A profile-aware methodological framework for collaborative multidimensional modeling

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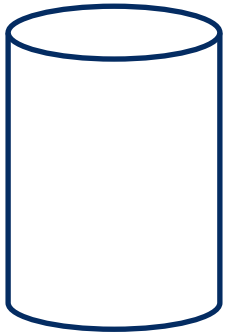
10TH INTERNATIONAL CONFERENCE ON DATA SCIENCE, TECHNOLOGY AND APPLICATIONS

Citizen observatories

Existing Scenario
&
Problems



Citizens collect data

Researchers work on data

Researchers define indicators and maps

Volunteer data is « bad quality » data

Decision-makers, stake-holders and citizens do not understand results

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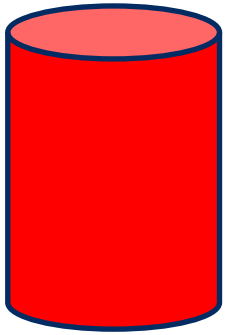
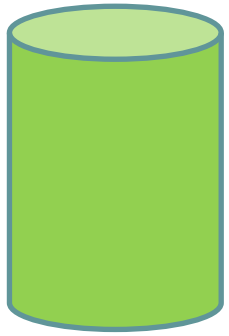
Citizen observatories

Our vision

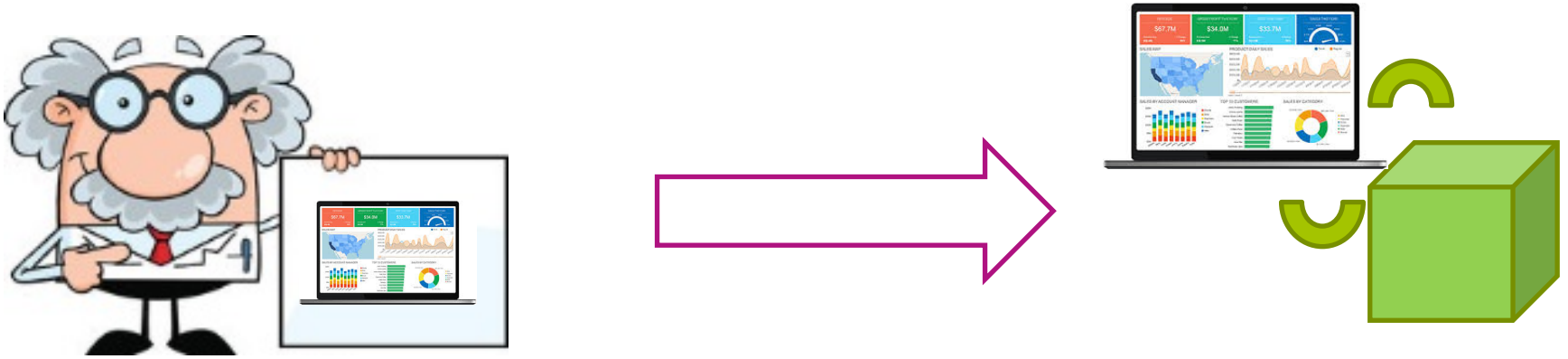


Citizens collect data



Researchers work on data quality

Researchers & citizens co-design indicators



Researchers implement indicators (data and maps)

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Researchers & citizens analyze indicators

Researchers & citizens work togheter

Plan

- Background
- Case study
- Requirements

- Preliminaries
  - ICSOLAP & ProtOLAP
- Our new methodology
  - E-Pivot Table
  - Quality
  - Collaborative design
  - Experiments

- Conclusion & Future work

Background

Citizen science (1/2)

- Citizen science has been defined as an *“online, distributed problem-solving and production model*"
- Relies on crowdsourcing, i.e., on a large pool of people gathering inputs such as ideas, funding, etc.
- Volunteers:
  - provide data and
  - collaboratively edit them,

  despite not being formally trained experts in the application domain

Citizen science (2/2)

- Citizen science has been applied in several application domains
  - Urbanism
  - Traffic jam
  - Ecology
  - Natural risks
  - …
- Examples are crowdsourcing systems are numerous
  - OpenStreetMap, OpenEI, Wikipedia, etc.

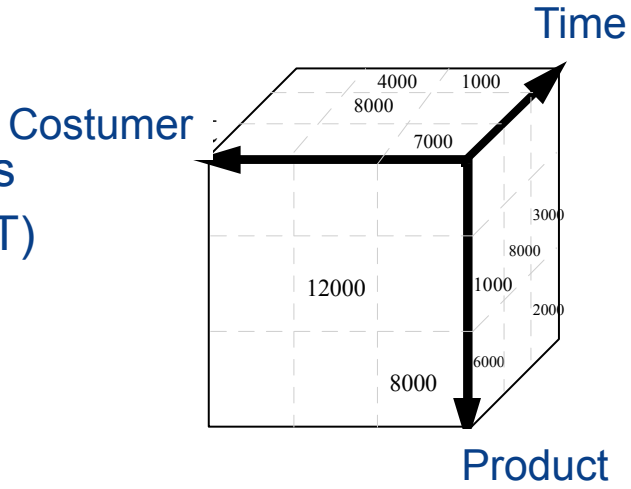
Data Warehouse & OLAP (1/4)

- Data warehouse is: "*A collection of integrated, subject oriented, time-variant, and non-volatile data from various sources into a single and consistent data repository to support decision-making*" (Inmon, 1996)

Cube

Facts, measures, dimensions, and hierarchies

Aggregations (SUM, MIN, MAX, AVG, COUNT)

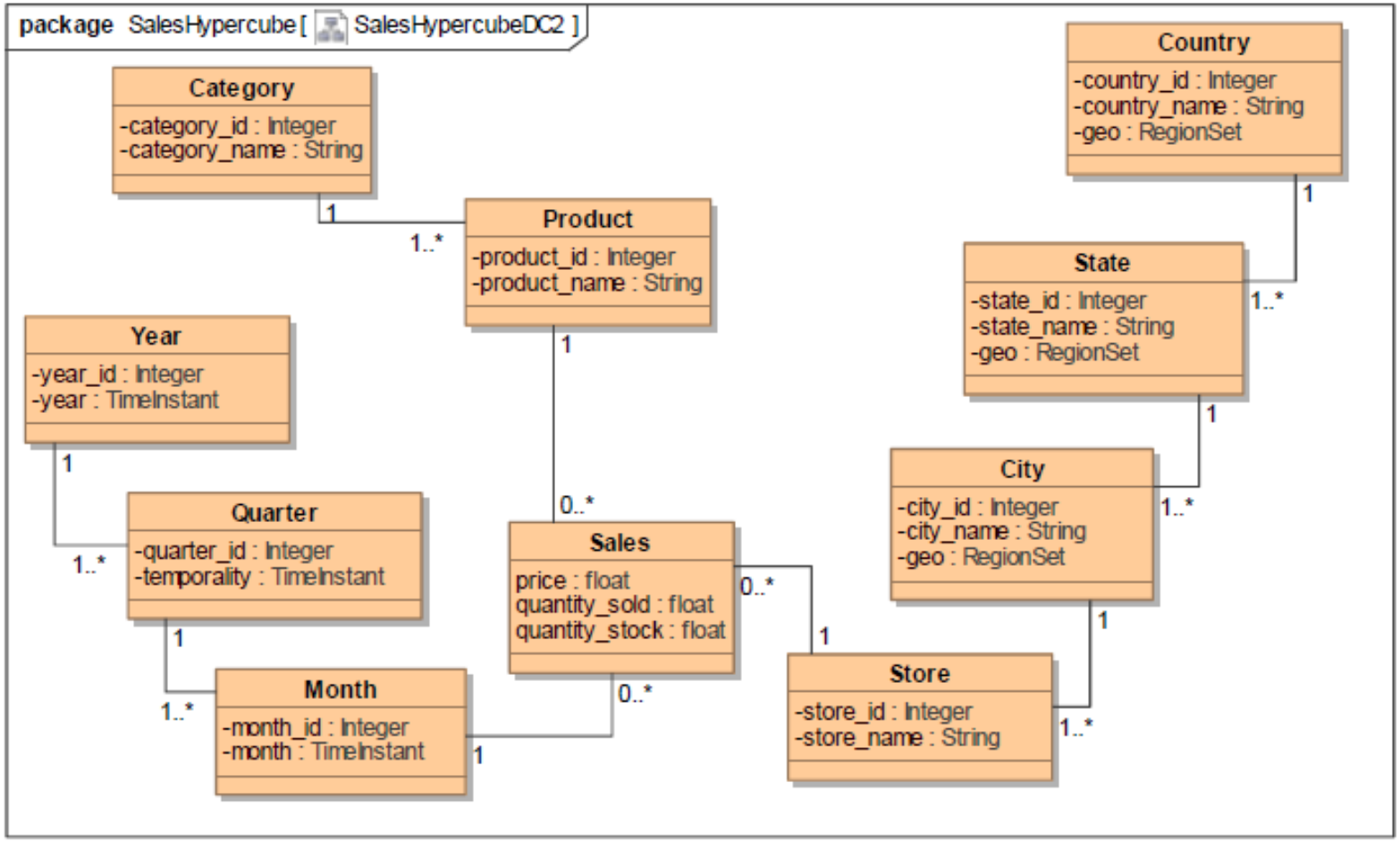


Data Warehouse & OLAP (2/4)

- OLAP analysis
  - Drilling, Slicing, pivot, etc.
  - Interactive analysis and aggregation of huge volume of data

- OLAP : "*A visual platform built especially to support rapid and easy spatiotemporal analysis and exploration of data following a multidimensional approach comprised of aggregation levels available in tabular and diagram displays*"

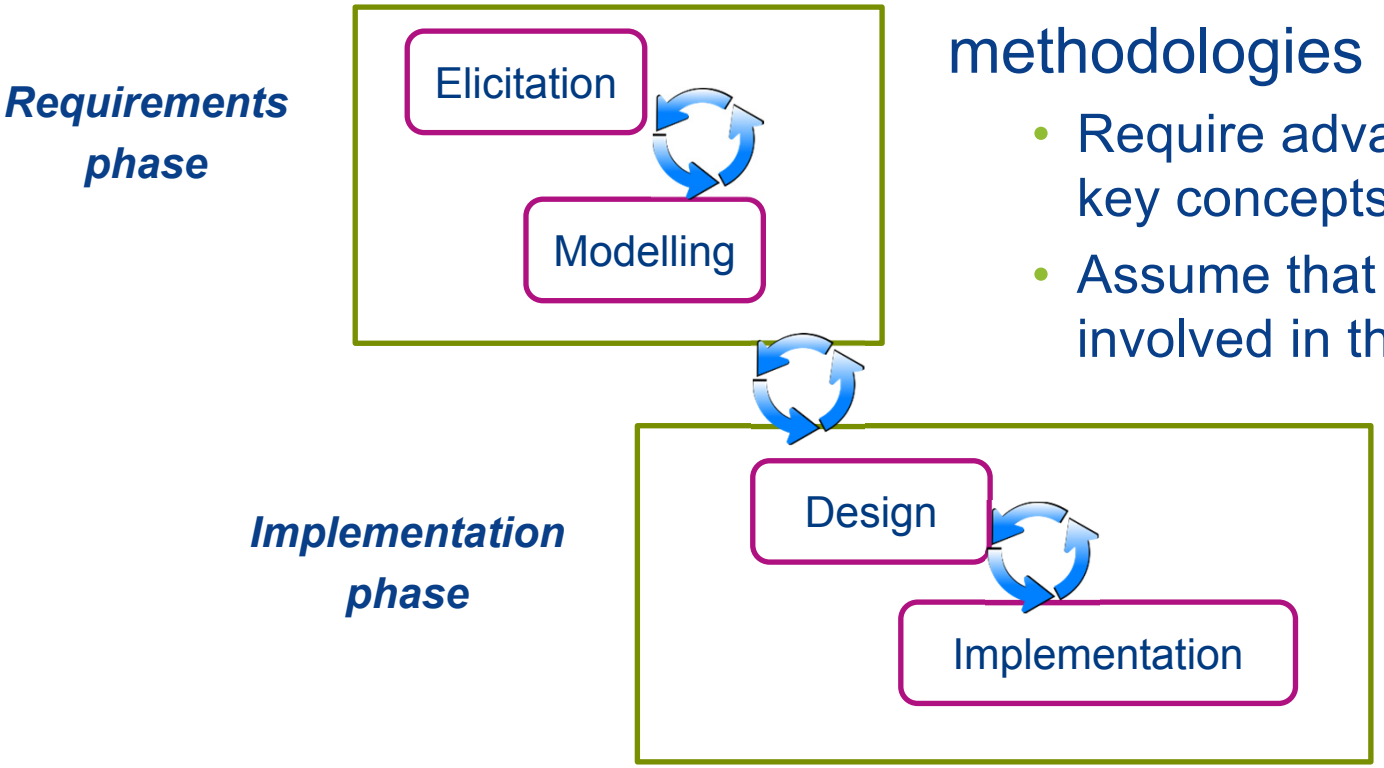
Data Warehouse & OLAP (3/4)



✓ *What is the total sold by month and city at 50 Km far from Paris*

Data Warehouse & OLAP (4/4)

- DW design process steps:



Classical DW elicitation methodologies

- Require advanced knowledge of key concepts of DW modeling
- Assume that users are actually involved in the whole project

Group Decision Support Systems

- Group Decision Support Systems (GDSSs): "*Interactive computer-based environments that support concerted and coordinated team effort toward completion of joint tasks*"

- Group facilitation is defined as a process in which a person (***facilitator***), who is considered as trustworthy by all the group members, intervenes to help improve the way they identify and solve problems, and make decisions.

