An Ontological Framework for Decision Support

Marco Rospocher

rospocher@fbk.eu
https://dkm-static.fbk.eu/people/rospocher
@marcorospocher

Fondazione Bruno Kessler
Trento, Italy

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Decision Making

- The decision making process of a Decision Support System (DSS) typically consists of three phases:

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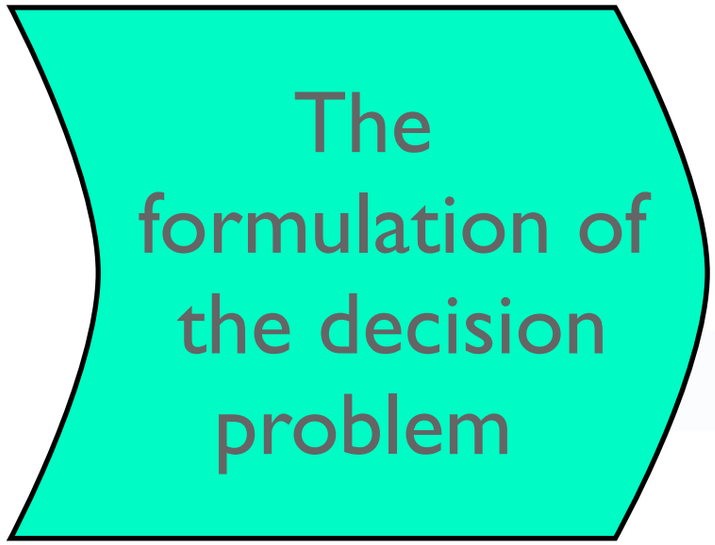

Problem

Decision Making

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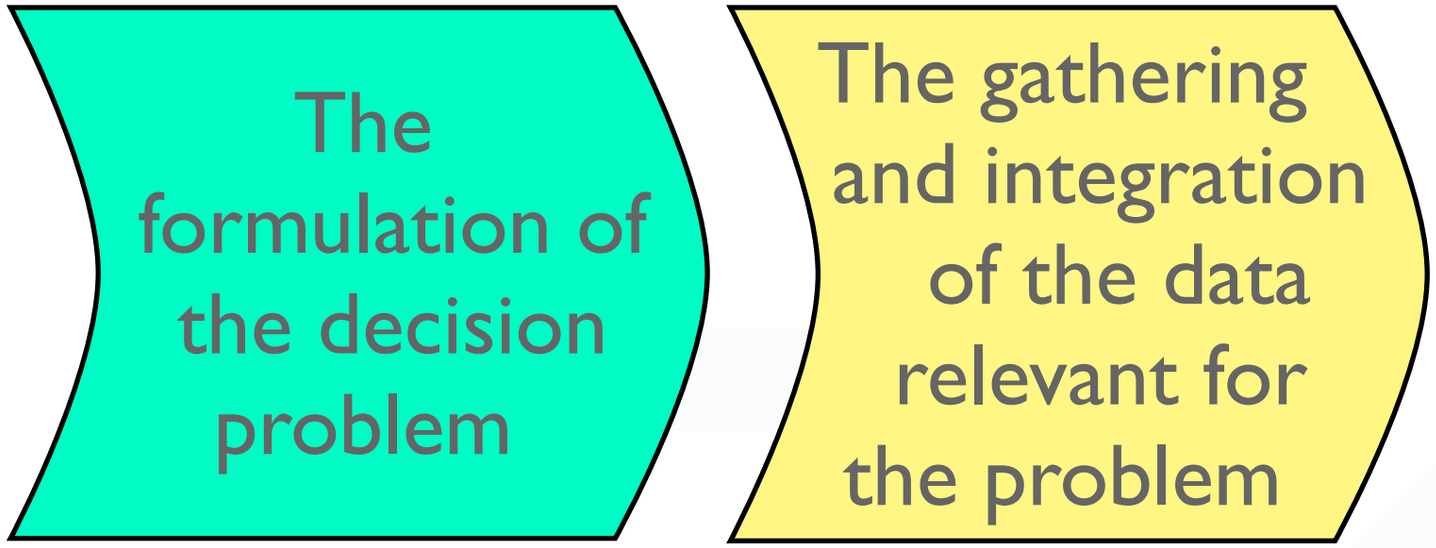

