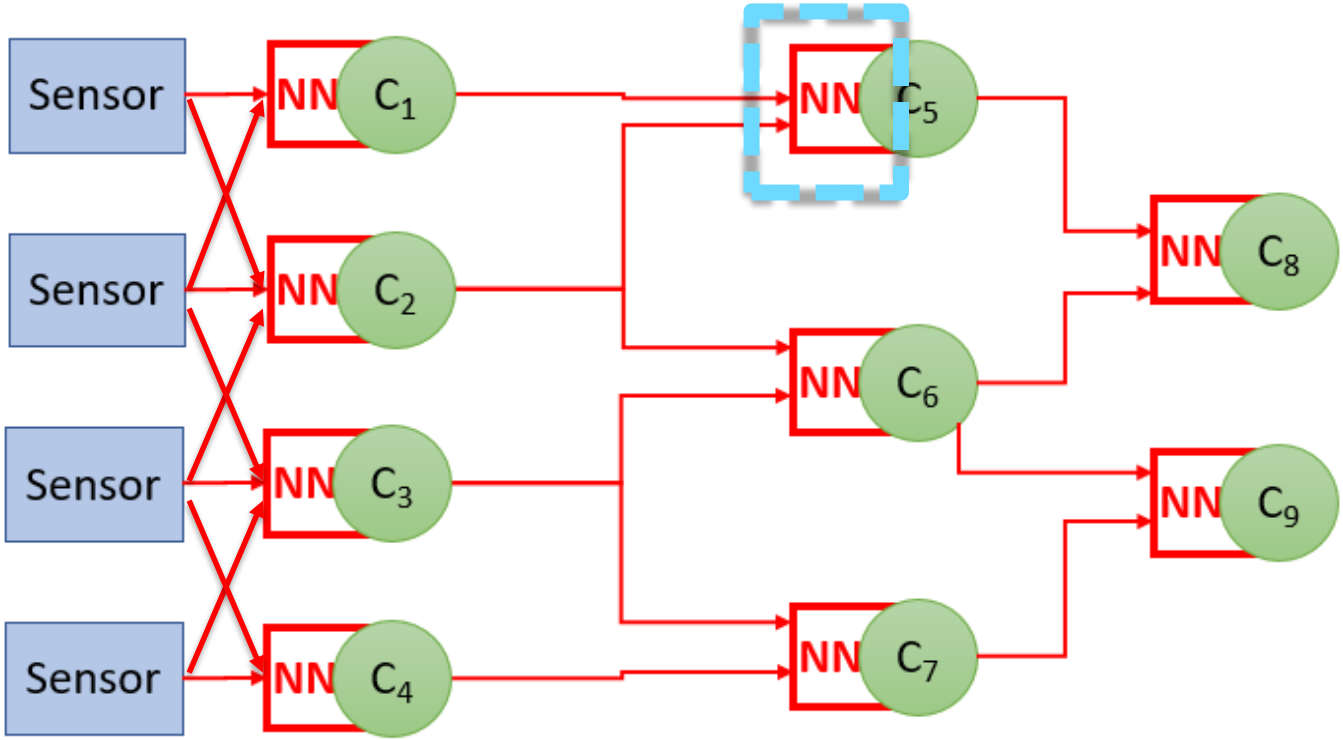
'Humane' relations

Piece by piece

Missing input

Different levels

INTEGRATED NEURO AND SYMBOLIC



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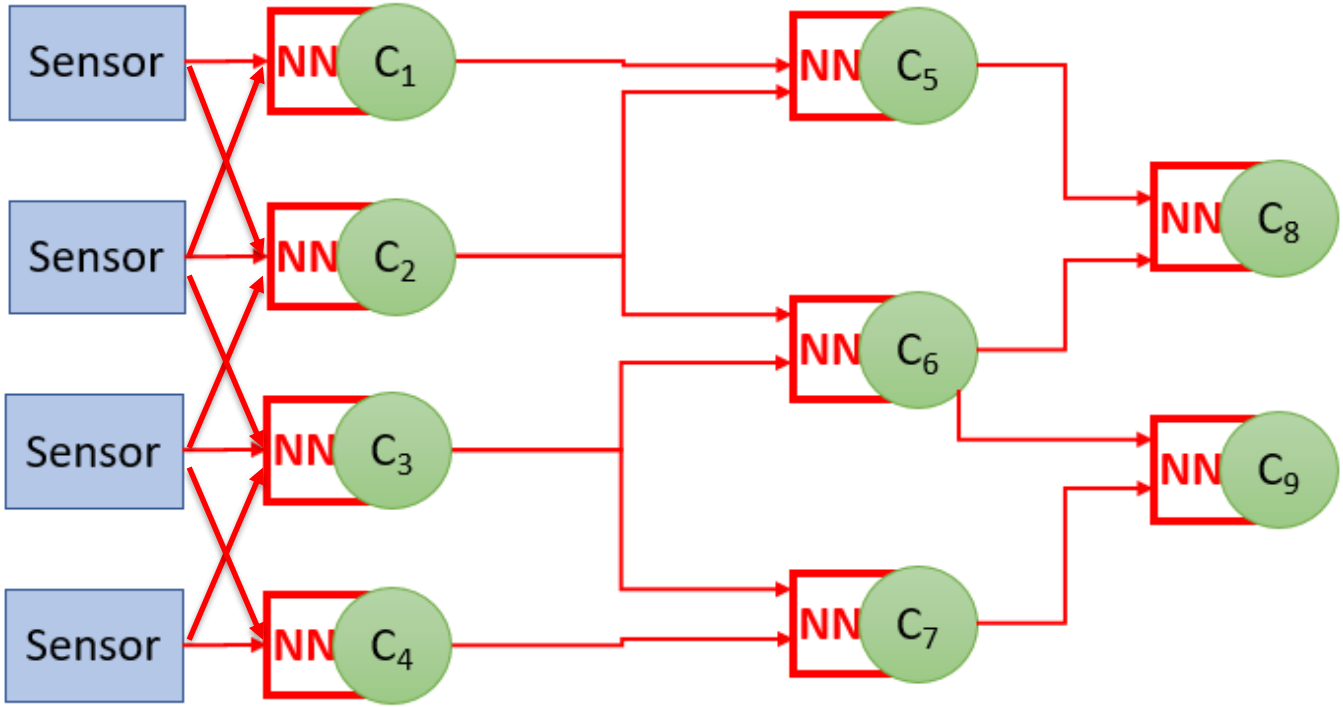
INTEGRATED NEURO AND SYMBOLIC