Case study

- Bimonte, S. et al. **VGI users & data centered methods for the analysis of farmland biodiversity indicators open issues**. AGILE 2018, AGILE 2018 – Lund, June 12-15, 2018

- Bimonte, S. et al. **Collect and analysis of agro-biodiversity data in a participative context: A business intelligence framework.** Ecol. Informatics 61: 101231 (2021)

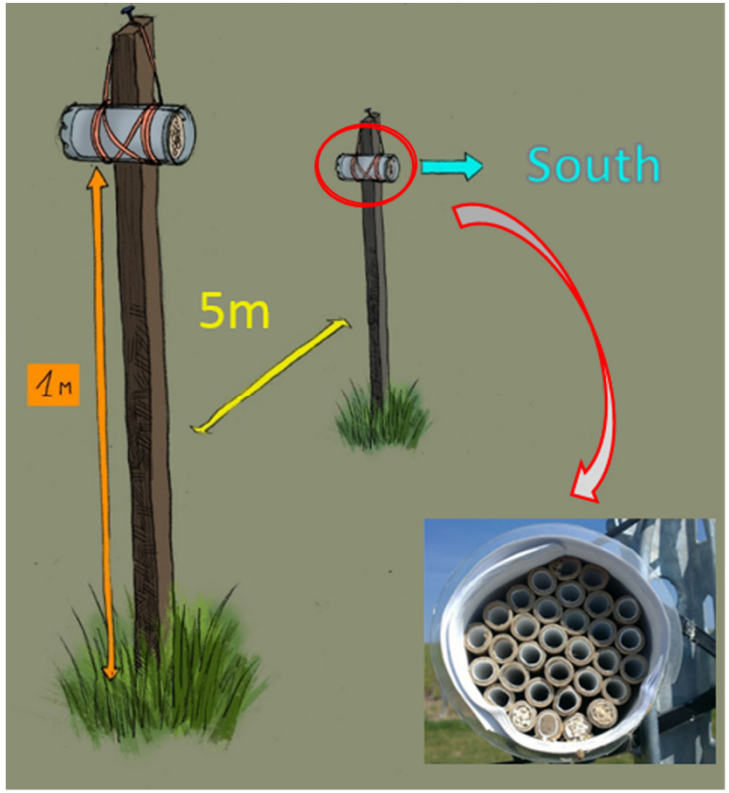
- VGI4Bio.fr

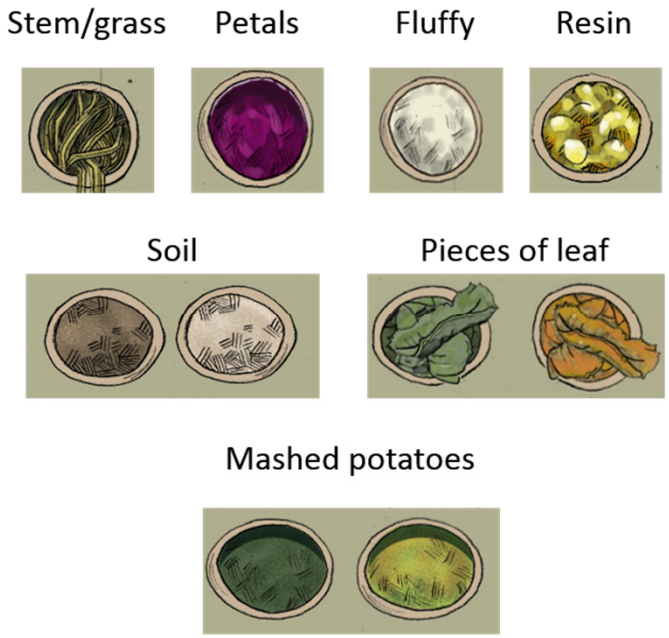
Case study (1/3)

- Project ANR VGI4Bio (www.vgi4bio.fr)
  - mobilize two volunteers databases (Visionature and Observatoire Agricole de la Biodiversité - OAB) to build OLAP applications to analyze farmland biodiversity indicators.
  - Visionature and OAB have 7682 and 1500 volunteers that produce data, respectively.
  - Possible users interested in analyzing these data:
    - the volunteers themselves that are interested in analyzing data to improve their data production quality, their related daily practices, etc.;
    - public and private organisms (DREAL, Chambre d'Agriculture, etc.).
  - These users are involved in the design of cubes
    - ***Unskilled OLAP, ICT users***

Case study (2/3)

- Example of data collection for pollinators





Case study (3/3)

- Example of OLAP analysis

departement	commune	(All) species	SOMME(abondance)
BAS-RHIN		All species	186
		COTON	7
		PETALES	0
	BLAESHEIM-CODE-INSEE:67049	All species	75
		COTON	0
		PETALES	0
	BOLSENHEIM-CODE-INSEE:67054	All species	8
		COTON	4
		PETALES	0
	DUNTZENHEIM-CODE-INSEE:67107	All species	10
		COTON	3
		PETALES	0
HAUT-RHIN		All species	21
		COTON	0
		PETALES	0
	LAPOUTROIE-CODE-INSEE:68175	All species	6
		COTON	0
		PETALES	0
	ROUFFACH-CODE-INSEE:68287	All species	0
		COTON	0
		PETALES	0

Requirements

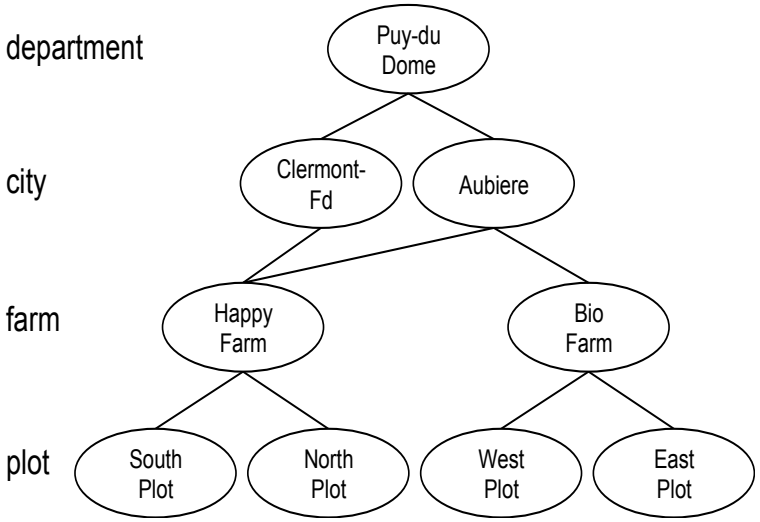
Sakka, A., et al. **Volunteer Data Warehouse: State of Art.** International Journal of Data Warehousing and Mining (to appear)

Requirements

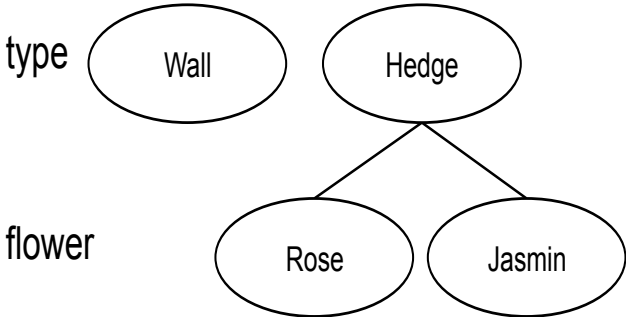
- Real life OLAP applications are quite complex
  - Complex hierarchies
  - Facts
  - Aggregations

Requirements

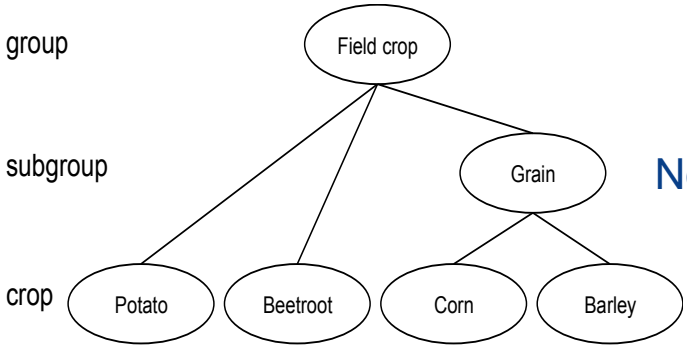
- Example of complex hierarchies



Non-strict



Non-onto



Non-covering

Requirements

- ***Requirement:*** Support complex Data Warehouse models

Requirements

- Citizen science introduces another type of actors in DW projects: volunteers

- They are numerous and different from employed actors of classical DW projects

Requirements

- From our experience

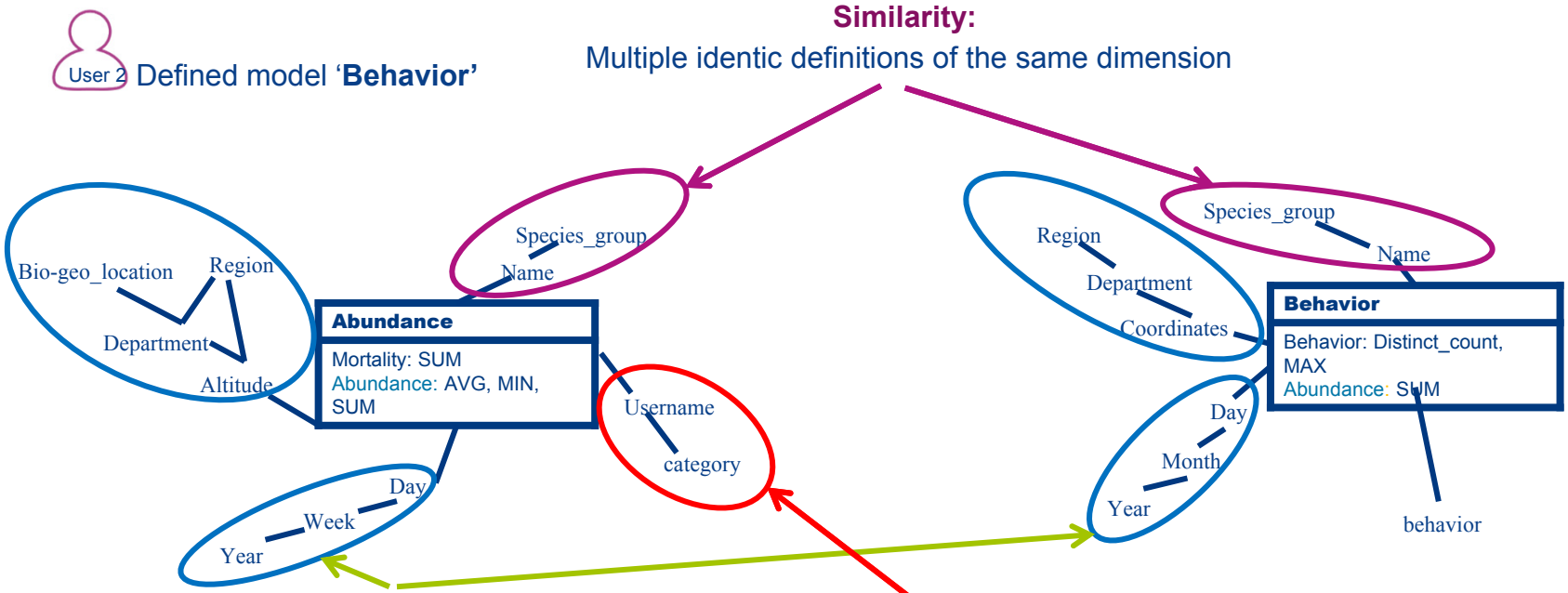
Criteria	Involved users	
	Volunteers	Employed
Knowledge of DW fundamentals	None / Very low	Low / Medium
Involvement in the overall BI project	Partial	Full
Geographical distribution	Very high	Very low
Understanding of the project goals	Low / Medium	Medium / High
Possibility of reaching unified vision	Very low	High
Proficiency in the subject matter	Medium	High / Very high
Availability to elicitation sessions	Low	High / Very high
Number	Very high	Very low

Requirements

- Volunteers define DW models that can present
  - Similarities, Differences, and Conflicts

User 1 Defined model '**Abundance**'

User 2 Defined model '**Behavior**'



Requirements

- Handling ***divergent requirements***
- Handling ***requirements rejection***

=> ***Requirement:*** Provide an additional design step with more engaged volunteers (i.e. ***committers***) to finalize missing elements and solve requirements conflicts

Requirements

- For volunteers is very difficult to validate the quality (completeness, minimality, relevance, etc.) of the provided DW schemata
  - Example: is the schema complete?, are some dimensions missing (such as for example land use, or urban network)?