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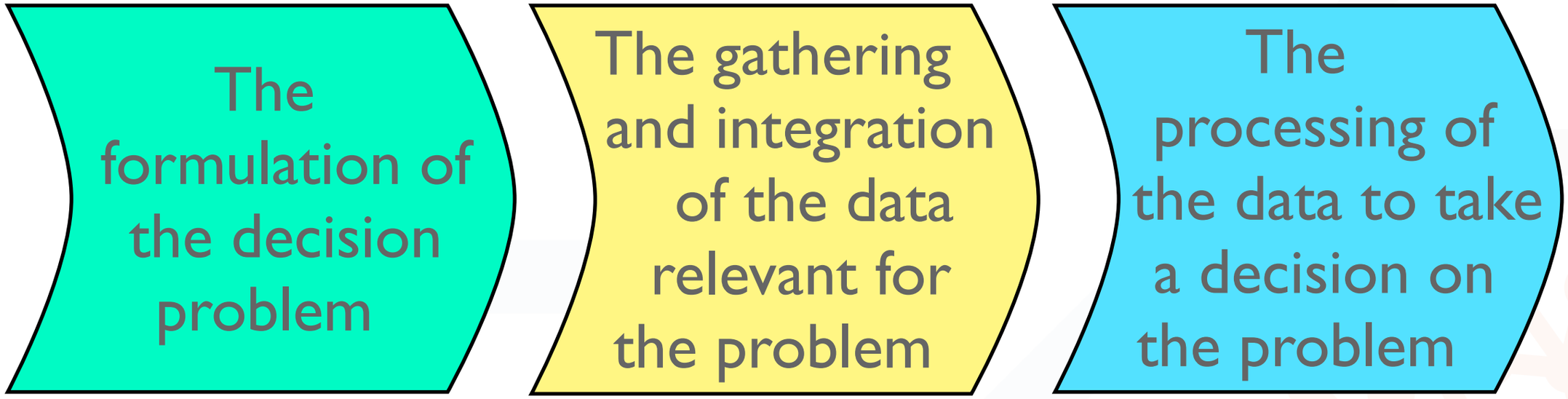

Our Contribution

- We propose to adopt an ontology-based knowledge base as the main (enhanced) data structure of a DSS:
  - T-Box: formally represents the content manipulated in the three decision-making phases (problem, data, conclusions)
  - A-Box: each request submitted to the system corresponds to a single incrementally-built A-Box (a "semantic request script")

Advantages

- Facilitates the integration of heterogeneous knowledge and data sources
- Semantic exposure of DSS processing to external services
- Some of the inference steps of the DSS can be performed via state of the art logical reasoning services

Outline

- PESCaDO Use Case: An Environmental DSS
- The Decision Support Knowledge base (DSKB)
  - Problem component
  - Data component
  - Conclusion component
  - Semantic Request Script (SRS)
- Incremental construction of a SRS
- Exploitation of SRSs
- On Engineering the DSKB
- Conclusions

Use Case (VIDEO)

- A multilingual web-service platform providing personalized environmental information and decision support
- Example scenarios:
  - A pollen allergic person, planning to do some outdoor activities, interested in being notified of potentially harmful environmental conditions
  - A city administrator, to be informed whether the current air quality situation requires some actions to be urgently taken
- The PESCaDO DSS demo-video
- PESCaDO FP7 EU Project
  - Demos, Videos, Ontologies, etc: http://www.pescado-project.eu

Use Case (VIDEO)

Please, access: https://youtu.be/tFKzu6Uxals

(longer version, with voice comments: https://youtu.be/wEXk2sGFG1k)

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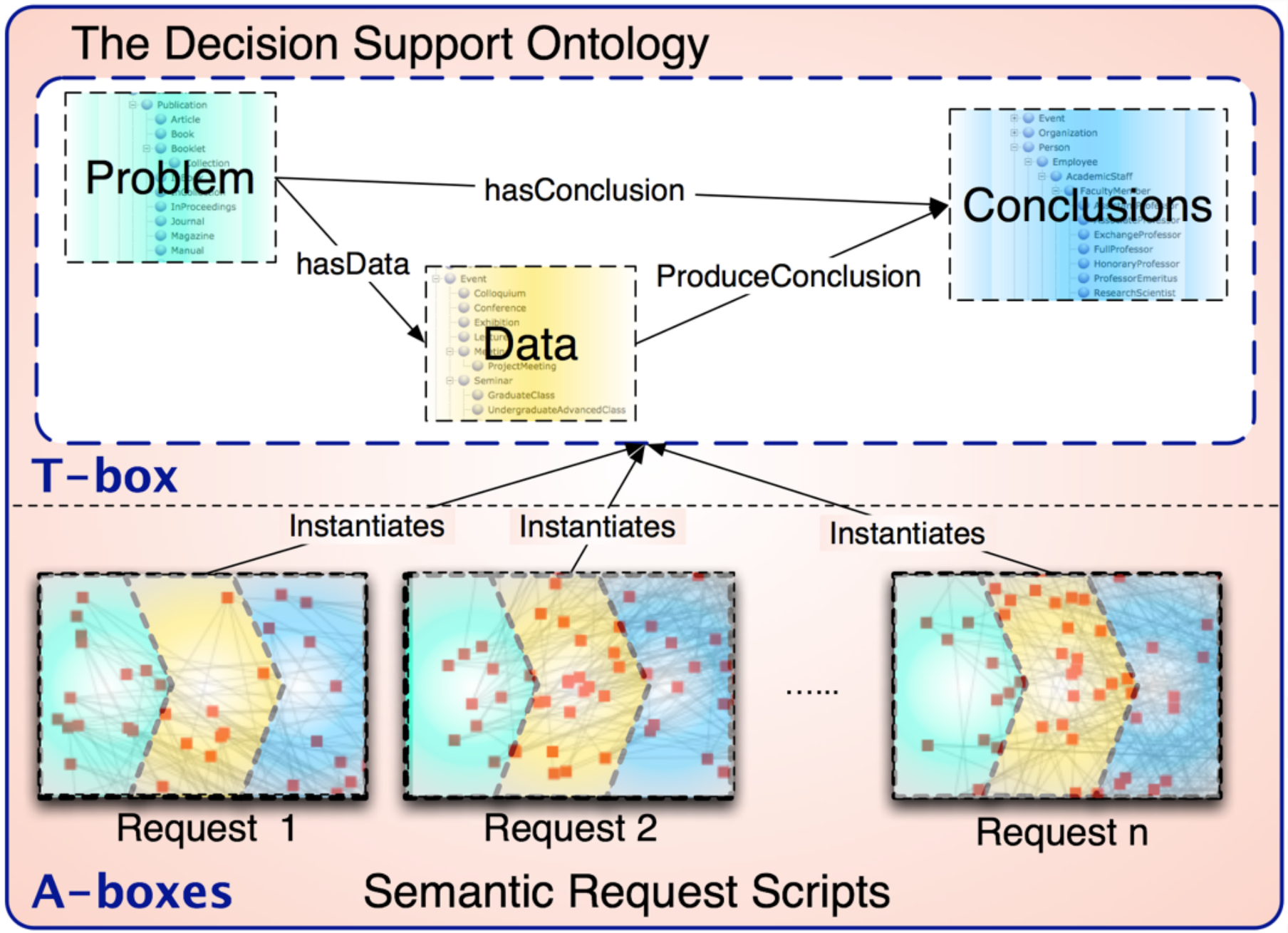
The Decision Support Knowledge Base