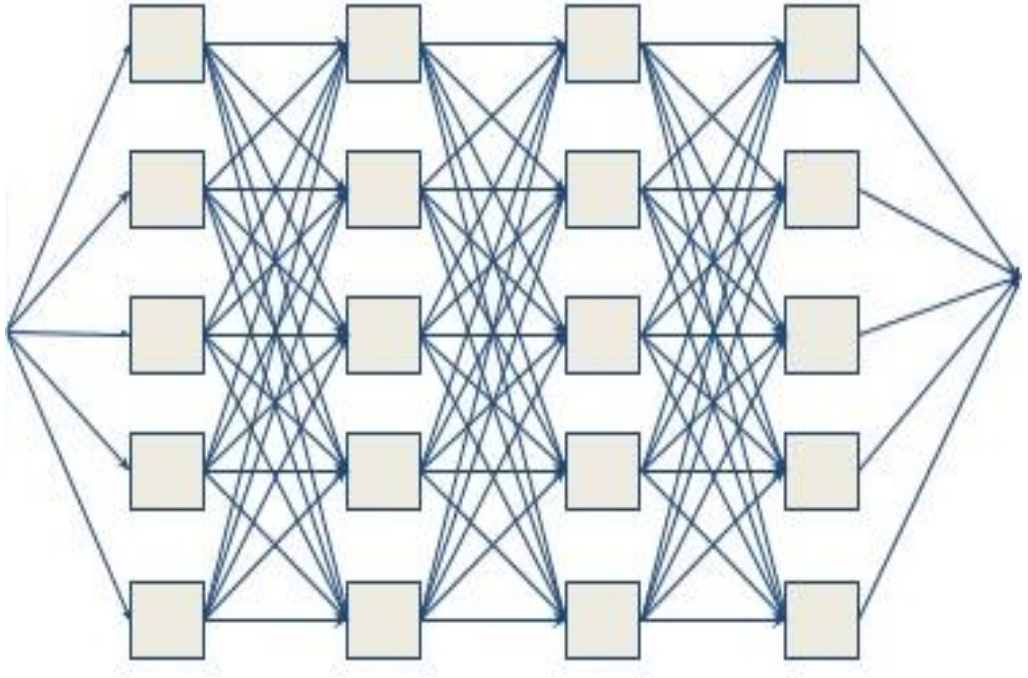
'Humane' relations

Piece by piece

Missing input

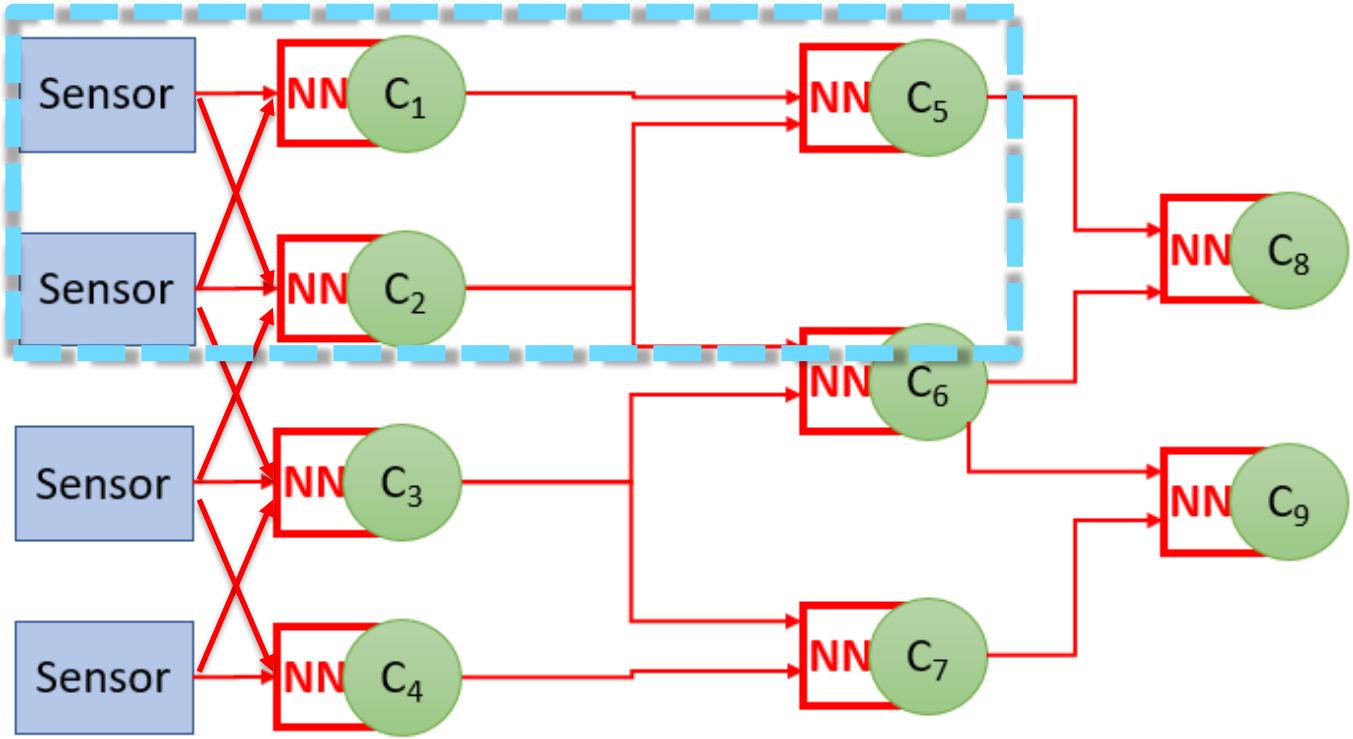
Different levels

Input data



Output data

INTEGRATED NEURO AND SYMBOLIC



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Piece by piece

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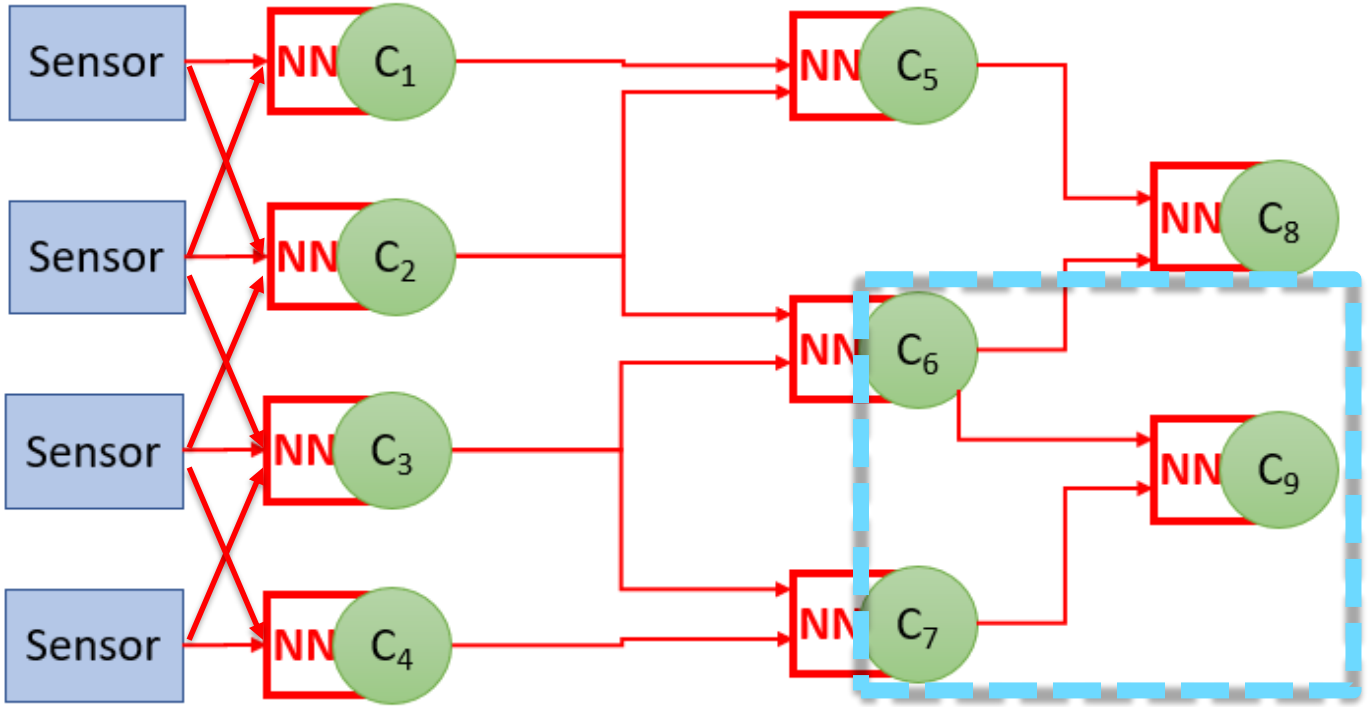
INTEGRATED NEURO AND SYMBOLIC