Requirements

- ***Requirement:*** the methodology must:
  - be accompanied by some semi-structured interviews that allow guiding volunteers to identify the multidimensional schema problems in terms of semantic quality (i.e. **quality based design**)
    - The quality associated with data (such as distributive, normalization, etc.) is let to the DW experts since it depends on the structures of the DW
  - be supported with some tools that allow correct (modify, delete, add) the DW schema elements that appears erroneous (i.e. ***edit actions***)
    - Example: the temporal level 'week' could be removed since it is not explicative of any natural phenomena and is not useful for the analysis

Requirements

- Due to the huge number of volunteers that might have many different needs in this project, providing an implementation for each proposed model is unrealistic because of its high human, temporal and financial costs

- ***Requirement:*** Reduce as much as possible time process from elicitation time to the prototypes (i.e***. early rapid prototyping***)
  - Example: in our case study we have 15 volunteers and each volunteer produce 3-5 DW schema in a very time expensive process

Requirements

- ***Requirement:*** Usage of a ***very simple elicitation formalism*** because of volunteers have none or very low knowledge of DW fundamentals
  - Example: in our case study, some OAB volunteers are not comfortable also with uploading their data using a simple web page. They cannot understand complex design decision-making systems

	Handling Divergent Requirements	Handling Requirements' Rejection	Quality Based Elicitation	Correction Actions	Prioritization	Committers Involvement	Early Rapid Prototyping	Simple elicitation	Distributed Time/Space	Design Approach
Bonifati et al. 2001	Manually	-	-	-	-	-	-	Interviews	-	Hybrid
Winter et al.2003	-	-	-	-	Yes	-	-	-	-	Req-driven
Paim et al. 2003	Review sessions, Prototyping	Review sessions, Prototyping	-	-	-	-	-	Interviews, Workshops, Scenarios	-	-
Nabli et al. 2005	-	-	-	-	-	-	-	2D sheets	-	Req-driven
Guo et al. (2006)	-	-	-	-	-	-	-	Interviews	-	Hybrid
Gam et al (2007)	Map formalism	-	-	Yes	-	-	-	Map Formalism	-	Req-driven
Giorgini et al. 2005-2008	-	Basic operation DW-tool	-	-	-	-	-	Interviews, TROPOS	-	Req-driven/ Hybrid
Prakash et al. 2008	-	-	-	-	-	-	-	GDI model	-	-
Jucik et al. (2010)	-	-	-	-	-	-	-	Interviews, Questionnaires, Feedbacks	Yes	-
Romero et al.2010	-	-	-	-	-	-	-	Filtering functions	-	Req-driven
Cravero et al(2013)	-	-	-	-	-	-	-	-	-	Req-driven
Khouri et al. 2014	Semantic ontologies, Pivot model	-	-	-	-	-	-	-	-	Req-driven
Kumar et al.(2014)	Review sessions	-	-	-	-	-	-	Interviews, Workshops, Prototyping, Use cases, GDI, DWARF …	-	-
Di-Tria et al(2015)	-	-	-	-	-	-	-	-	-	Hybrid
Elavin et al (2017)	-	-	-	Yes	-	-	-	NL	-	Req-driven
Nasiri et al. 2017	-	-	-	-	-	-	-	Guidelines	-	-
Ren et al. (2018)	Semantic ontologies	-	-	-	-	-	-	-	-	Req-driven

Preliminaries

ICSOLAP & ProtOLAP

ICSOLAP

•Boulil, K. et al. **Conceptual model for spatial data cubes: A UML profile and its automatic implementation**. Comput. Stand. Interfaces 38: 113-132 (2015)

•https://www.youtube.com/watch?v=2VQUrmU1yYk

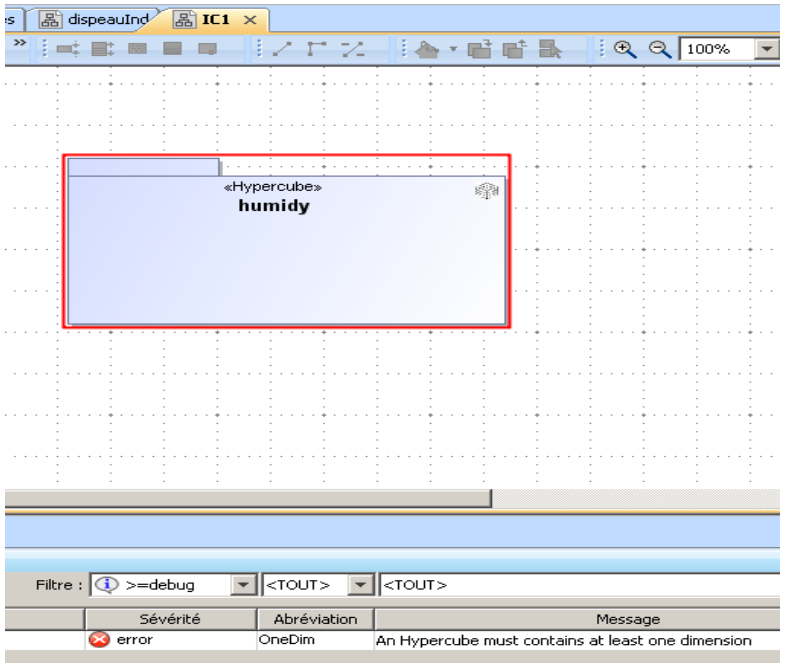
•**Available as Opensource for MagicDraw and Eclipse CASE tools**

ICSOLAP UML Profile (1/2)

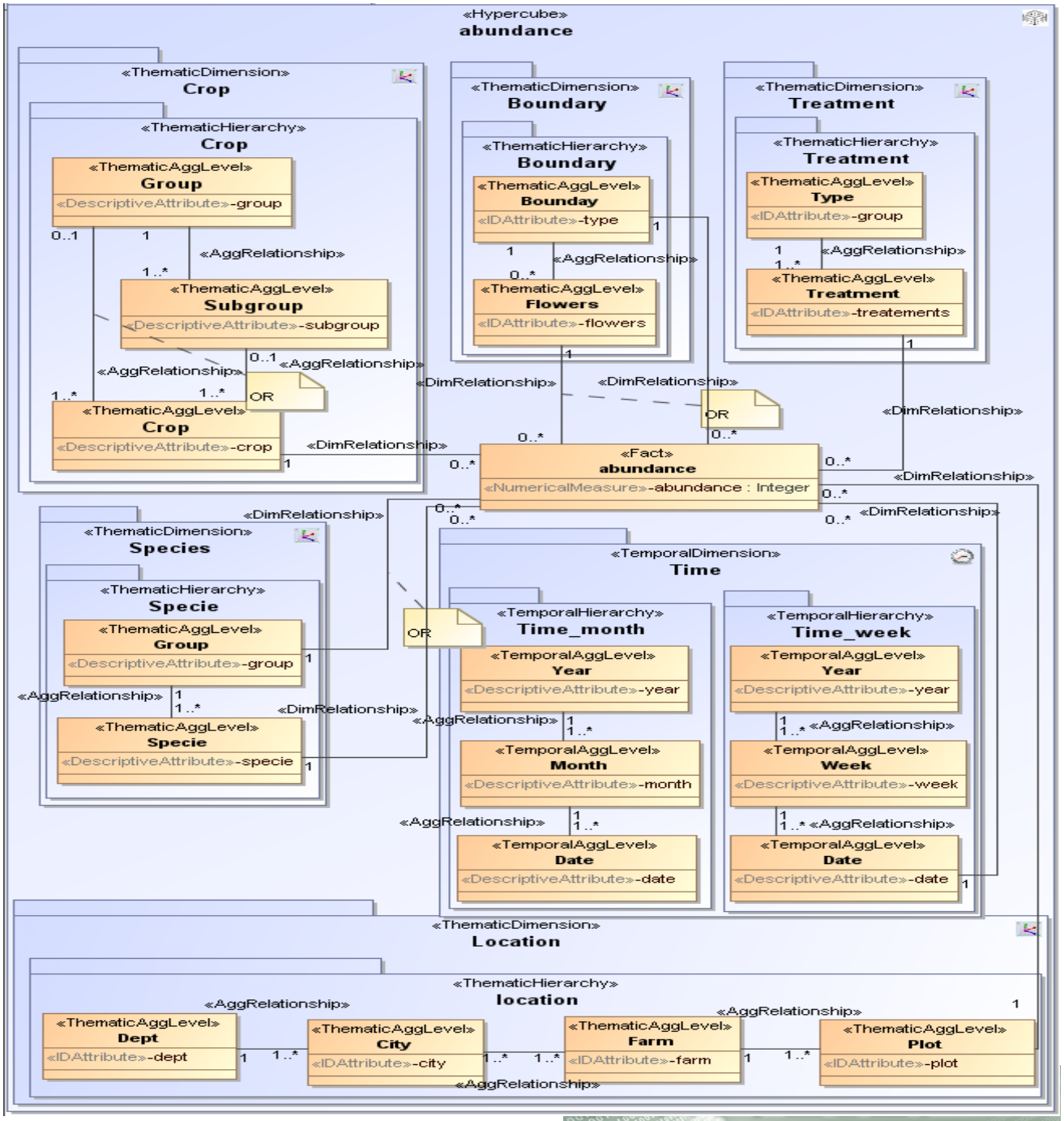
- To support advanced conceptual modeling we use in our framework the ICSOLAP UML Profile
- Our UML profile allows modeling advanced multidimensional issues:
  - complex dimensions (non-covering, non-onto and multiple hierarchies),
  - spatial dimensions,
  - multigranular facts,
  - complex aggregations, etc.
- We have successfully used ICSOLAP in several real applications: energy consuming, water quality, biodiversity

ICSOLAP UML Profile (2/2)

- We have implemented our profile in the commercial CASE tool MagicDraw
- OCL constraints are checked at design time



VGI4bio DW schema for the analysis of biodiversity in agricultural plots



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ProtOLAP

- Bimonte, S. et al. **ProtOLAP: rapid OLAP prototyping with on-demand data supply**. DOLAP 2013: 61-66

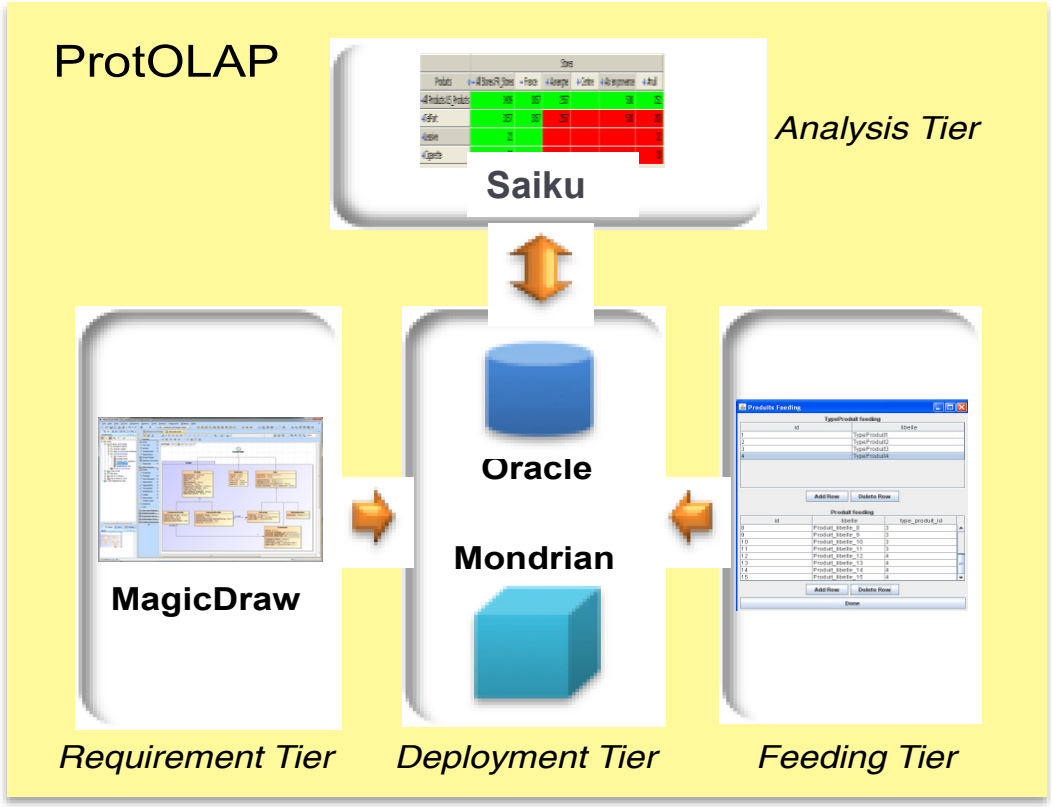
- Bimonte, S. et al.**Volunteered Multidimensional Design to the Test: The Farmland Biodiversity VGI4Bio Project's Experiment**. DOLAP 2019

