Introducing data visualization dashboards in the technological ecosystems

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First, we begin with a little of context

- Full Professor in the Department of Computer Science and Automation at the University of Salamanca (USAL)
- 4 six-year periods of research, 1 six-year period of transferring and innovation, and 5 five-year periods of recognized teaching
- Gloria Begué award for teaching excellence in 2019 (USAL)
- Head of the Research Group Recognized by the USAL GRIAL (research GRoup on InterAction and eLearning), a group that is a Consolidated Research Unit of the Junta de Castilla y León Government (UIC 81)
- Included in the University of de Stanford's World's Top 2% Scientists list (2019, 2020, 2021)
- Vice-Rector of Technological Innovation of this University (2007-2009)
- He is currently the Deputy Director of the Research Institute for Educational Sciences (IUCE), the Rector's Delegate for Digital Learning and Teaching and the Coordinator of the Doctorate Programme in Education in the Knowledge Society
- For more information
  - Google Scholar (http://goo.gl/sDwrr0)
  - WoS (https://bit.ly/3QNo6fN)
  - Scopus (https://bit.ly/3lYoog7)
  - ORCID (http://orcid.org/0000-0001-9987-5584)

University of Salamanca

- Oldest university in Spain (since 1218, more than 800 years of history)
- Medium-size university (around 30,000 students)
- Traditional, face-to-face university
- https://www.usal.es/

University of Salamanca

https://youtu.be/jPpF0HYs6cg

GRIAL Research Group [1]

- Recognized group inside the University of Salamanca (since 2006)
- Excellence research group (since 2007)
- https://grial.usal.es

Who we are

GRIAL is a multidisciplinary research group, fundamentally a mixture of Informatics and Education, but including researchers from other disciplinary fields (Philosophy, Philology, Humanities, etc.)

Research lines

- Digital humanities [2]
- eLearning methodologies [3]
- ICT and educational innovation [4]
- Information science [5]
- Interactive learning systems [6]
- Learning Technologies [7, 8]
- Quality and assessment in education [9]
- Social responsibility and inclusion [10]
- Strategic management of knowledge and technology [11]
- Technological ecosystems [12]
- Visual analytics [13]
- Web engineering and software architecture [14]

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Selected projects

Building the future of Latin America: engaging women into STEM
https://wstemproject.eu/ [15, 16]

Integrating STEAM and computational thinking development by using robotics and physical devices
http://robosteamproject.eu/ [17]

Visual analytics and machine learning for decision making in health ecosystems (AVisSA)
https://grial.usal.es/avissa [18]

Limits of the traditional information systems

Knowledge management

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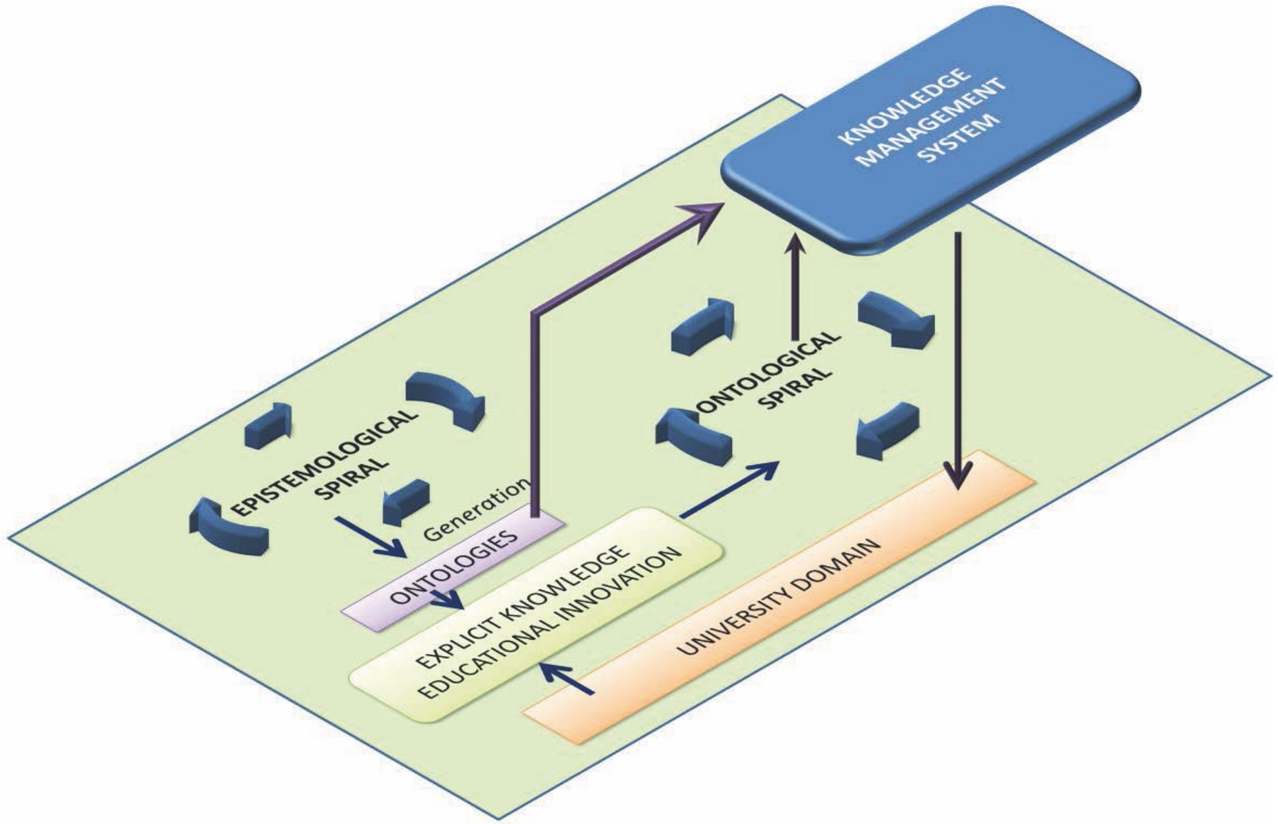
Information Society's evolution into the Knowledge Society is directly related to the evolution of information systems