'Humane' relations

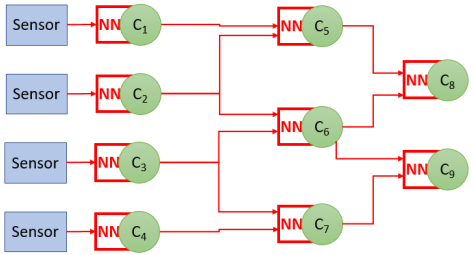
Piece by piece

Missing input

<u>Different levels</u>

INTEGRATED NEURO AND SYMBOLIC

- By studying the resulting NN of a trained concept network we found
  - Some concepts require only a simple NN,
  - Other concepts require a more elaborate NN
    - missing concepts? feedback to expert
  - Links between concepts that are and are not useful
    - feedback to expert, or automate addition/deletion of links



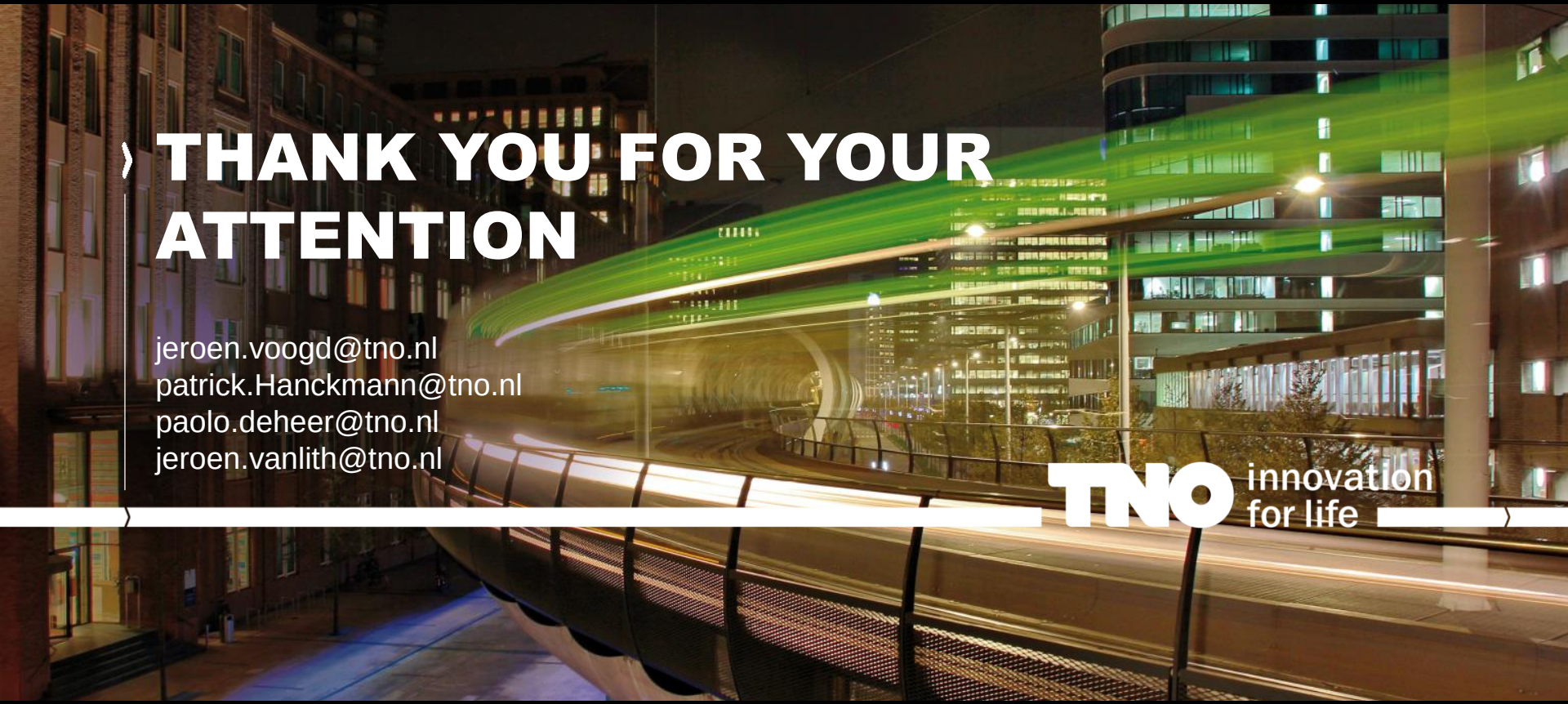
- The results are - again - not as good as using a NN, but explainable!

- Concept networks can with re-training be reused in other operations

CONCLUSIONS

- Analysts and decision makers can be supported by simulation
- Fit-for-purpose models have to be made/tailored during the operation
- The combination of expert knowledge and AI can help determine what is and is not important in an explainable way

- Several important technologies are being developed within NATO
  - MSaaS, Datafarming
- Neuro-Symbolic Modelling is a promising approach to combine low-level data with expert knowledge
  - Cross-panel: Big Data and Artificial Intelligence for Military Decision Making