- https://www.youtube.com/watch?v=WNHEwi4e3bg

- **Available as Opensource**

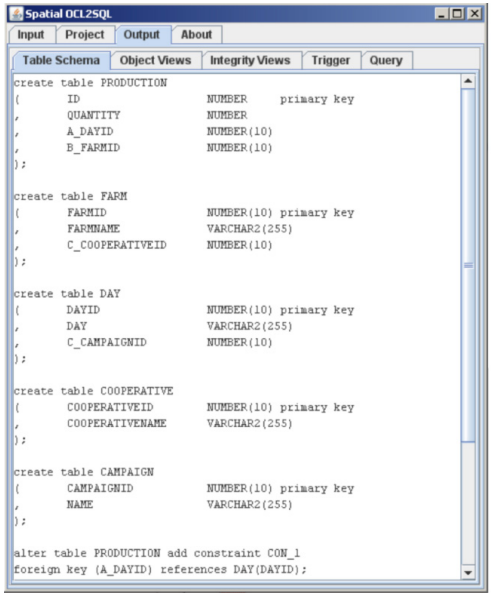
ProtOLAP

- ProtOLAP: methodology and tool for rapid DW prototyping



ProtOLAP tool (1/2)

- ProtOLAP takes as input the XMI file representing the ICSOLAP conceptual schema
- It automatically generates:
  1. the relational schema
  2. Mondrian XML metadata representing multidimensional elements, and the MDX-based calculated members for complex indicators
- This phase is completely automated without any intervention of designers → this accelerates software development and promotes standard processes

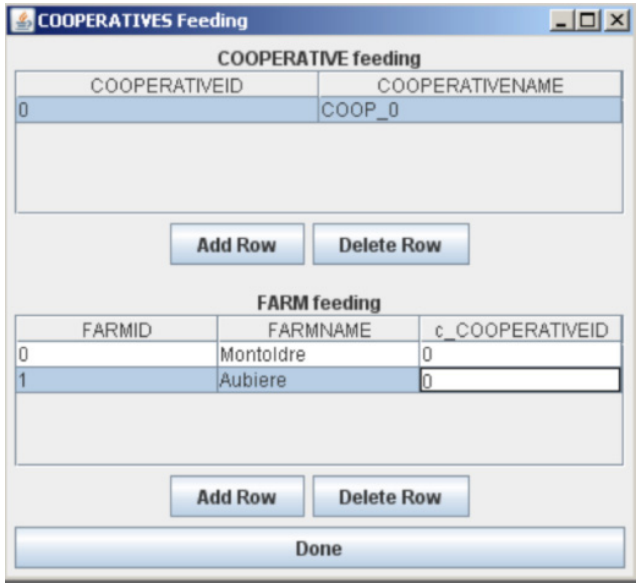



```
<!-- The Mondrian definition of the EDEN indicators -->
<Measure name="sum" column="QUANTITY" aggregator="sum" visible="false" formatString="Standard" />
- <CalculatedMember name="AVG-SUM" dimension="Measures" visible="true" formatString="#,###.##">
    <formula>Max(Descendants([COOPERATIVES].CurrentMember, [COOPERATIVES.NodesHierarchy].[FARM]),[Measures].
    [sum])</formula>
  </CalculatedMember>
</Cube>
```

ProtOLAP tool (2/2)

- A visual interface to feed both dimensions members and facts

- Example of dimensions feeding:
  - automatically create dummy members to saving time (e.g. temporal dimension)
  - manually by letting decision-makers insert the name of members to provide a better understanding (e.g. product dimension)



Our new design methodology

- Sakka, A. et al. **A profile-aware methodological framework for collaborative multidimensional modeling**. Data Knowl. Eng. 131-132: 101875 (2021)

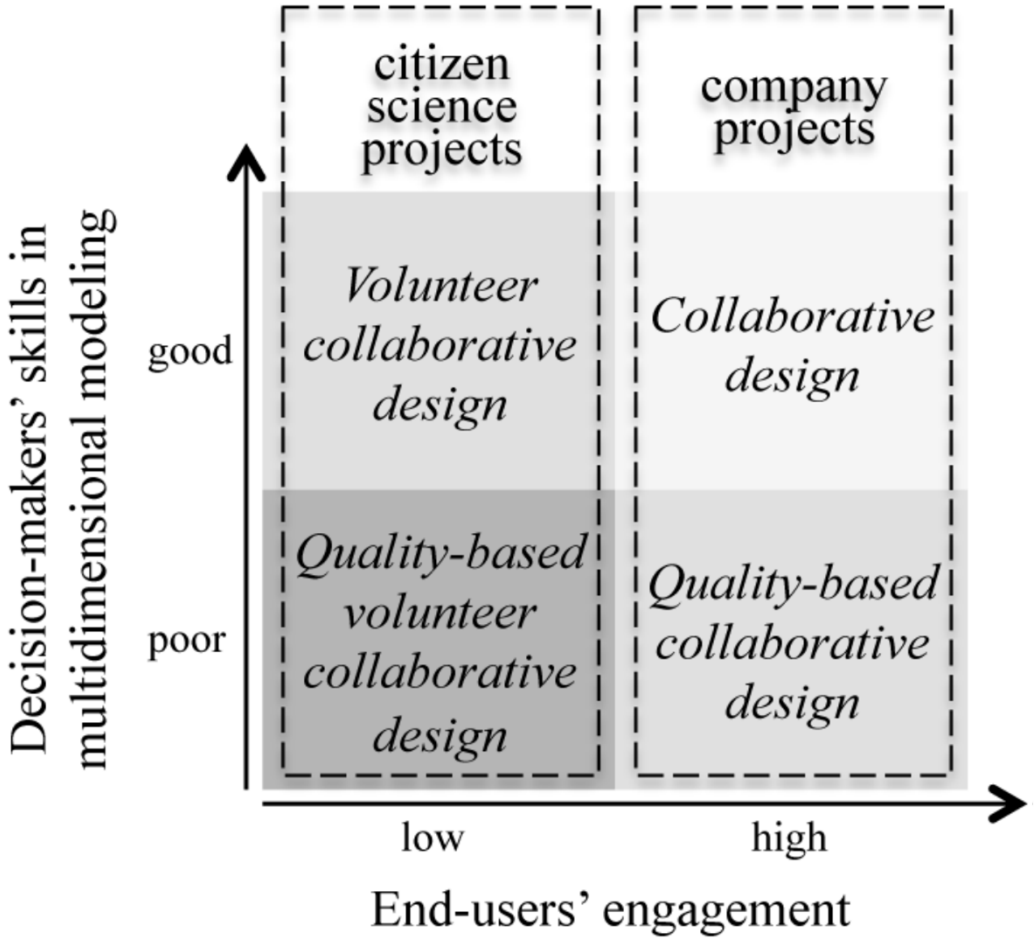
- Bimonte, et al. **Requirements-driven data warehouse design based on enhanced pivot tables.** Requir. Eng. 26(1): 43-65 (2021)

- Sakka, A. **A Volunteer Design Methodology of Data Warehouses.** ER 2018: 286-300

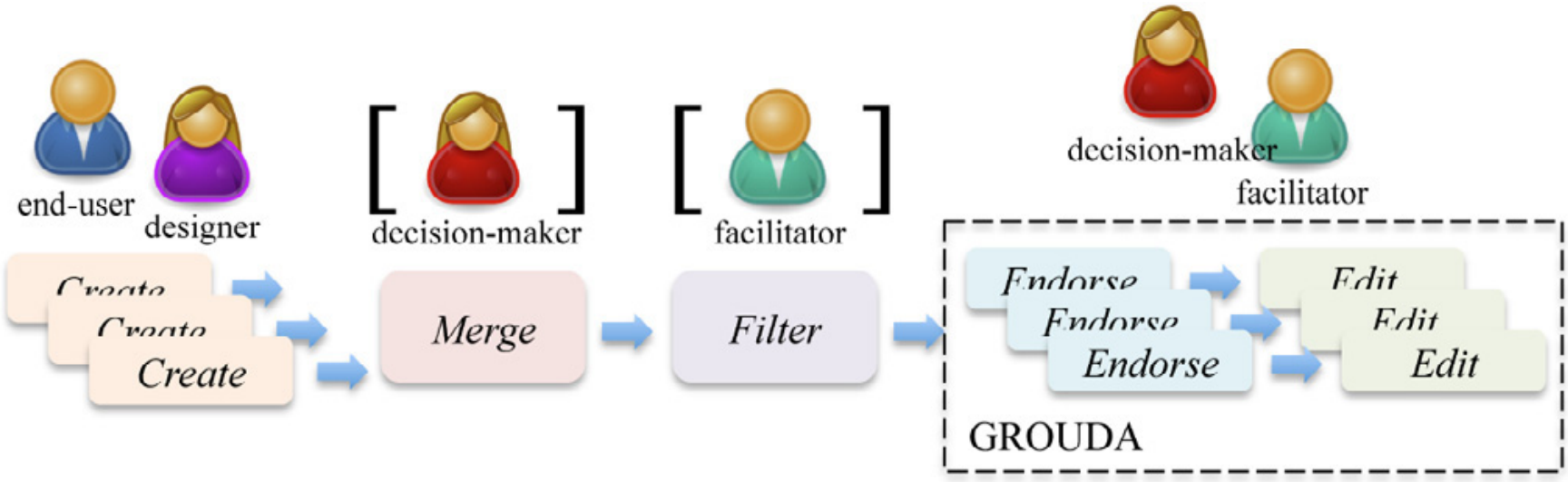
DW Users Classification (1/2)

- We classify users based on their authoritativeness:
  - **(non-authoritative) *end-users***: just express analysis requirements,
  - **(authoritative) *decision-makers***: validate the end-users requirements and integrate them with their own requirements