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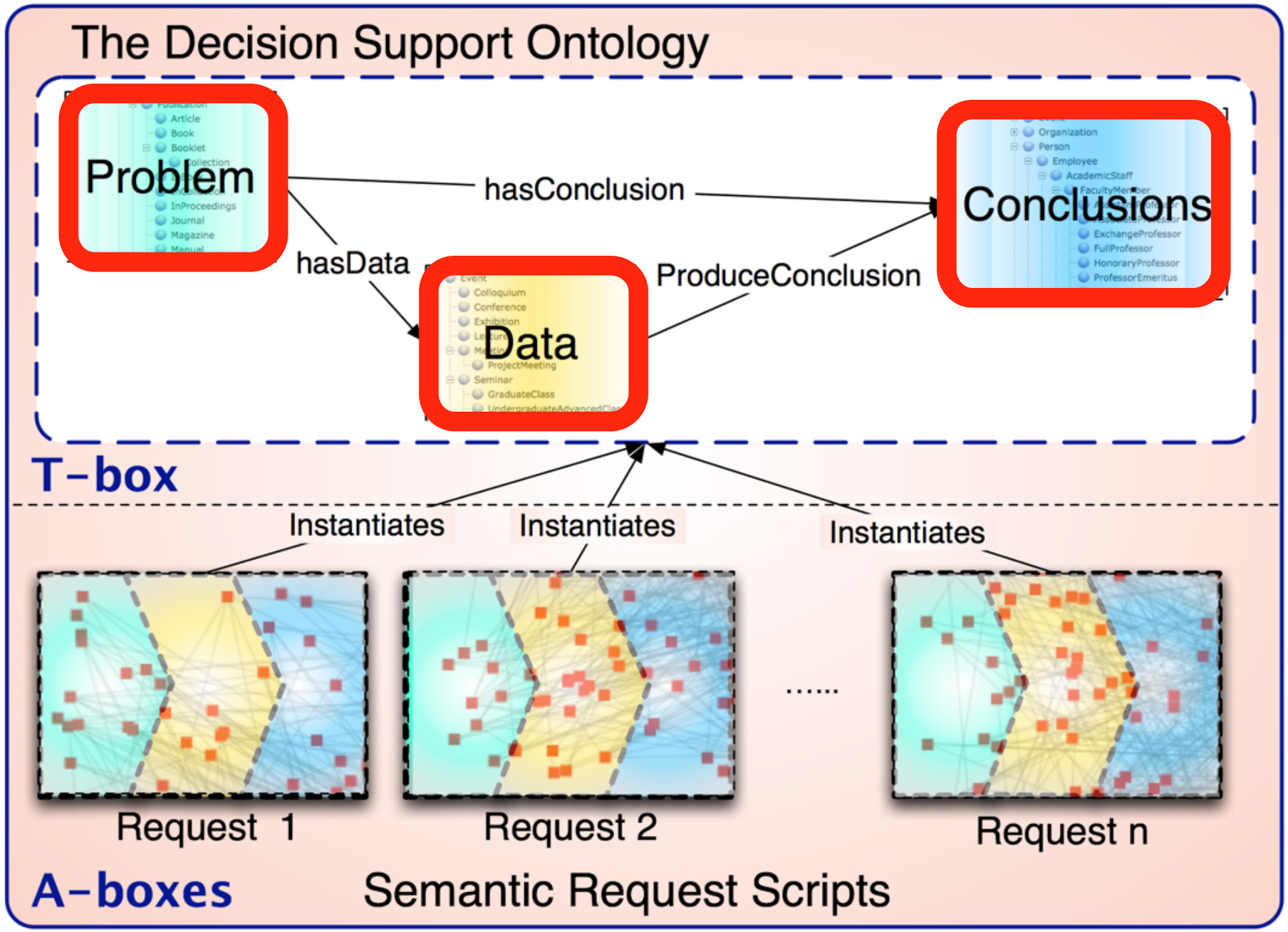