THANK YOU FOR YOUR ATTENTION

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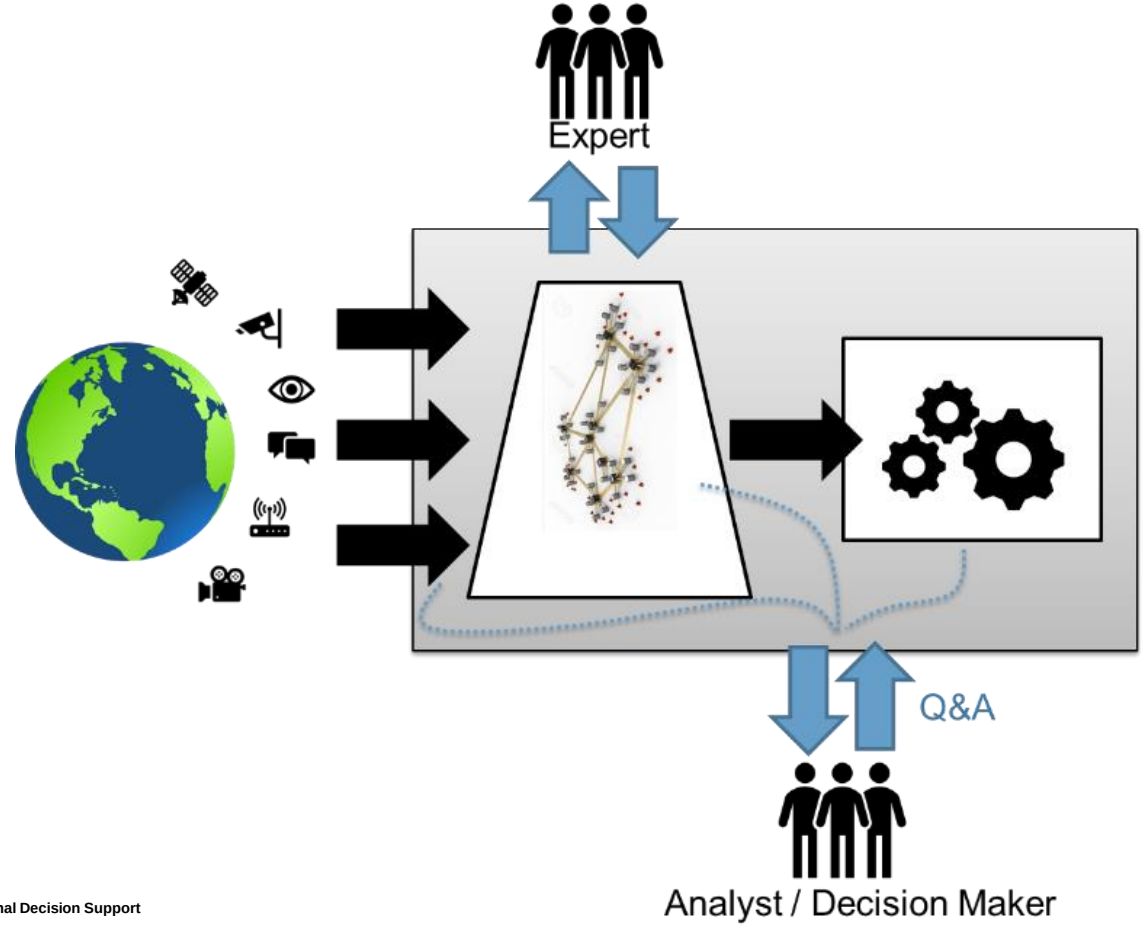
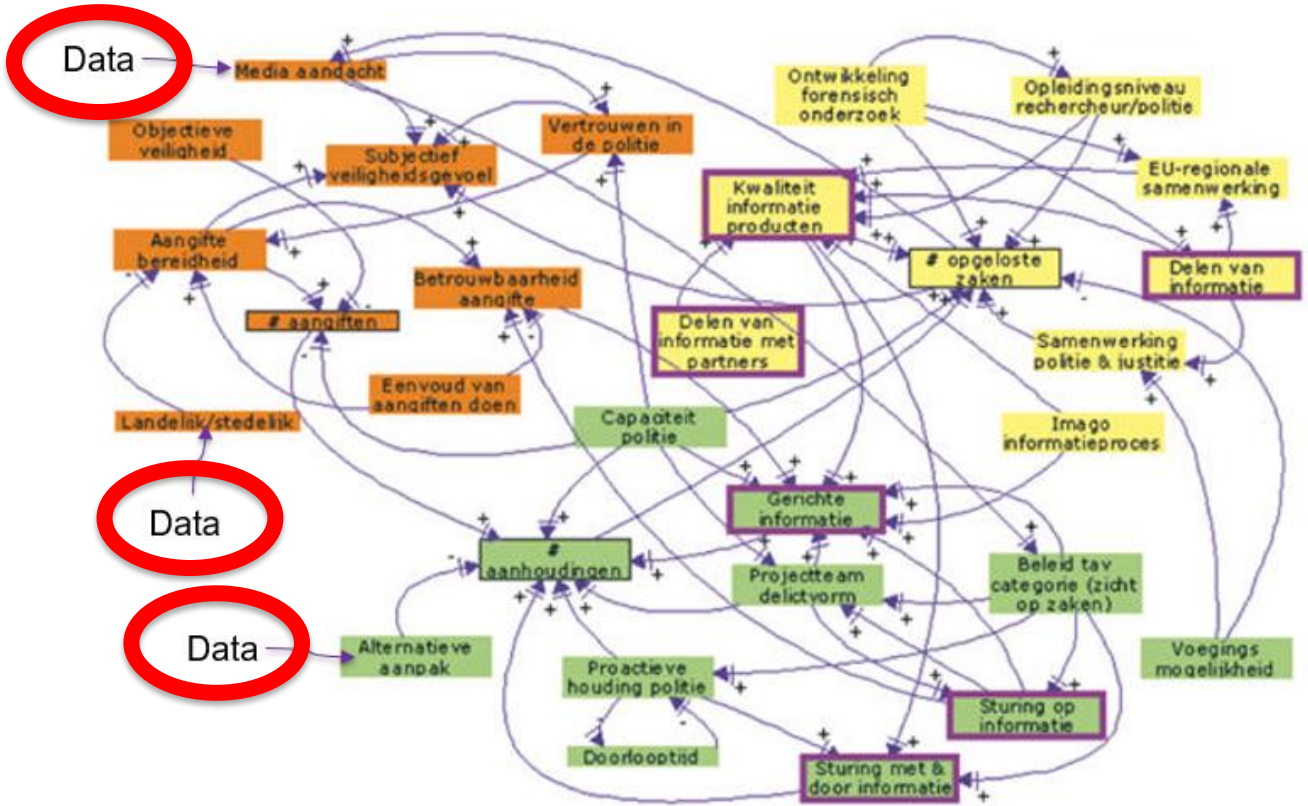
TNO innovation for life