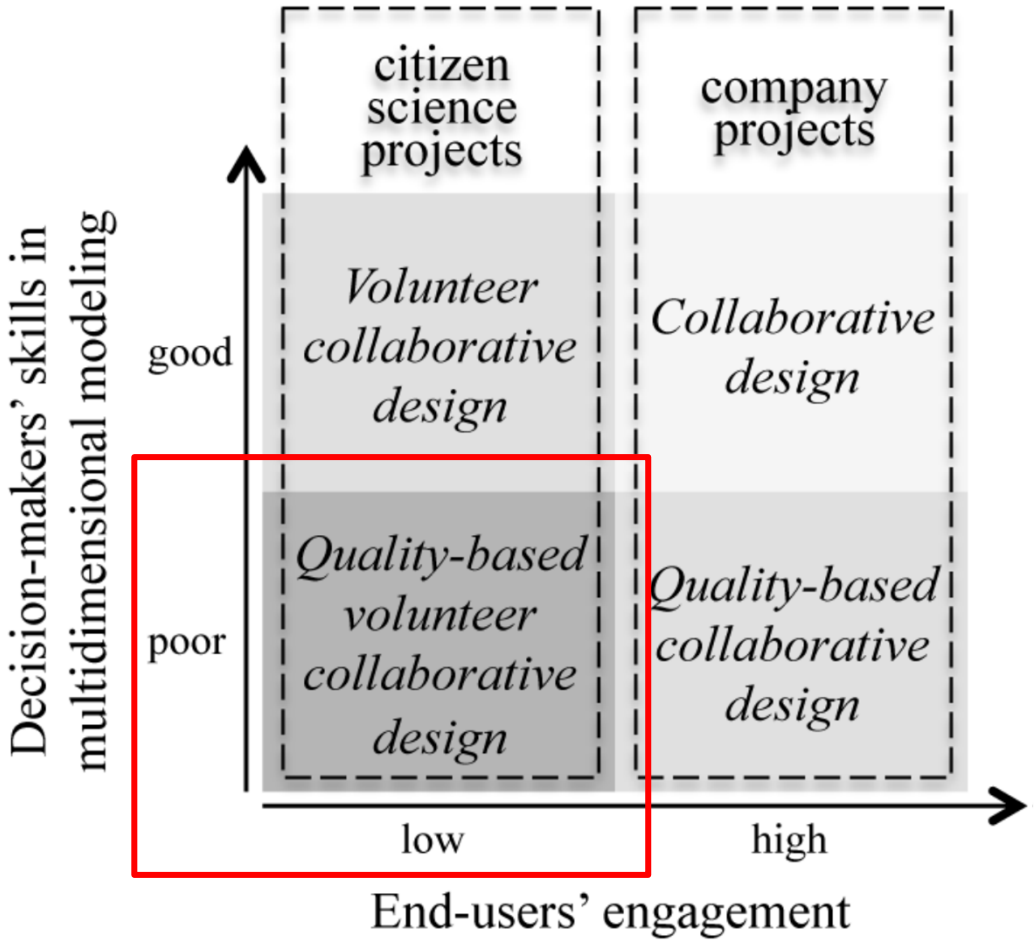
DW Users Classification (2/2)



Methodology overview



Quality-based volunteer collaborative design methodology



Quality-based volunteer collaborative design methodology

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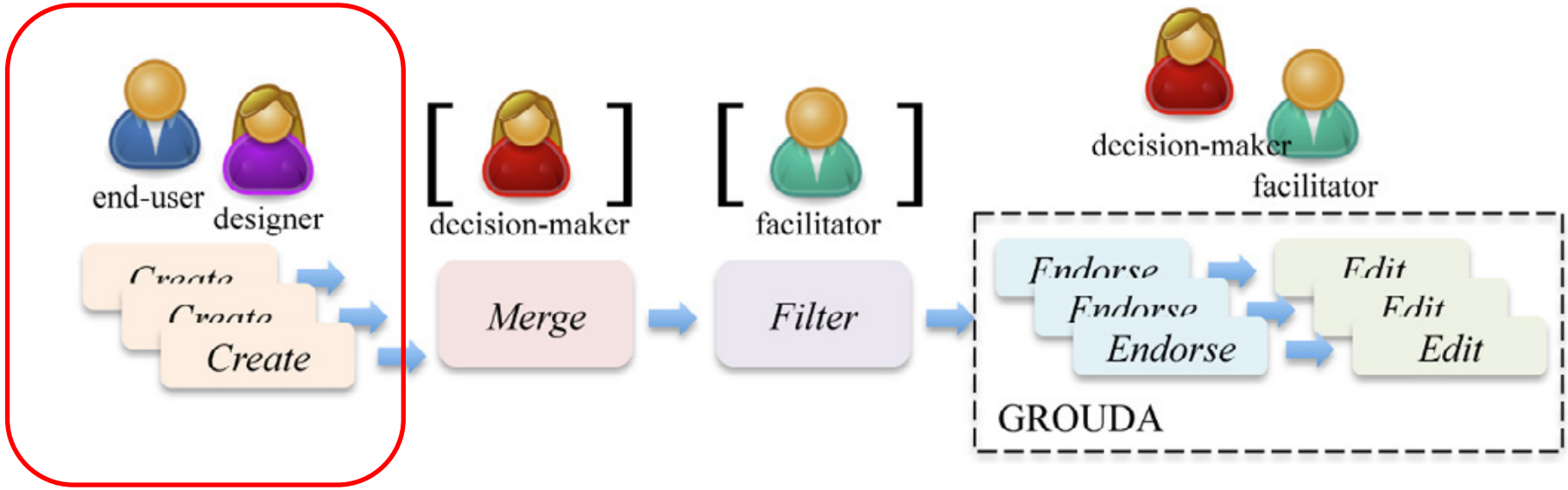
Quality-based volunteer collaborative design methodology



E-Pivot table requirement elicitation methodology

- Bimonte, S., L. Antonelli, S., Rizzi. **Requirement-Driven Data Warehouse Design Based on Enhanced Pivot Tables.** Journal Requirements Engineering (To appear)

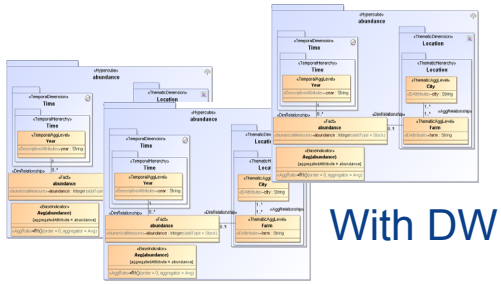
- https://www.youtube.com/watch?v=dQ5v8PNTiNY

E-Pivot table methodology

Volunteer

DW experts

E-Pivot Table

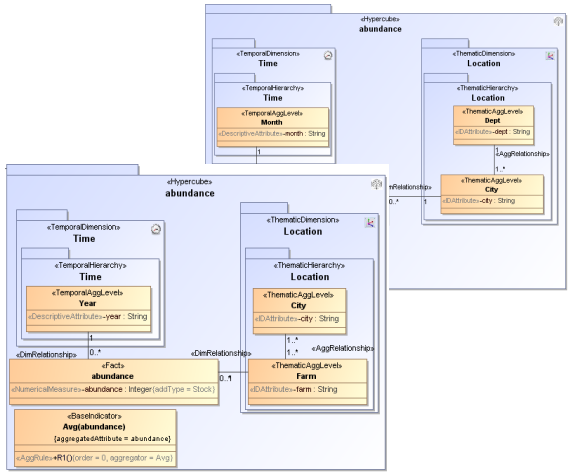


With DW prototypes

Volunteer

DW experts

E-Pivot Table



With DW prototypes

Requirements identification

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E-Pivot table methodology

- Classical Pivot table do not support complex hierarchies

		Measures
species	type_traitement	MOYENNE(SOMME(MAX(abondance)POUR:annee)POUR:parcelle)
−All species	+All type_traitements	1.727
PETALES	+All type_traitements	0.098
RESINE	+All type_traitements	0.108
COTON	+All type_traitements	0.491
HERBES	+All type_traitements	1.106
MORCEAUX-DE-FEUILLES	+All type_traitements	1.273
FEUILLES-MACHEES	+All type_traitements	2.069
TERRE---BOUE	−All type_traitements	6.943
	+MOLLUCIDE	5.876
	+FONGICIDE	6.592
	+AUTRE	6.653
	+HERBICIDE	6.789
	+TOUT TRAITEMENT	6.801
	+INSECTICIDE	6.902
	+PAS DE INSECTICIDE	6.962
	+PAS DE AUTRE	6.991
	+PAS DE HERBICIDE	7.086
	+PAS DE TRAITEMENT	7.142
	+PAS DE MOLLUCIDE	7.179
	+PAS DE FONGICIDE	7.231

Slicer:

E-Pivot table based methodology

- Pivot tables are queries over DW
  - Can be formally translated into DW models (Nabli et al., 2005)
  - Represent
    - Schema
    - Data
    - Aggregation

- **Decision-makers are familiar with pivot tables**

E-Pivot table methodology: steps (1/4)

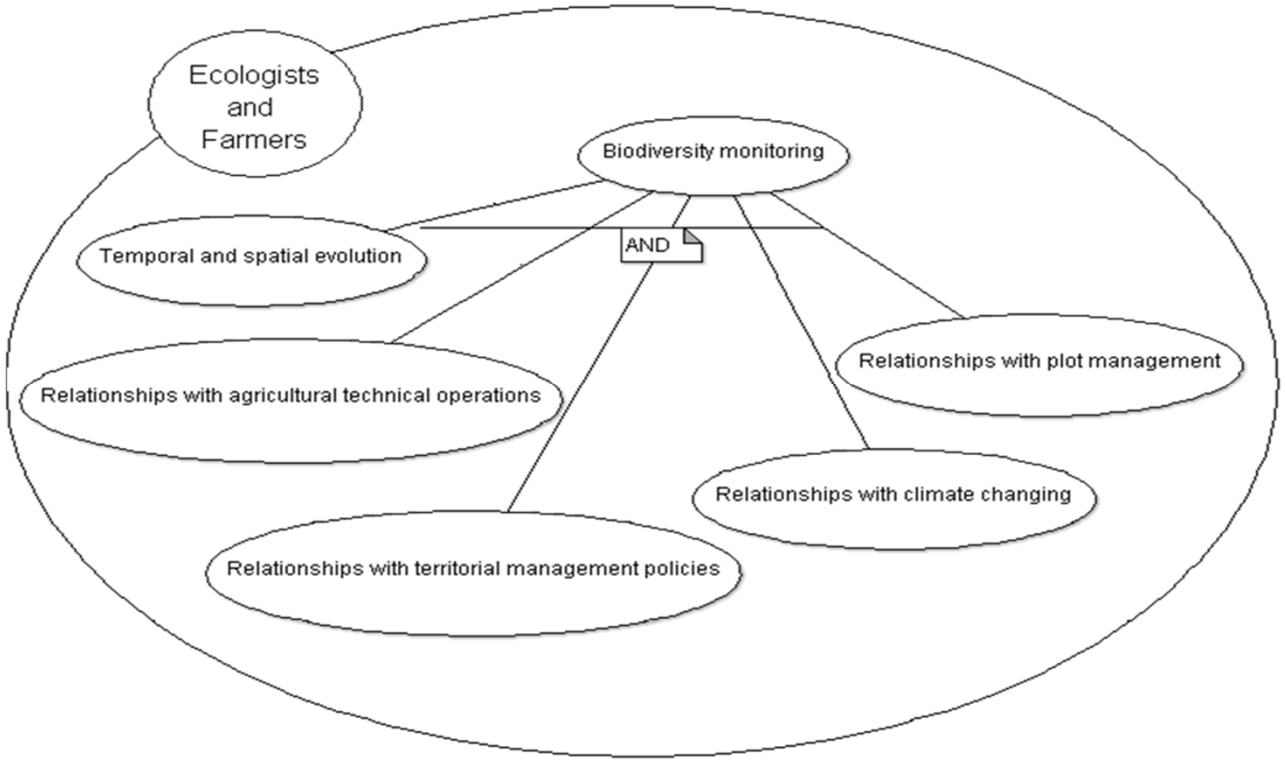
- 0. ***Tutorial***. Presenting some existing OLAP applications to the decision makers, and explains to them the main concepts of DW and OLAP

- 1. ***Goal modeling*** `(input: interviews; output: goal model)`

Creating a model that defines the analysis goals and subgoals of each decision maker (Giorgini et al., 2008)

E-Pivot table methodology

- ***Goal modeling*** example



E-Pivot table methodology: steps (2/4)

- 2. ***E-Pivot table modeling*** `(input: goal model, semi-structured interviews; output: e-pivot tables model)`

Refining the requirements specified in the goal models previously created

  - First, decision makers express detailed requirements for each goal/subgoal by drawing e-pivot tables.
  - Basically, e-pivot tables enhance classical pivot tables by establishing a graphical convention to visualize data in irregular hierarchies.
  - Then, DW experts use a semi-structured interview to ask some specific questions to decision makers about their e-pivot tables in order to understand their needs better, and to incite decision makers to reason about possible errors and changes to be made.