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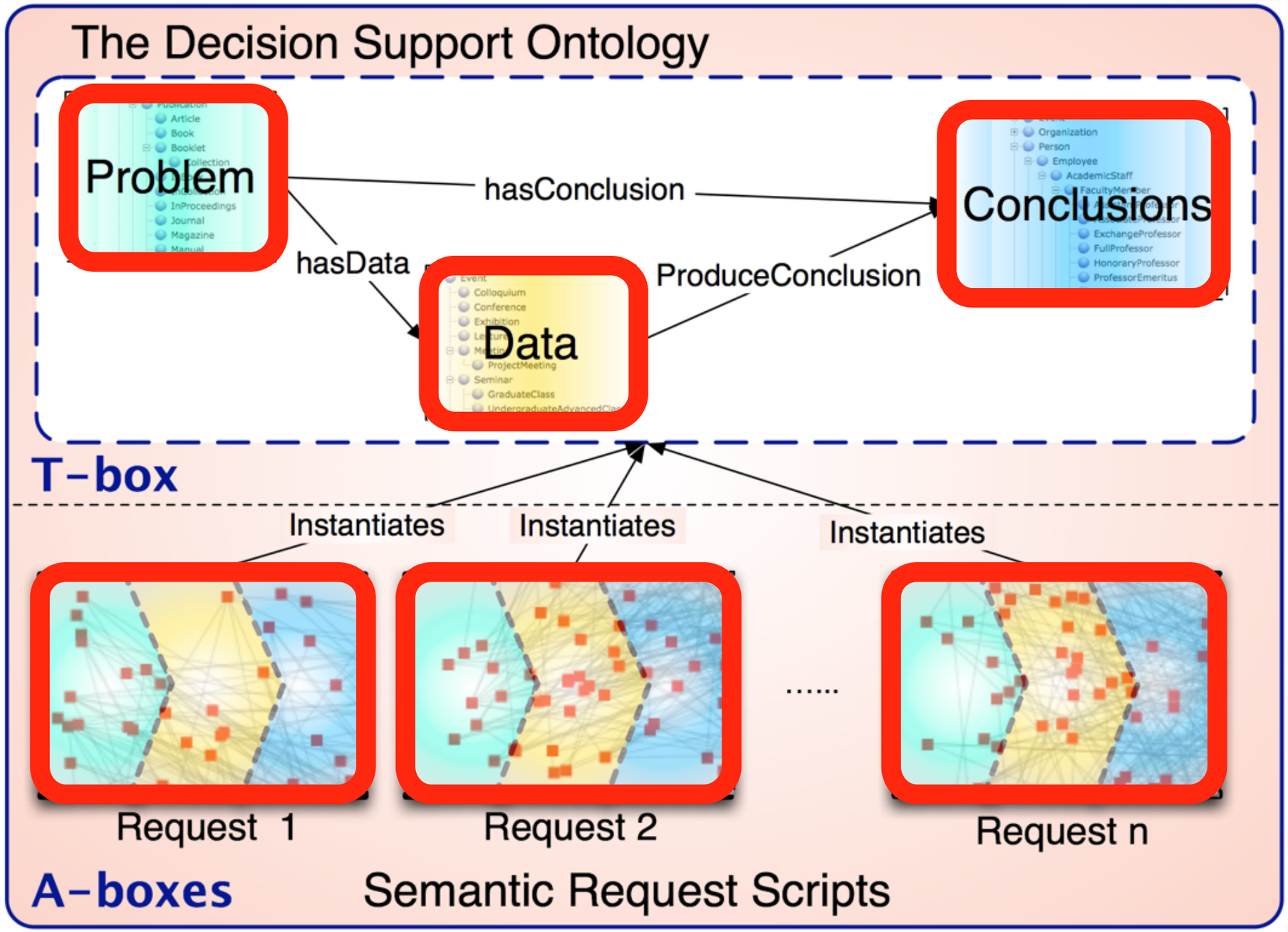