SIMULATION-BASED SUPPORT SYSTEM



RELATIONAL CONCEPT NETWORK



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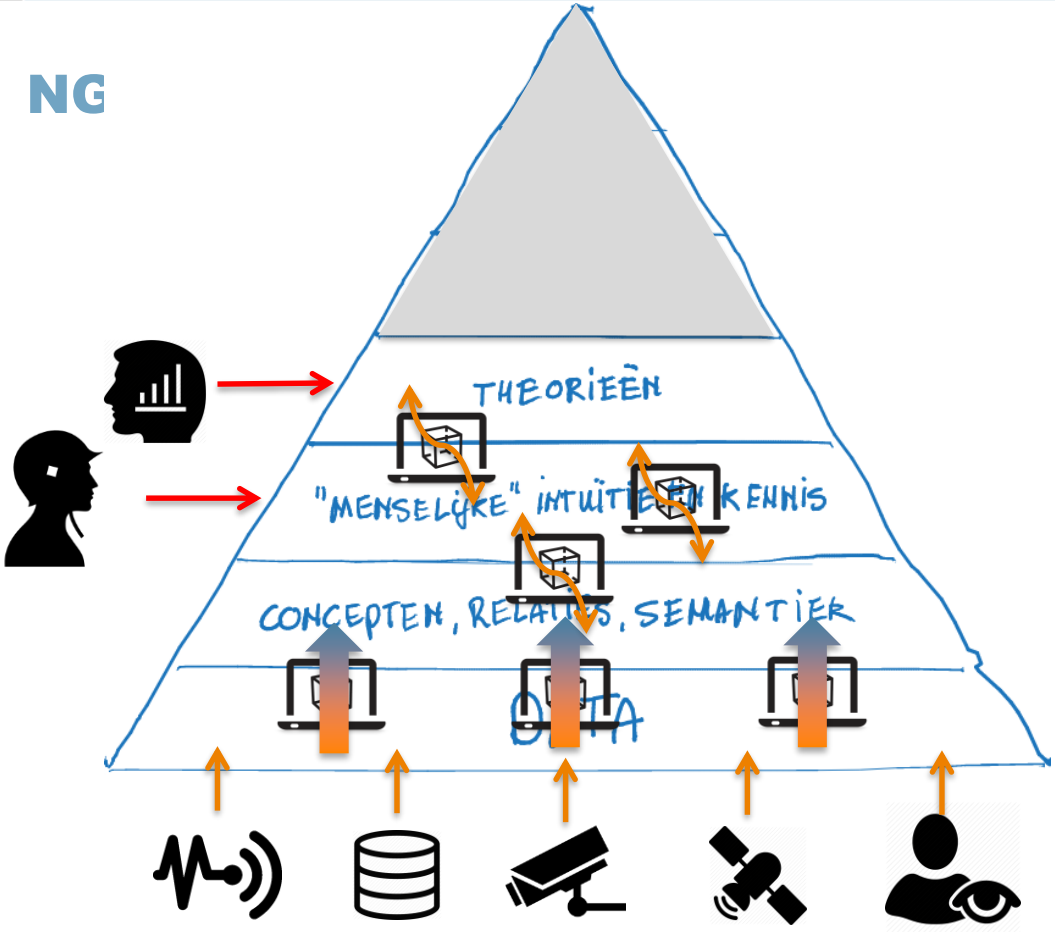
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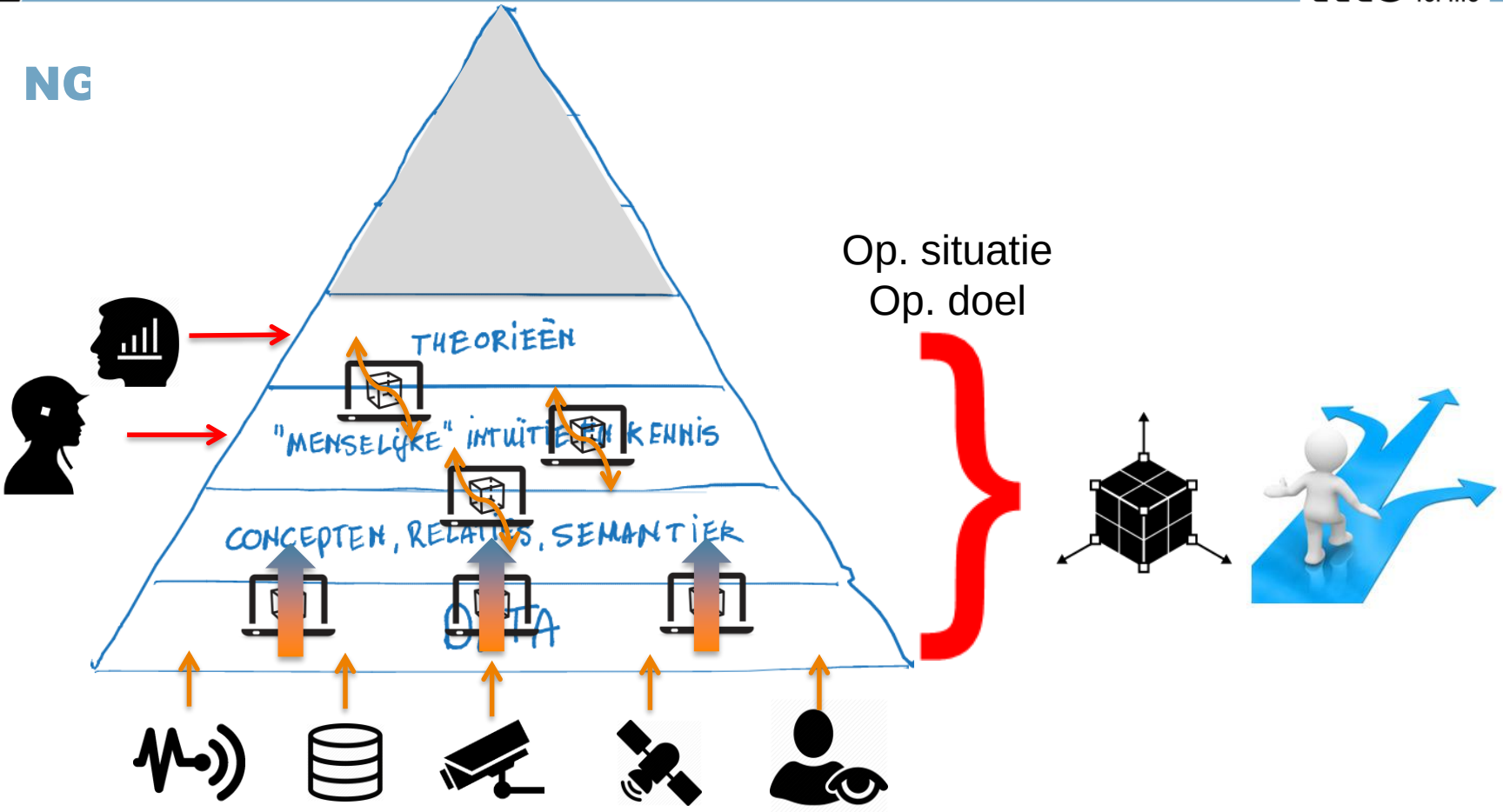