E-Pivot table based methodology

- Examples of complex structures

strict hierarchy (a)

non-strict hierarchy (b)

non-onto hierarchy (c)

non-covering hierarchy (d)

many-to-many fact-dimension relationship (e)

multigranular fact (f)

Location		Time		Avg(abundance)
department	city	year	month	
Haut-Rhin	Lapoutroie	2018	Sep-18	13
Haut-Rhin	Rouffach	2018	Oct-18	12
Bas-Rhin	Strasburg	2018	Oct-18	14

(a)

Location		Time	Avg(abundance)
city	farm	year	
Aubiere	Happy Farm	2017	13
Clermont-Fd			
Aubiere	Bio Farm	2017	12
Aubiere	Bio Farm	2018	14

(b)

Boundary		Location	Avg(abundance)
type	flower	plot	
Wall		West Plot	12
Hedge	Rose	East Plot	15
Hedge	Jasmin	North Plot	13

(c)

Crop			Time	Avg(abundance)
group	subgroup	crop	month	
Field crop		Potato	Sep-18	12
Field crop	Grain	Corn	Oct-18	15

(d)

Treatment		Time	Avg(abundance)
type	product	year	
Fungicide	Prosaro	2018	12
Fungicide	Joao		
Fungicide	Joao	2017	13

(e)

Species		Time	Avg(abundance)
group	species	year	
Butterfly	———	2018	12
Butterfly	Pieris	2018	14

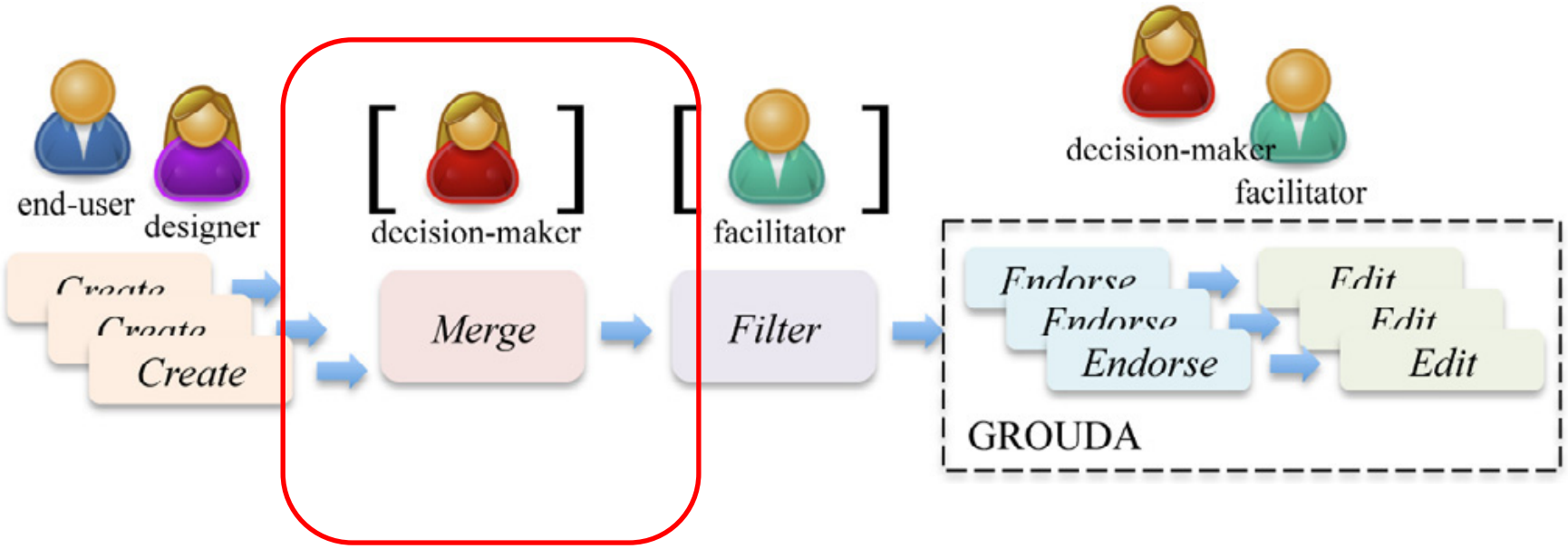
(f)

E-Pivot table methodology: steps (4/4)

- 4. ***Implementation*** (input: DW schema based on the ICSOLAP profile; output: SQL statements, Mondrian XML for DW prototype, and pivot tables issued from the DW prototype

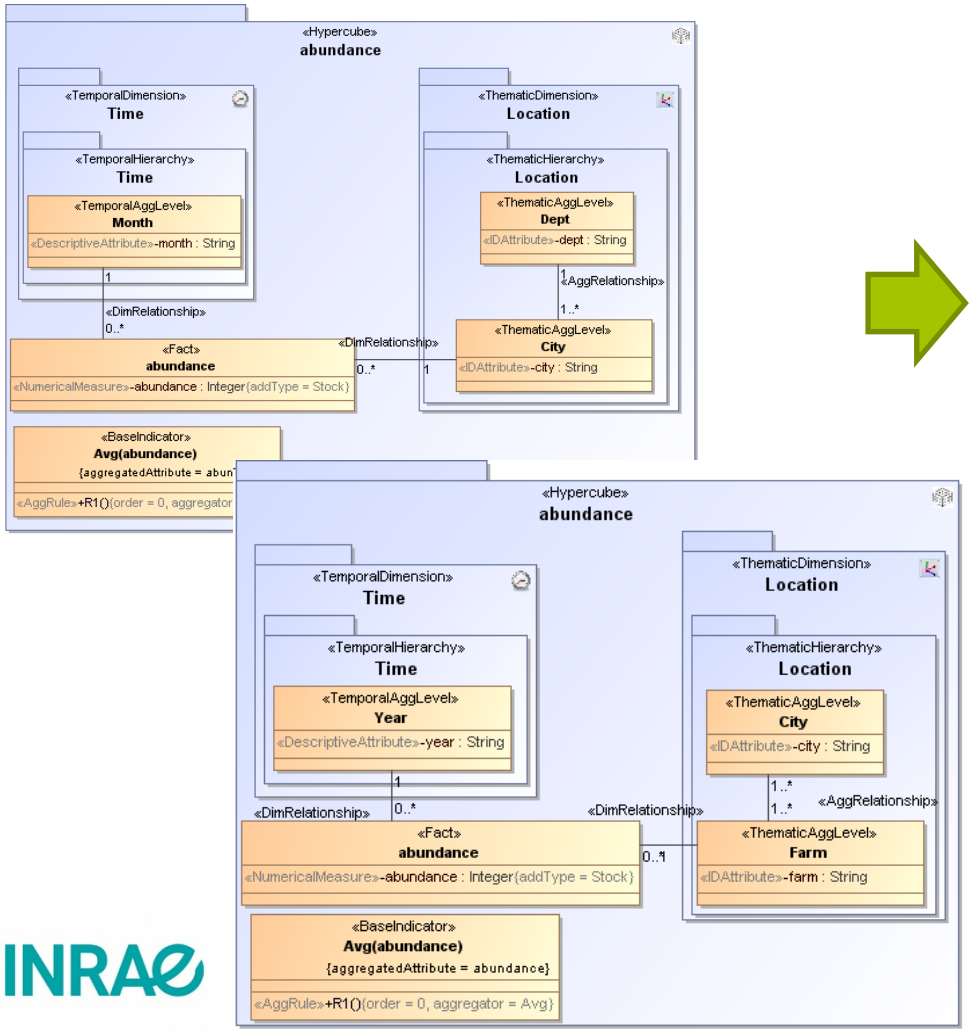
For each ICSOLAP model, the DW experts implement a prototype of the DW using ProtOLAP and show it to the decision makers

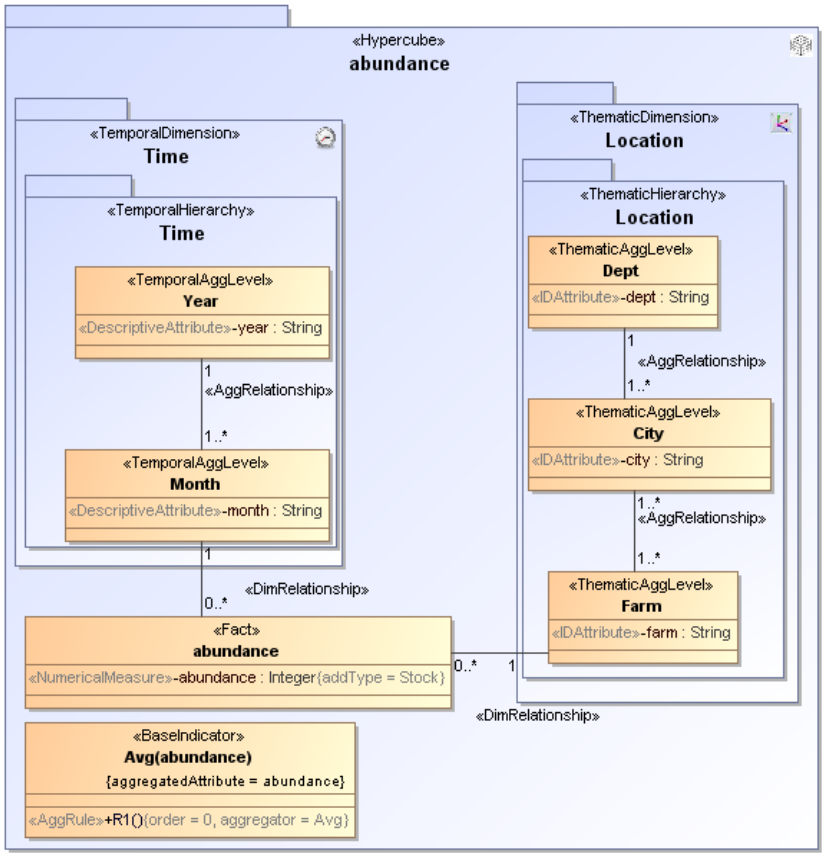
Quality-based volunteer collaborative design methodology



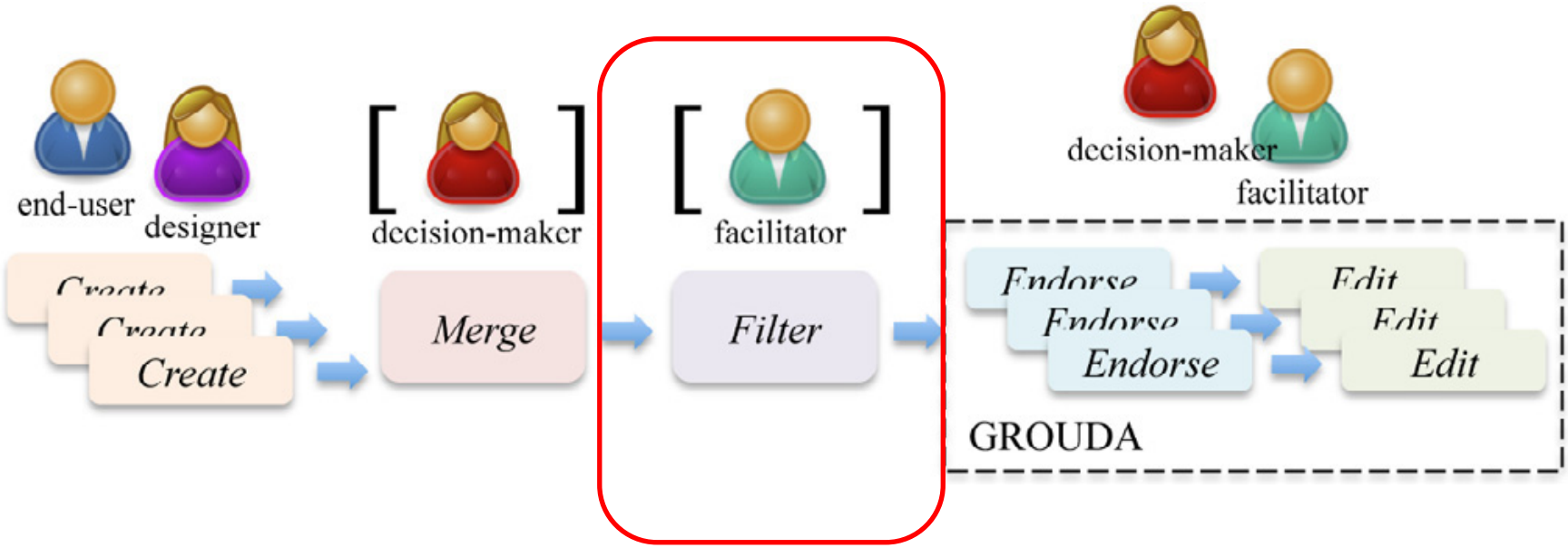
Merge

- Semi-automatic algorithm





Methodology overview



Quality: Filter

- *Trustworthiness* metric: assessing the reputation and reliability of end-users
  - It represents the degree of confidence that can be associated to each level and each indicator suggested by end-users
- Based on three factors: *Expertise, Reputation, Attractiveness*

Quality: Filter

- *Expertise* of end-user i ($Expi$)
  - Each end-user indicates her degree of expertise concerning the application domain of the cube schema using the ordinal scale {'low'; 'medium'; 'high'; 'expert'}

Quality: Filter

- *Reputation* of volunteer i. Reputation belongs to the community, not to the person whose trust was evaluated and it depends on many factors, including the previous behavior of that person