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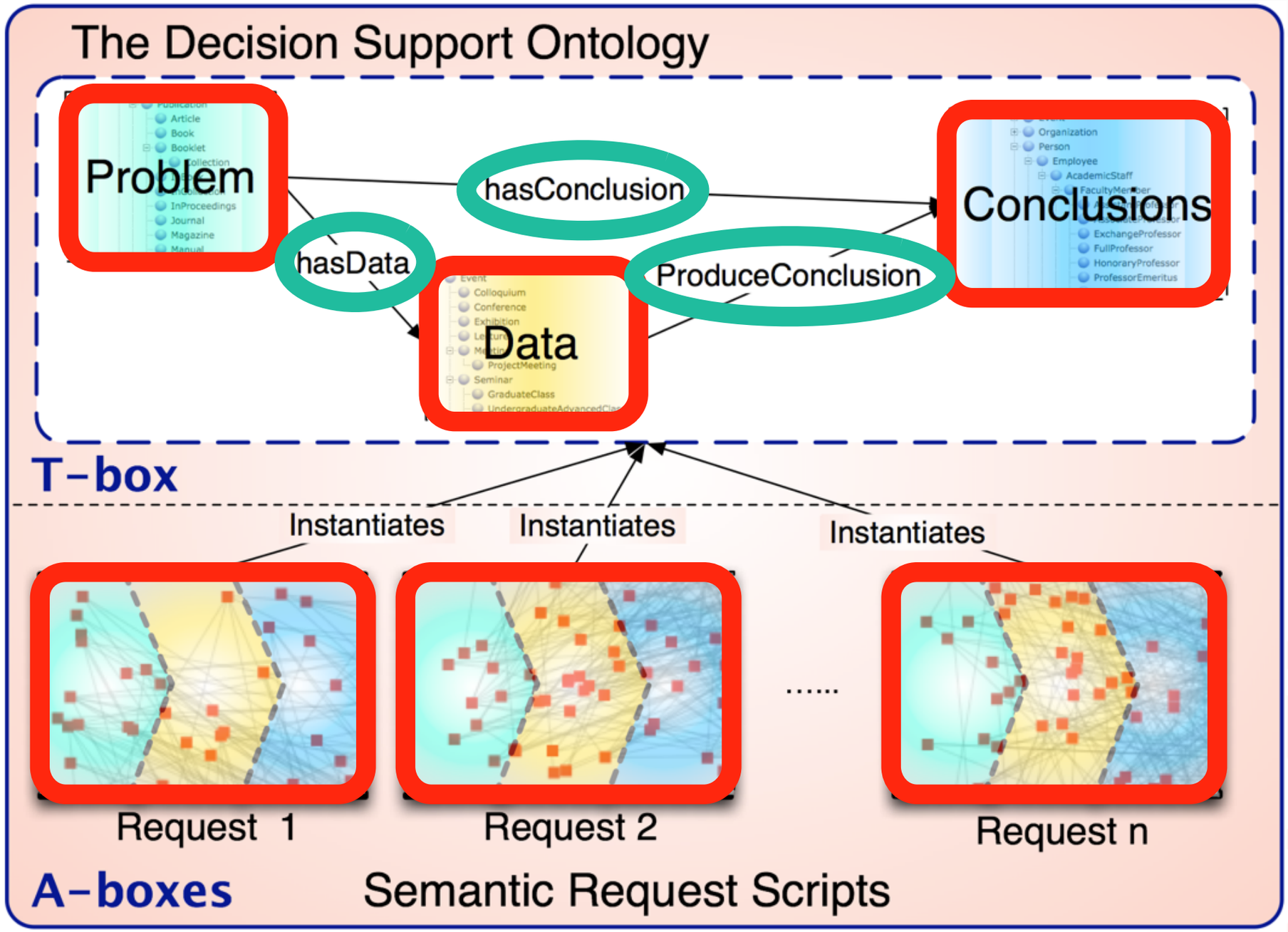

The Problem Component

- Formally describes all the aspects of decision support problems that the user can submit to the DSS
- Examples of content:
  - taxonomy of the request types supported by the system
  - input parameters needed by the DSS to provide adequate decision support
  - user profile
  - ...
- May also be used to dynamically constrain the user input in the DSS User Interface

The PESCaDO Problem Component

- Organized in sub-modules (Request, User, Activity)
- Interrelated by object properties and subclass axioms
  - Examples of constraints:
    - CheckAirQualityLimits subClassOf hasRequestUser only AdministrativeUser
    - AnyHealthIssue subClassOf hasRequestActivity some (AttendingOpenAirEvent or PhysicalOutdoorActivity or Traveling)
  - Used in the PESCaDO UI to guide the users in formulating their decision support problems
- Additional Parameters: time, location

The PESCaDO Problem Component

- Request
  - InstructionRequest
    - SuggestAdministrativePlan
  - ReportRequest
    - CheckAirQualityLimits
    - CheckBlackIceCondition
    - CompareAirQualityInMultipleRegions
    - ReportAirQualityForecast
  - WarningRequest
    - AnyHealthIssue
    - AnyRestrictionForPrivateTransport
    - WarningDueToEnvironmentalConditions