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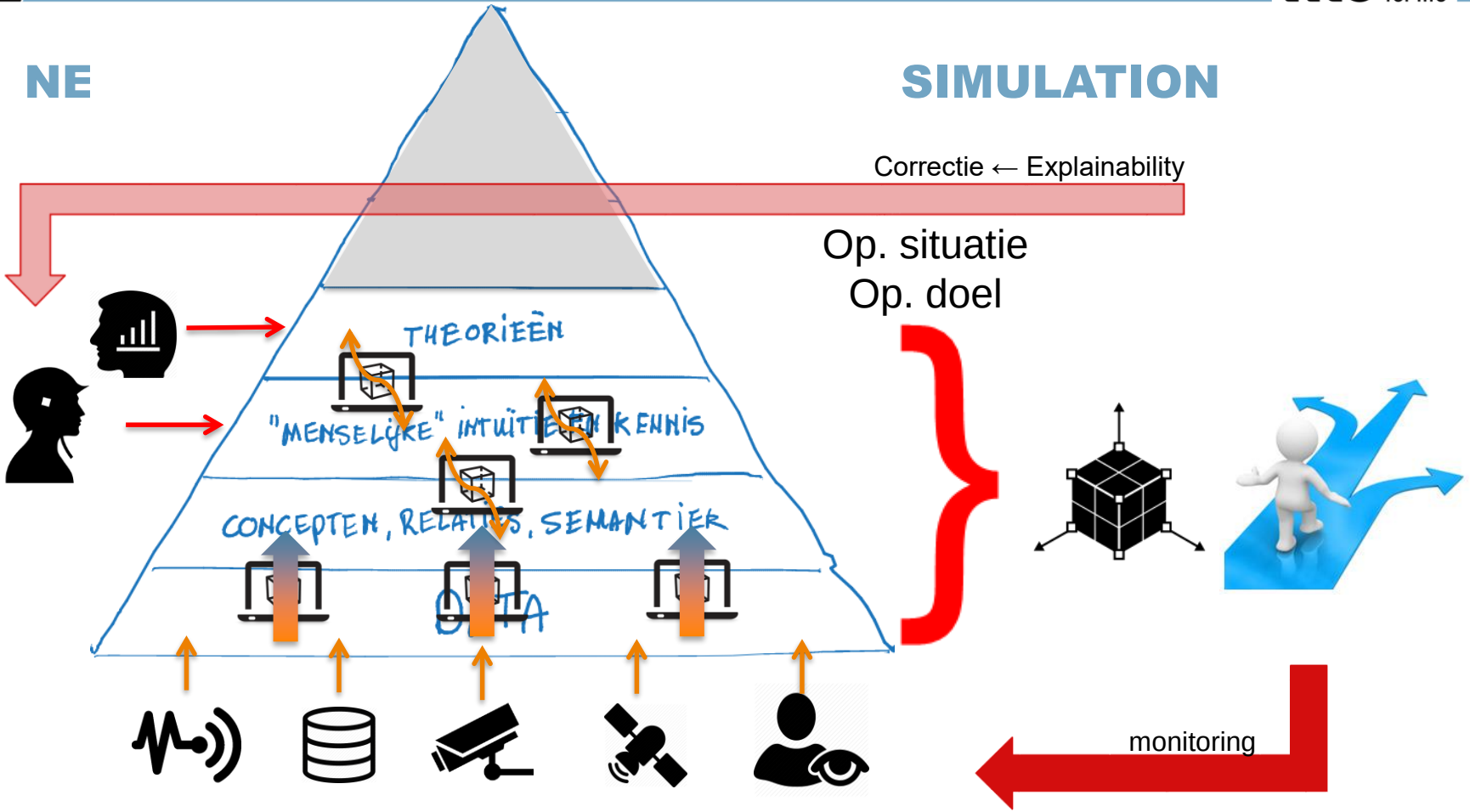

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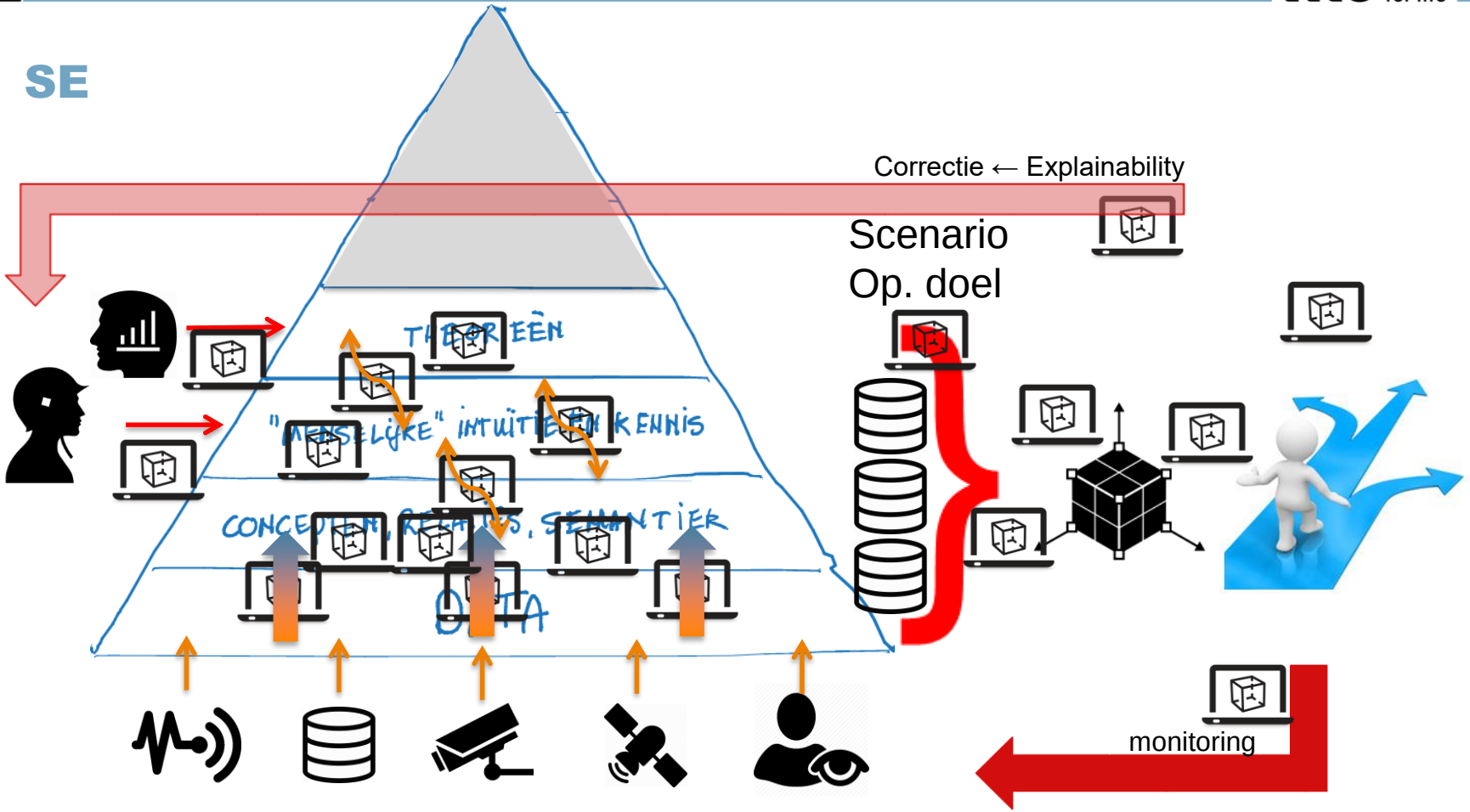