- $Repi = f(1 - rdi/di)$ where:
  - rdi represents the number of rejected data entries made by i;
  - di represents the number of all data entries entered by i (therefore $rdi \leq di$);
  - f is a function with domain and codomain [0,…, 1]

  - In our case study $Repi = (1 - rdi/di)^2$

Quality: Filter

- *Attractiveness* represents the "popularity" of a multidimensional element within the proposed cube schemata, and provides an important measure of its quality. Indeed, according to the *many eyes principle*, the more a piece of data is defined/edited, the higher its quality

- $Attr_i(e)$ = {1 , if user i has defined the element e
  0 , otherwise}

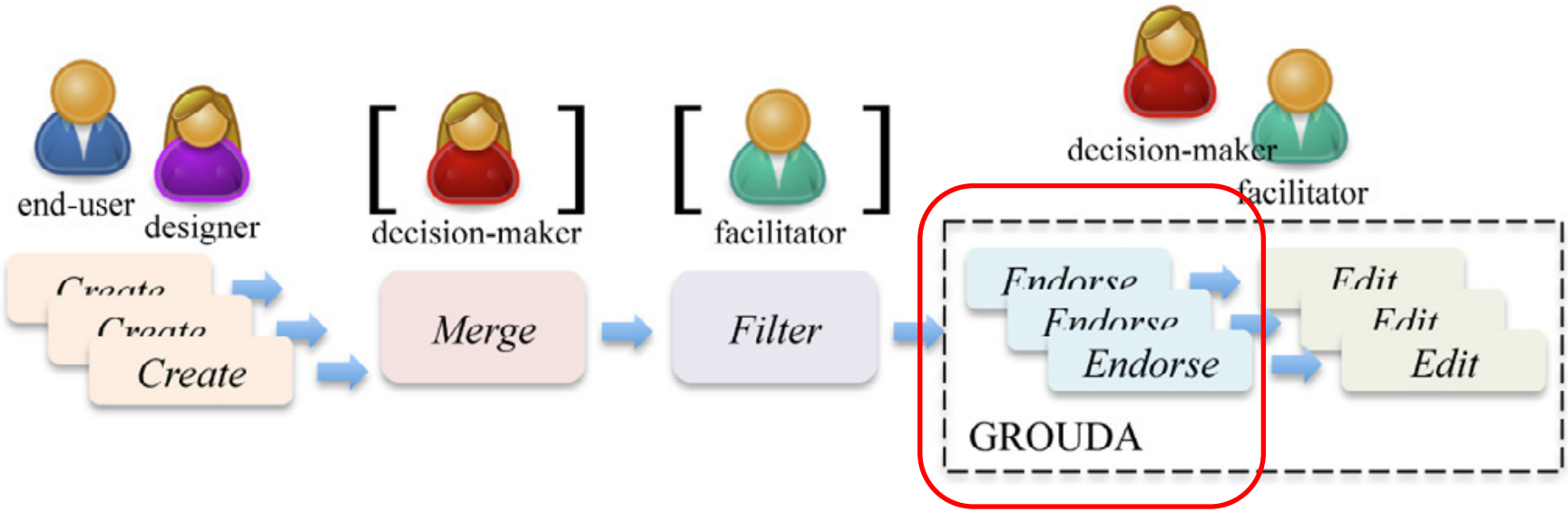
Quality: Filter

- *Trustworthiness* of a multidimensional element e as:

$Trust(e) = \Sigma i(w^{exp} \times Expi + w^{rep} \times Repi) \times Attri(e)/$
$\Sigma\ i(w^{exp} \times Expi + w^{rep} \times Repi)$ where:

w^{exp} and w^{rep} are weights such that w^{exp} and $w^{rep} = 1$

Methodology overview



Quality: Endorse

- *Completeness* refers to sets of multidimensional elements, and indicates whether all necessary concepts have been modeled in the cube schema
- *Precision* refers to single multidimensional elements, and indicates whether an element is represented with sufficient precision and detail
  - Example: Time dimension is not precise enough since it starts at year level
- *Relevance* refers to single multidimensional element and indicates whether they are useful for analysis
- *Minimality* refers to sets of multidimensional elements and indicates whether they present redundancies

Endorse

- *Consistency* refers to single multidimensional element and indicates to what extent the rules characterizing the application domain have been adhered to
  - Example: for hierarchy group of species are grouped by specie

- *Certainty* refers to single multidimensional elements and indicates that there are no ambiguities in the names chosen for them
  - Example: Location used as name level for representing City is ambiguous

Endorse

- *Confidentiality* indicates whether a multidimensional element can be part of the cube schema or it should be removed for legal, anonymization, or confidentiality issues

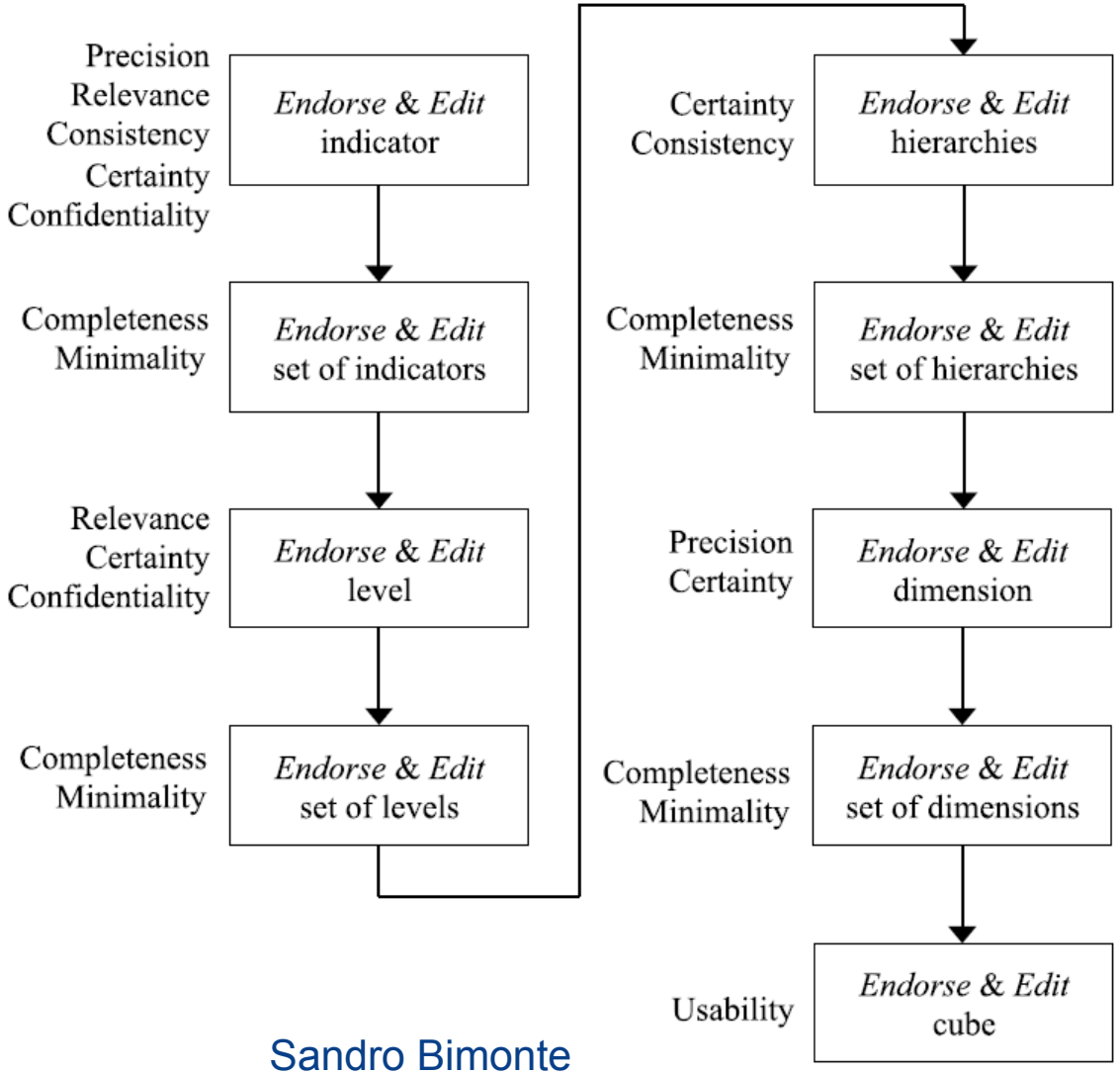
- *Usability* indicates if, overall, a cube schema facilitates analysis

Endorse

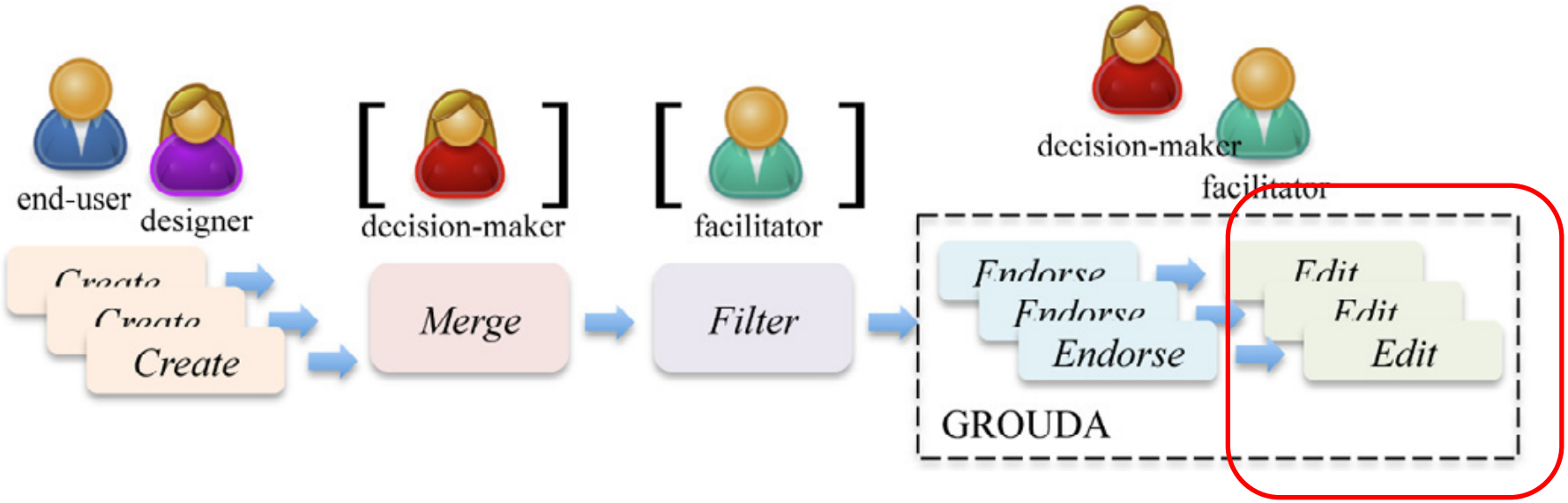
Quality attributes for cube schemata and their applicability to cube schema elements.