- Activity
  - AttendingOpenAirEvent
  - LongTermStaying
    - GoingOnHolidayLongTermStaying
    - LivingLongTermStaying
  - PhysicalOutdoorActivity
  - Travelling
    - BikeOrFeetTravelling
      - FeetTravelling
      - BikeTravelling
    - CarTravelling
    - PublicTransportTravelling

- User
  - AdministrativeUser
  - EndUser
    - AdultUser
    - ChildUser
    - ElderlyUser
    - InfantUser
    - PregnantFemaleUser
    - UserSensitiveToAirPollutant
    - UserSensitiveToPollen
      - UserSensitiveToAlderPollen
      - UserSensitiveToBirchPollen
      - UserSensitiveToGrassesPollen
      - UserSensitiveToMugwortPollen
    - UserSensitiveToWeather
    - UserSufferingOfAllergicRhinitis
    - UserSufferingOfCirculatoryDisease
    - UserSufferingOfNasalOrEyeAllergy
    - UserSufferingOfRespiratoryDisease
    - YoungUser
  - Expert

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The Data Component

- Formally describes the data accessed and manipulated by the DSS (aka *domain* ontology of the DSS)

- An ontology to be used as data component may be already available in the web

- It favors the integration of (structured) data provided by heterogeneous sources (web-sites, LOD)

The PESCaDO Data Component

- It describes environmental related data:
  - meteorological data (e.g., temperature, wind speed)
  - pollen count data
  - air quality data (e.g., NO2, PM10, air quality index)
  - traffic and road conditions
- Details represented
  - observed, forecast, or historical data,
  - the time period covered
  - type of the data (e.g., instantaneous, average, minimum, maximum)
  - mapping between qualitative and quantitative values
    - moderate birch pollen count corresponds to 10 - 100 grains per meter cube of air
  - data source (e.g., measurement station, web-site, web-service) details, e.g., geographical location, confidence value
- It facilitated the integration of data obtained from heterogenous sources, and with different techniques
  - e.g., content distillation from text and images

The PESCaDO Data Component

- It describes
  - meteorological data (e.g., temperature, wind speed)
  - pollen count data

```
EnvironmentalData
    EnvironmentalData SubClassOf hasFromDateTime some dateTime
    EnvironmentalData SubClassOf hasEnvironmentalDataNature exactly 1 EnvironmentalDataNature
    EnvironmentalData SubClassOf hasEnvironmentalDataEnvironmentalDataType exactly 1 EnvironmentalDataType
    EnvironmentalData SubClassOf hasToDateTime some dateTime
EnvironmentalNode
    EnvironmentalNode SubClassOf hasEnvironmentalNodeLocation max 1 Location
    EnvironmentalNode SubClassOf hasEnvironmentalNodeEnvironmentalNodeAreaType max 1 EnvironmentalNodeAreaType
    EnvironmentalNode SubClassOf hasEnvironmentalNodeName exactly 1 string
    EnvironmentalNode SubClassOf hasEnvironmentalNodeForm exactly 1 EnvironmentalNodeForm
    EnvironmentalNode SubClassOf hasEnvironmentalNodeEnvironmentalNodeType max 1 EnvironmentalNodeType
    EnvironmentalNode SubClassOf hasEnvironmentalNodeConfidenceValue max 1 double
    EnvironmentalNode SubClassOf hasEnvironmentalNodeEnvironmentalData only EnvironmentalData
    EnvironmentalNode SubClassOf
        hasEnvironmentalNodeEnvironmentalNodeSourceOfEmissionType max 1 EnvironmentalNodeSourceOfEmissionType
    EnvironmentalNode SubClassOf hasEnvironmentalNodeURL max 1 anyURI
    EnvironmentalNode SubClassOf hasEnvironmentalNodeEnvironmentalNodeLandUseType max 1 EnvironmentalNodeLandUseType
```

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The Conclusion Component

- Formally describes the output produced by the DSS by processing the problem description and the data available, e.g.
  - warnings/suggestions/instructions/decisions
  - data aggregations, data analysis results
- A weight (e.g. confidence, relevance) may be assigned to the conclusions produced
- Tracking of the data that triggered conclusions ("ProduceConclusion" object property)

The PESCaDO Conclusion Component

- It describes conclusion types like
  - exceedances of air pollutants limit values detected from data
  - warnings and recommendations that may be triggered by environmental conditions