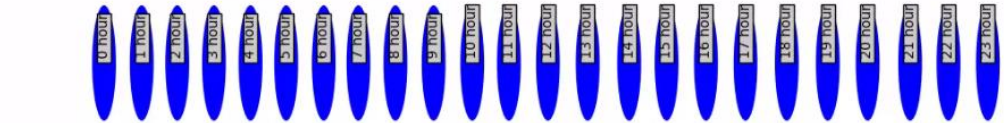
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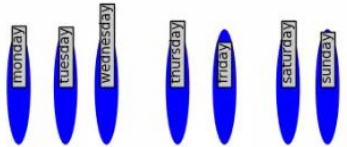
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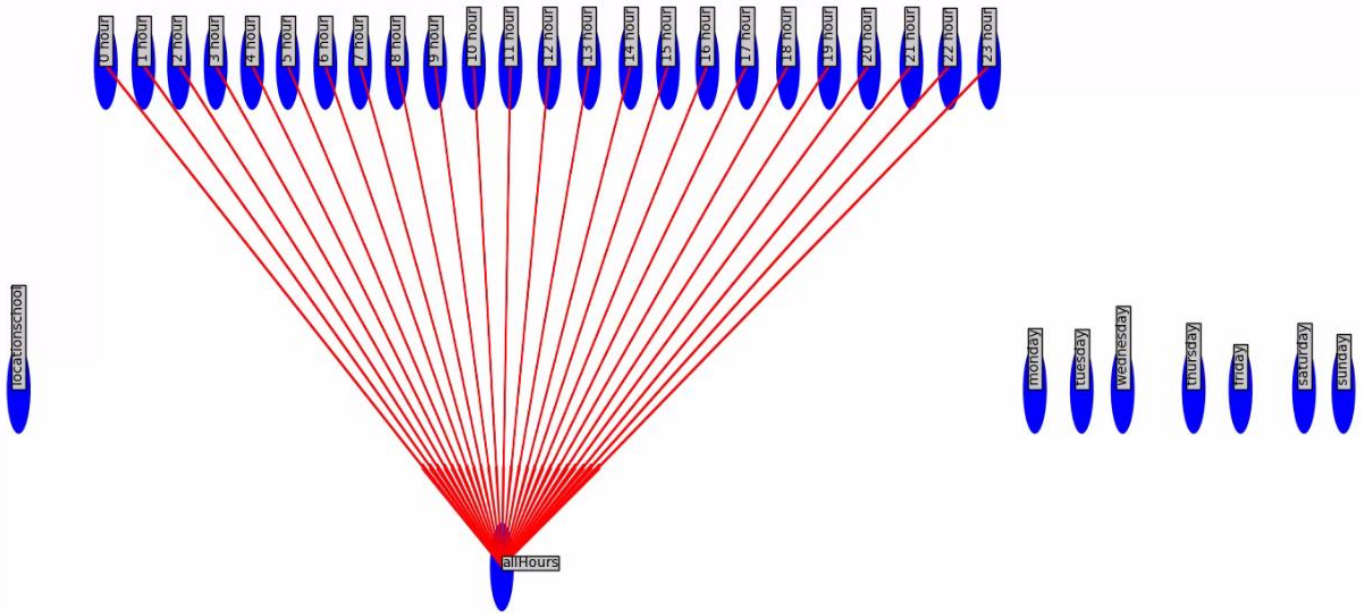
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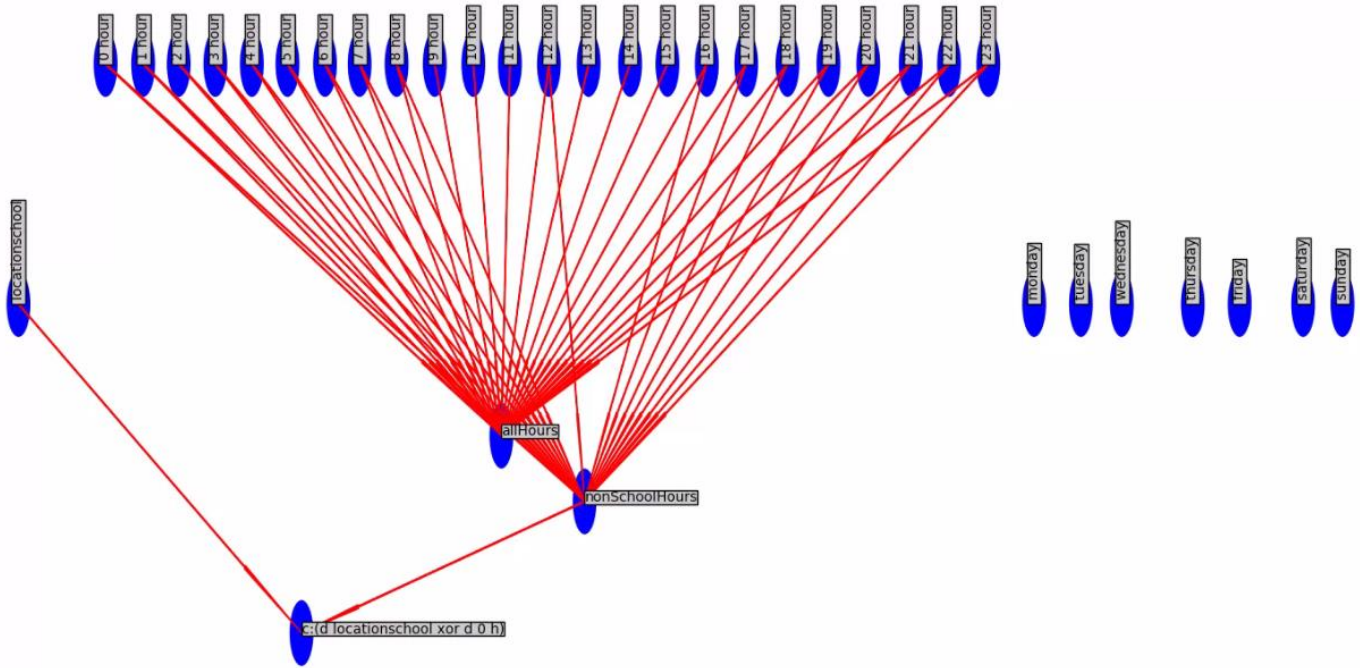