	Indicator	Set of indicators	Level	Set of levels	Hierarchy	Set of hierarchies	Dimension	Set of dimensions	Cube
Completeness		yes		yes		yes		yes	
Precision	yes						yes		
Relevance	yes		yes						
Minimality		yes		yes		yes		yes	
Consistency	yes				yes				
Certainty	yes		yes		yes		yes		
Confidentiality	yes		yes						
Usability									yes

Endorse and Edit



Methodology overview

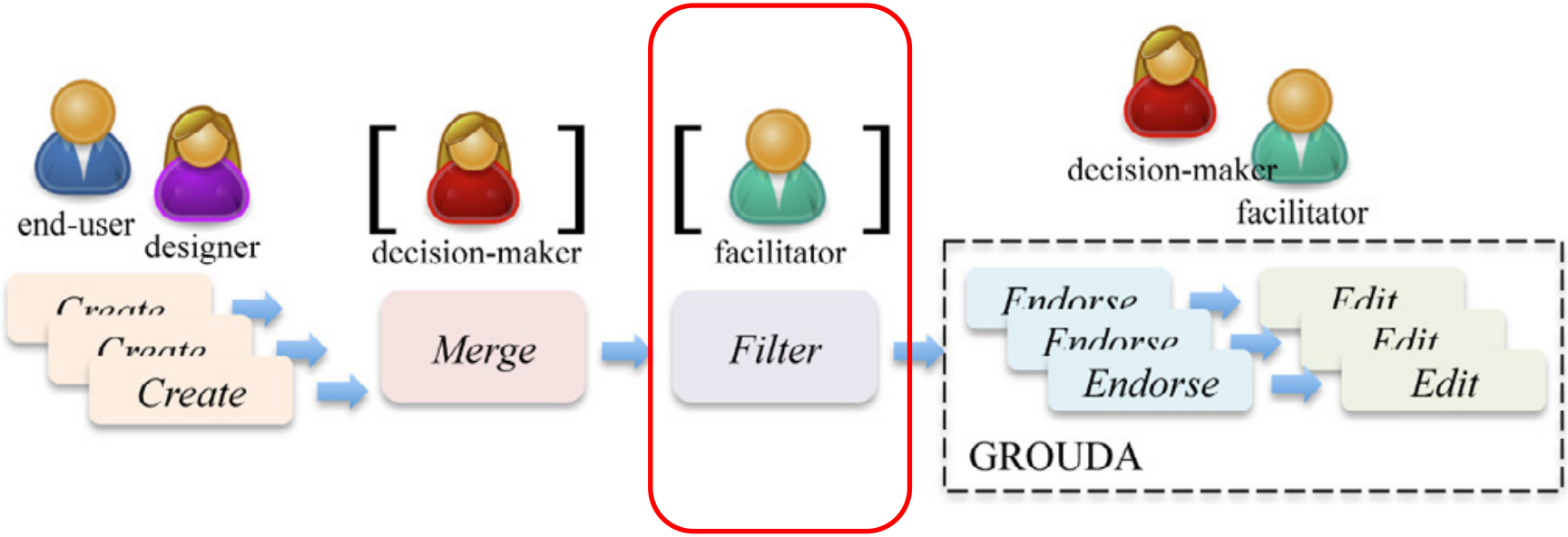


Edit

Actions on cube schema elements that can be triggered in presence of quality problems during *Endorse*.

	Indicator	Level	Hierarchy	Dimension
Completeness	add	add	add	add
Precision	modify	add		
Relevance	delete	delete		
Minimality	delete	delete	delete	delete
Consistency	modify		modify	
Certainty	rename	rename	rename	rename
Confidentiality	delete	delete		
Usability	delete	delete	delete	delete

Methodology overview



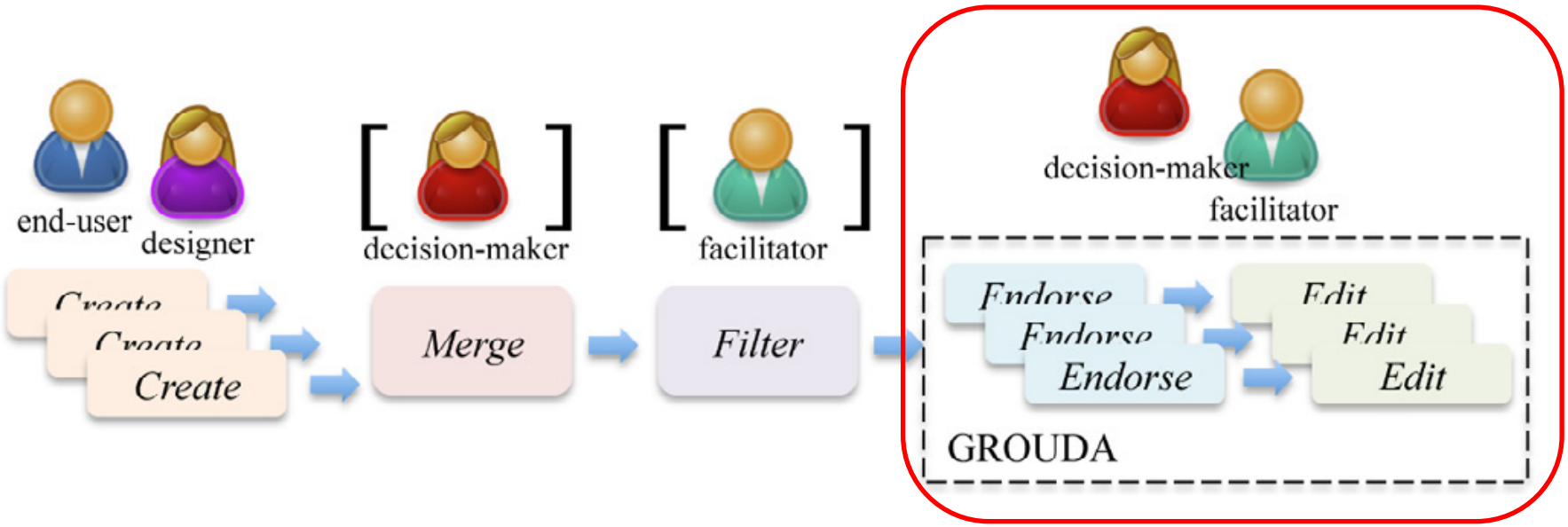
Collaboration: Filter step

- To take into account the varying users' profiles and skills, our framework recommends a different implementation of the **Filter**:

1. "*Are the end-users volunteers?*". This question is directed at the facilitator
    - **No**: the reputation of all end-users is set to 1 when computing trustworthiness
    - **Yes**: the reputation of end-users is computed

2. "*Do you consider yourself an expert of the application domain?*". This question is directed at the facilitator
    - **No**: *Filter step is automated based on the trustworthiness metric*
    - **Yes**: *facilitator can manually select the well-defined elements of the cube schemata proposed by end-users*

Methodology overview



Collaboration: Endorse step

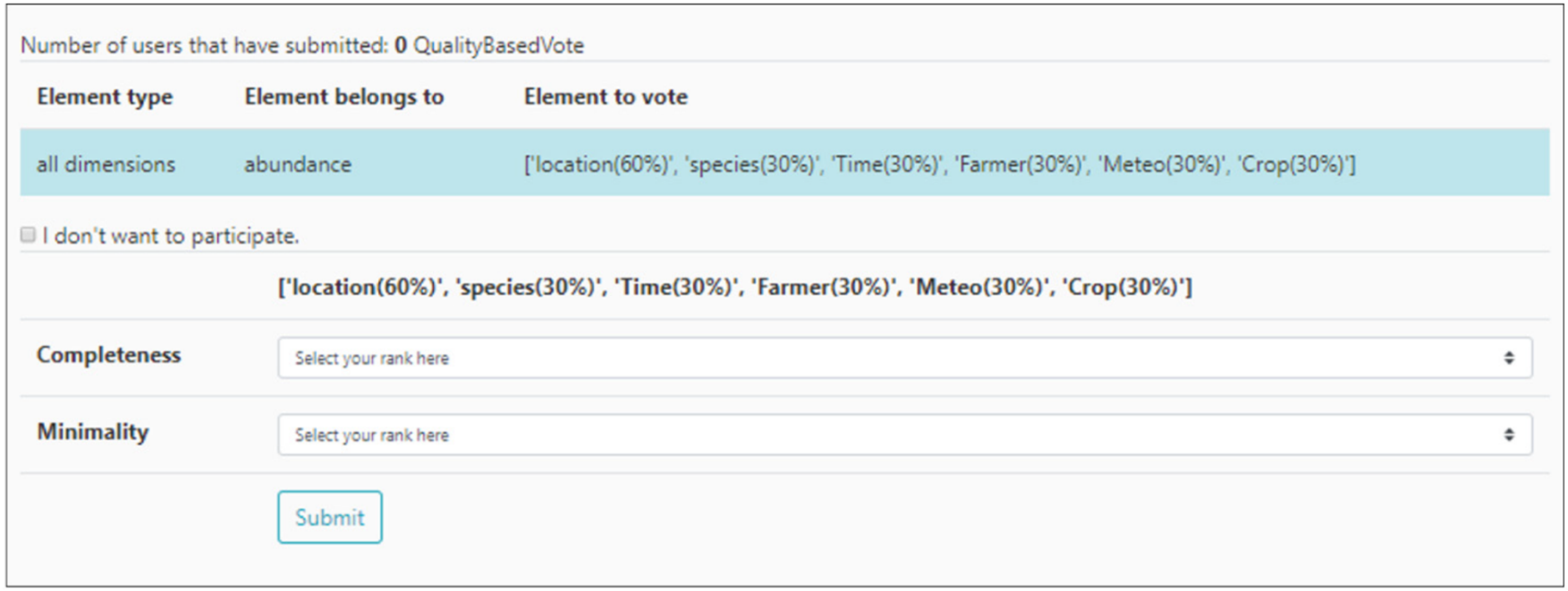
- To take into account the varying users' profiles and skills, our framework recommends a different implementation of the **Endorse** step depending on the answers give to the question:

"*Do you think your skills in multidimensional modeling are good?*". This question is directed at decision-makers.

- **No for at least one of them**: decision-makers must be supported by quality attributes and the *Endorse* step **is based on majority votes**
- **Yes for all**: considering that the evaluation of quality attributes can be long and tedious, the *Endorse* step can be carried out more informally via a **free discussion**

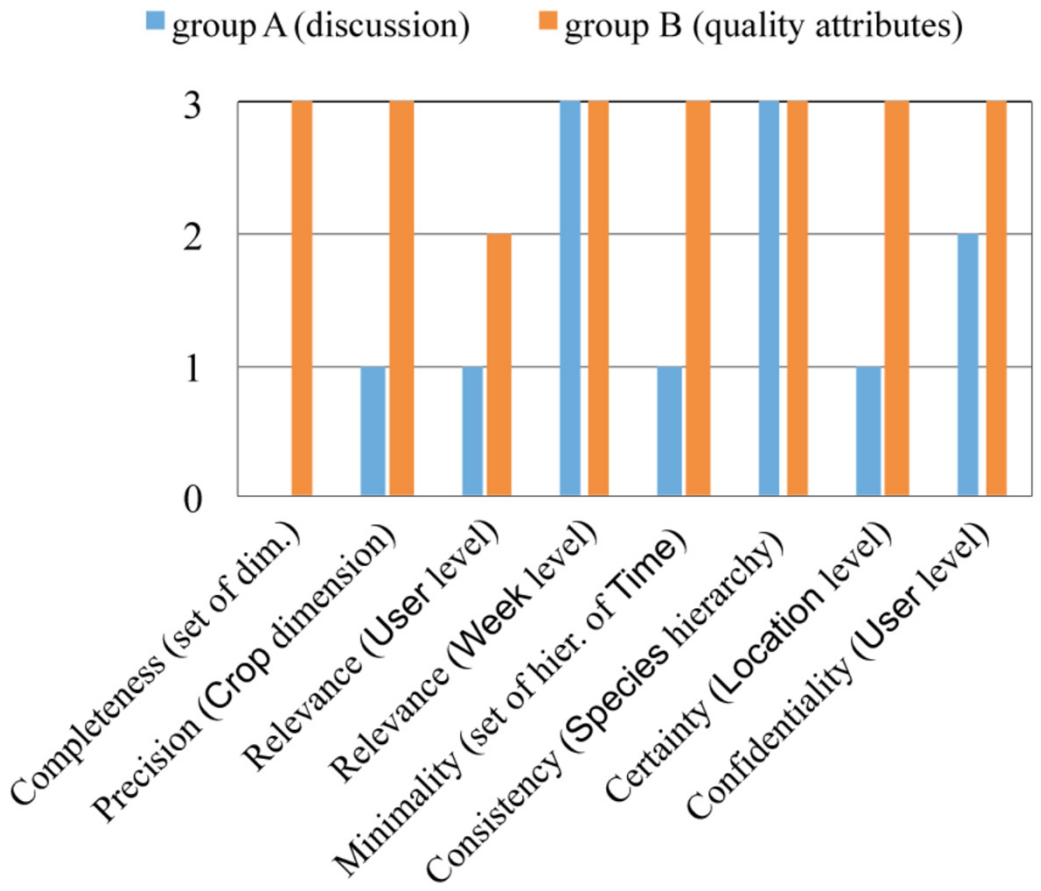
Collaboration: Implementation

- Vote and free discussion have been implemented in a web-based GDSS: GROUDA



Experiments about quality metrics

- We have conducted 2 main experiments about quality metrics of Endorse step
- All other steps have been also validated with real experiments



Conclusion & future work

Conclusion

- Involve volunteers in the definition of analysis is crucial for make the citizen observatory survive
- Use OLAP to analyze volunteers data by volunteers
  - *Yes but, how design a DW with such kind of non-skilled DW users?*
- We propose a new methodology based on:
  - E-pivot table
  - Group decision support systems
  - Rapid prototyping for validation
  - Quality metrics
- Each step is implemented with an “available tool” (ask me ;-))
- Validated on real and academic case studies

Future work

- We are finalizing a web based tool for E-Pivot Table
- Automatize the data source validation

Thanks to my collegues and students that worked with me

Questions ?

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