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  - warnings

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SRS: An A-Box of the DSKB

- **request_c4644d75-1ff9-451a-880c-5f2c40741b2b**
  - request_c4644d75-1ff9-451a-880c-5f2c40741b2b hasFromDateTime "2011-04-28T00:00:00+03:00"^^dateTime
  - request_c4644d75-1ff9-451a-880c-5f2c40741b2b hasRequestActivity activity_56c2e15e-43f2-4920-80dd-b2bc7dba5fde
  - request_c4644d75-1ff9-451a-880c-5f2c40741b2b hasRequestPrimaryUser allenAllergic
  - request_c4644d75-1ff9-451a-880c-5f2c40741b2b Type AnyHealthIssue
  - request_c4644d75-1ff9-451a-880c-5f2c40741b2b hasRequestLanguage englishLanguage
  - request_c4644d75-1ff9-451a-880c-5f2c40741b2b hasToDateTime "2011-04-29T00:00:00+03:00"^^dateTime
  - request_c4644d75-1ff9-451a-880c-5f2c40741b2b hasRequestGeoArea geoArea_2d84e62e-c70e-4ac4-a257-0cedaa85bcb0
  - request_c4644d75-1ff9-451a-880c-5f2c40741b2b hasData temperature_2d84e62e-c70e
  - ...
  - request_c4644d75-1ff9-451a-880c-5f2c40741b2b hasConclusion rule_-1cfe18bc_134615edfe6_-7cd1
  - ...
- **allenAllergic**
  - allenAllergic Type EndUser
  - allenAllergic hasUserAge 40
  - allenAllergic hasUserPreferredLanguage finnishLanguage
  - allenAllergic hasUserGender maleGender
  - allenAllergic hasUserName "Allen Allergic"^^string
  - allenAllergic isUserSensitiveTo birchPollen
- **activity_56c2e15e-43f2-4920-80dd-b2bc7dba5fde**
  - activity_56c2e15e-43f2-4920-80dd-b2bc7dba5fde hasPhysicalOutdoorActivityPhysicalOutdoorActivityType hiking
  - activity_56c2e15e-43f2-4920-80dd-b2bc7dba5fde Type PhysicalOutdoorActivity

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- temperature_2d84e62e-c70e hasEnvironmentalDataAggregationType maxAggregationType
- temperature_2d84e62e-c70e hasEnvironmentalDataValue temperature_2d84e62e-c70e_value
- temperature_2d84e62e-c70e hasEnvironmentalDataEnvironmentalDataType temperature
- temperature_2d84e62e-c70e hasEnvironmentalDataNature forecasted
- temperature_2d84e62e-c70e hasFromDateTime "2011-04-28T00:00:00+03:00"^^dateTime
- temperature_2d84e62e-c70e hasToDateTime "2011-04-29T00:00:00+03:00"^^dateTime
- temperature_2d84e62e-c70e Type EnvironmentalData
- temperature_2d84e62e-c70e ProduceConclusion rule_-1cfe18bc_134615edfe6_-7cd1

temperature_2d84e62e-c70e_rating
- temperature_2d84e62e-c70e_rating Type Rating
- temperature_2d84e62e-c70e_rating hasRatingWeight 1.0
- temperature_2d84e62e-c70e_rating hasRatingRatingValue coolTemperatureRating

temperature_2d84e62e-c70e_value
- temperature_2d84e62e-c70e_value hasValueValue 9.4
- temperature_2d84e62e-c70e_value Type TemperatureValue
- temperature_2d84e62e-c70e_value hasUnit degreeC
- ...

Data

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hasData

Problem

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- temperature_2d84e62e-c70e hasEnvironmentalDataRating temperature_2d84e62e-c70e_rating
- temperature_2d84e62e-c70e hasEnvironmentalDataAggregationType maxAggregationType
- temperature_2d84e62e-c70e hasEnvironmentalDataValue temperature_2d84e62e-c70e_value
- temperature_2d84e62e-c70e hasEnvironmentalDataEnvironmentalDataType temperature
- temperature_2d84e62e-c70e hasEnvironmentalDataNature forecasted
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- temperature_2d84e62e-c70e_rating Type Rating
- temperature_2d84e62e-c70e_rating hasRatingWeight 1.0
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hasData

rule_-1cfe18bc_134615edfe6_-7cd1
- rule_-1cfe18bc_134615edfe6_-7cd1 Type Recommendation
- rule_-1cfe18bc_134615edfe6_-7cd1 hasRecommendationRecommendationType recommendationType_endUser_AnyHealthIssue
- rule_-1cfe18bc_134615edfe6_-7cd1 hasConclusionWeight 1.0

Conclusions

temperature_2d84e62e-c70e
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hasData

hasConclusion

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activity_56c2e15e-43f2-4920-80dd-b2bc7dba5fd
- activity_56c2e15e-43f2-4920-80dd-b2bc7db
- activity_56c2e15e-43f2-4920-80dd-b2bc7db

rule_-1cfe18bc_134615edfe6_-7cd1
- rule_-1cfe18bc_134615edfe6_-7cd1 Type Recommendation
- rule_-1cfe18bc_134615edfe6_-7cd1 hasRecommendationRecommendationType recommendationType_endUser_AnyHealthIssue
- rule_-1cfe18bc_134615edfe6_-7cd1 hasConclusionWeight 1.0