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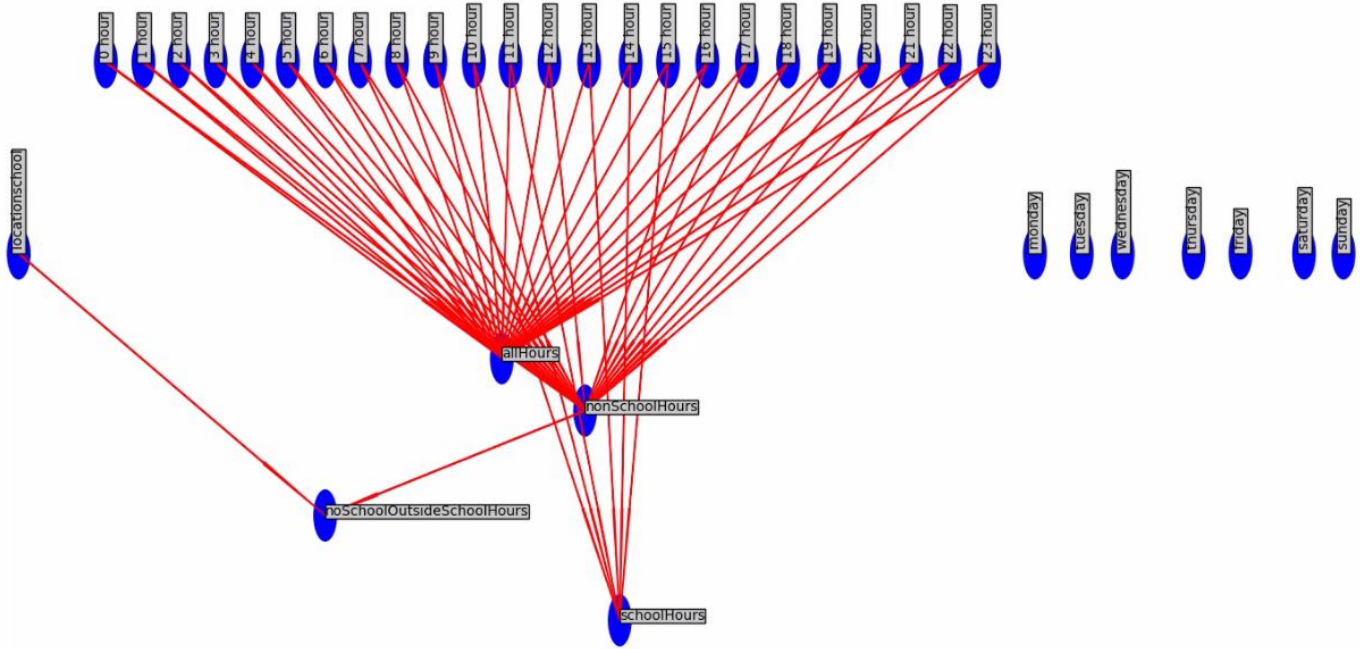
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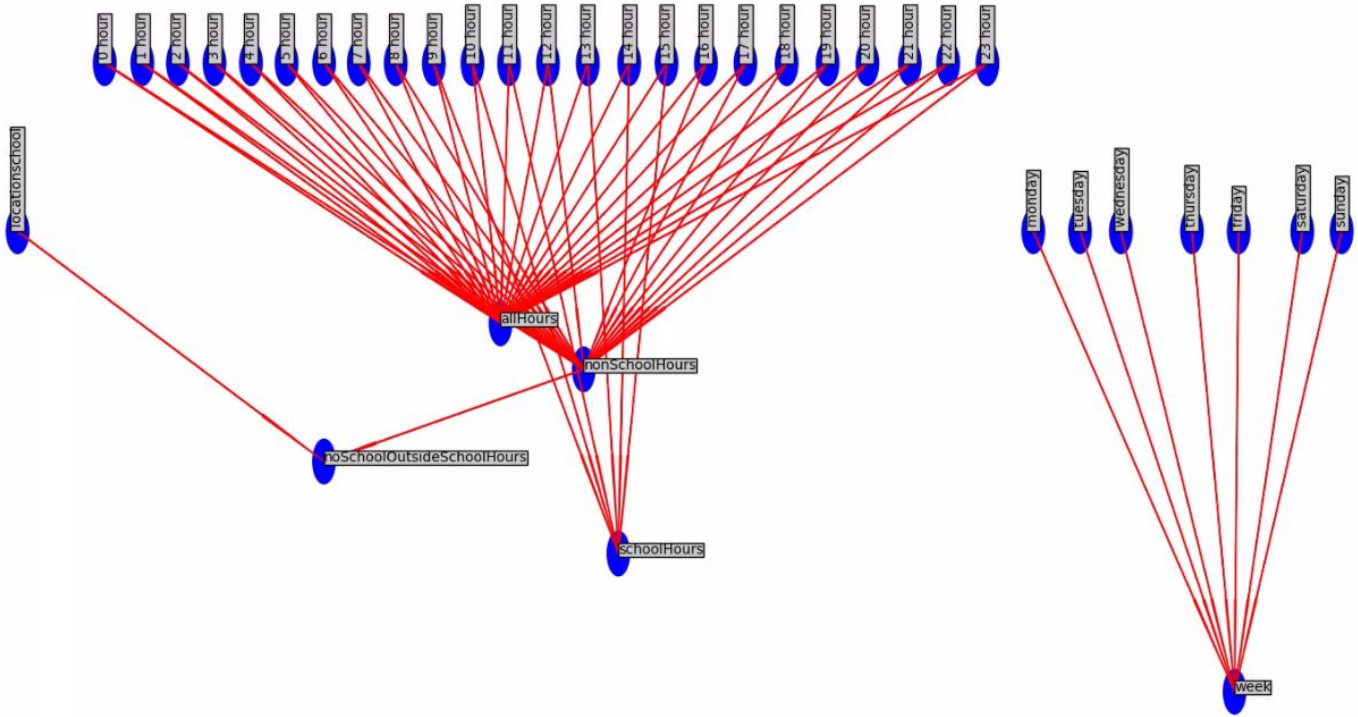
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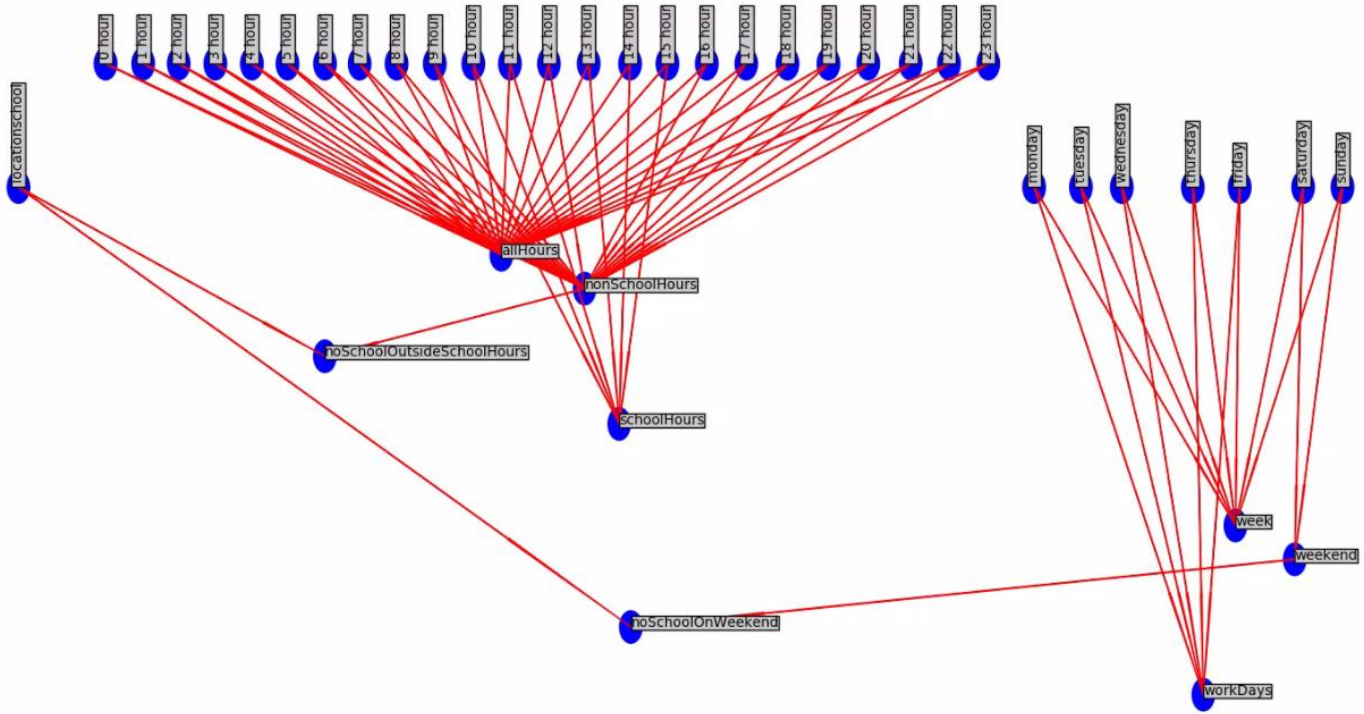
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