Conclusions

ProducesConclusion

temperature_2d84e62e-c70e
- temperature_2d84e62e-c70e has … c70e_rating
- temperature_2d84e62e-c70e has … ionType
- temperature_2d84e62e-c70e has … 70e_value
- temperature_2d84e62e-c70e hasEnvironmentalDataEnvironmentalDataType temperature
- temperature_2d84e62e-c70e hasEnvironmentalDataNature forecasted
- temperature_2d84e62e-c70e hasFromDateTime "2011-04-28T00:00:00+03:00"^^dateTime
- temperature_2d84e62e-c70e hasToDateTime "2011-04-29T00:00:00+03:00"^^dateTime
- temperature_2d84e62e-c70e Type EnvironmentalData
- temperature_2d84e62e-c70e ProduceConclusion rule_-1cfe18bc_134615edfe6_-7cd1

temperature_2d84e62e-c70e_rating
- temperature_2d84e62e-c70e_rating Type Rating
- temperature_2d84e62e-c70e_rating hasRatingWeight 1.0
- temperature_2d84e62e-c70e_rating hasRatingRatingValue coolTemperatureRating

temperature_2d84e62e-c70e_value
- temperature_2d84e62e-c70e_value hasValueValue 9.4
- temperature_2d84e62e-c70e_value Type TemperatureValue
- temperature_2d84e62e-c70e_value hasUnit degreeC

Data

Incrementally building SRSs

Exploitation of Logical Reasoning

- Phase1: Instantiation of the problem
  - consistency check to verify that the user request is compliant with the problem supported by the DSS
- Phase2: Instantiation of the data
  - data relevant for the user problem may be determined via ontology reasoning
    - PESCaDO: using "owl:hasValue" restrictions
      - e.g. userSensitiveToBirchPollen subClassOf RelevantAspect value Rain
- Phase3: Instantiation of the conclusions
  - instantiation depends on the decision support techniques adopted by the DSS
    - PESCaDO: two layers DL+RuleBased reasoning framework

Exploitation of SRSs

Natural language generation of DSS report

- A SRS provides a complete "semantic" snapshot of all the information processed and produced by the DSS for a request, with "explanations"
- A natural language report can be automatically generated from it
  - especially appreciated by laymen, media corporations, ...
- PESCaDO: multilingual personalized information generation from SRSs
  - text planning module
    - enrich the SRS with information on the content to be selected, and the way the text should be organized
  - linguistic generation module
    - produces the text in the three languages supported by the system

Exploitation of SRSs

Natural language generation of DSS report

Situation in the selected area between 08h00 and 20h00 of 07/05/2012. The ozone warning threshold value (240g/m3) was exceeded between 13h00 and 14h00 (247g/m3), the ozone information threshold value (180g/m3) between 12h00 and 13h00 (208g/m3) and between 14h00 and 15h00 (202g/m3). The minimum temperature was 2C and the maximum temperature 17C. The wind was weak (S). There is no data available for carbon monoxide, rain and humidity.

Ozone warning: ozone irritates eyes and the mucous membranes of nose and throat. It may also exacerbate allergy symptoms caused by pollen. Persons with respiratory diseases may experience increased coughing and shortness of breath and their functional capacity may weaken. Sensitive groups, like children, asthmatics of all ages and elderly persons suffering from coronary heart disease or chronic obstructive pulmonary disease, may experience symptoms. [...]

Exploitation of SRSs

Semantic Archive of SRSs

- SRSs could be archived in a semantic repository (e.g. Sesame, Virtuoso), incrementally fed
- Enables to:
  - fine-tune the decision support strategies implemented in the DSS
  - strengthen the cases selection in case-based reasoning DSSs
  - expose to the world the DSS processing in LOD format, favoring its exploitation by other applications/web-services
  - easily compute relevant statistics

On Engineering the DSKB

- Checks on the DSKB
  - formal consistency check
  - correct instantiation with the usage in the DSS
- Assessment of the adequacy of the DSKB for the DSS
  - all decision support problems to be supported by the DSS are formally representable in the Problem component
  - all the data relevant for the DSS are characterized in the Data component
  - all the conclusions and explanations to be generated by the DSS are formalized in the Conclusions component
- In PESCaDO:
  - Problem: all the types of problems defined in the use cases can be represented
  - Data: environmental experts assessment (appropriateness: 94% - completeness: 92%)
  - Conclusions: environmental experts assessment (appropriateness: 90% - completeness: 87%)

Conclusions

- We propose to adopt an ontology-based knowledge base as the main data structure in DSSs
- Each decision support request submitted to the DSS corresponds a semantic request script which describes
  - the request itself
  - the data relevant for the request
  - the conclusions/suggestions/decisions generated by DSSs
- Demonstrated the advantages in a concrete implementation for an environmental DSS (PESCaDO EU project)
  - integration of heterogeneous sources of data available in the web (e.g., web sites, web services)
  - tracking and exposure in a structured form of all the content processed and produced by the DSS for each request
  - exploitation of logical reasoning for several of the inference steps of the DSS decision-making process

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(most of them downloadable from my web-page)

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Use of the ontology in PESCaDO

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Thank you! Questions?

Marco Rospocher

rospocher@fbk.eu
https://dkm-static.fbk.eu/people/rospocher
@marcorospocher

Fondazione Bruno Kessler
Trento, Italy