Knowledge management emerges as a competitive advantage in any type of organization [19]

Knowledge management models

Suricata model [20]

Knowledge spirals model [21]



Technological ecosystems

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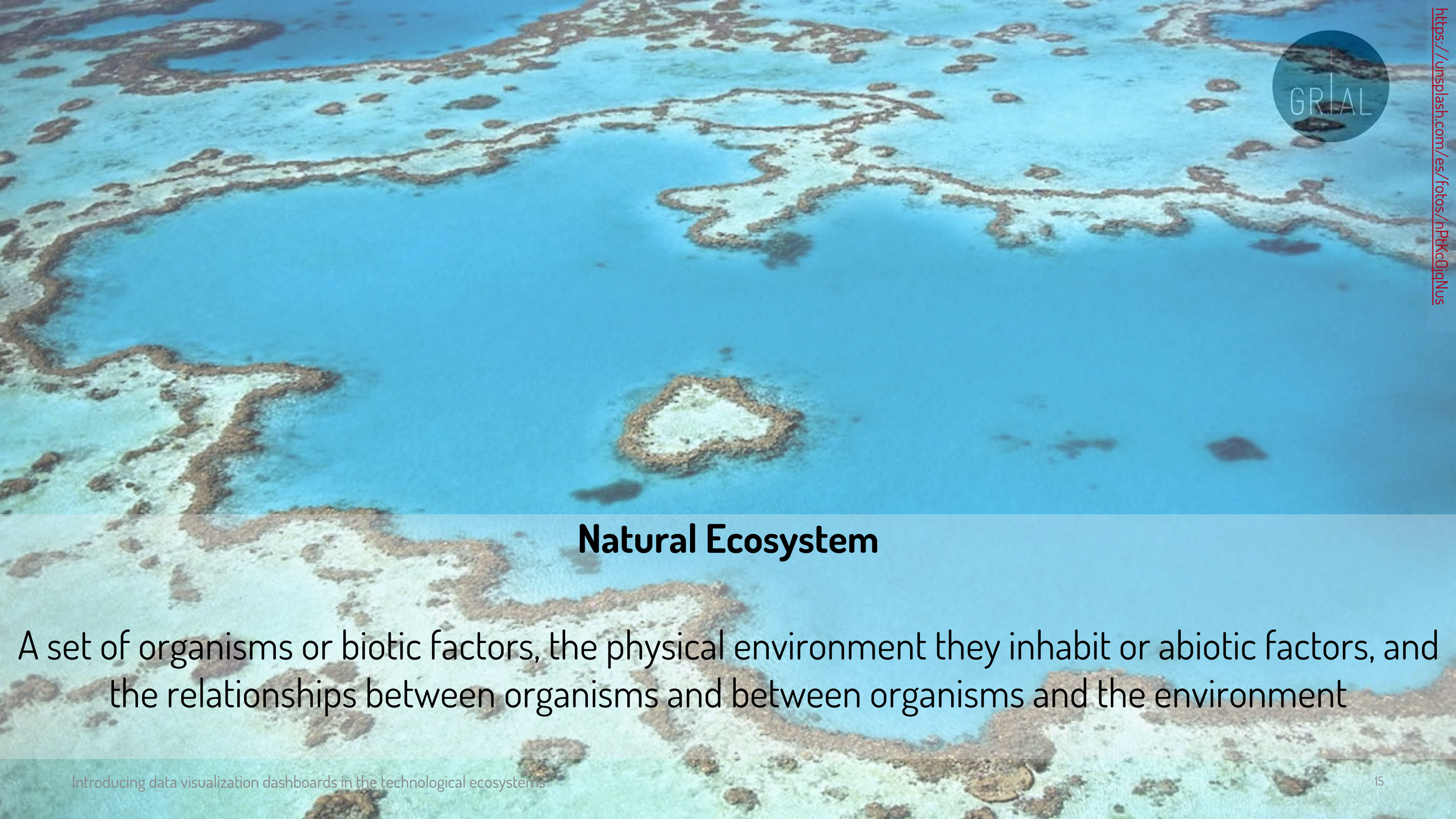
A new metaphor for conceptualizing software systems

Technological ecosystems solve knowledge management problems in heterogeneous contexts, considering the evolution of traditional information systems [22, 23]

The ecosystem metaphor comes from biology and has been transferred to the area of technology, adapting the ideas of Moore [24] and Iansiti & Levien [25], to reflect the evolving nature of software systems



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Natural Ecosystem

A set of organisms or biotic factors, the physical environment they inhabit or abiotic factors, and the relationships between organisms and between organisms and the environment

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Technological Ecosystem

In a technological ecosystem, there is a set of people and software components that play the role of organisms; a set of elements that allow the ecosystem to function (hardware, networks, etc.); and a set of information flows that establish the relationships between the software components and between them and the people involved in the ecosystem [26]

Technological ecosystem definition

A technology ecosystem is a set of people, and software components that relate to each other through information flows in a physical environment that supports these flows [27]

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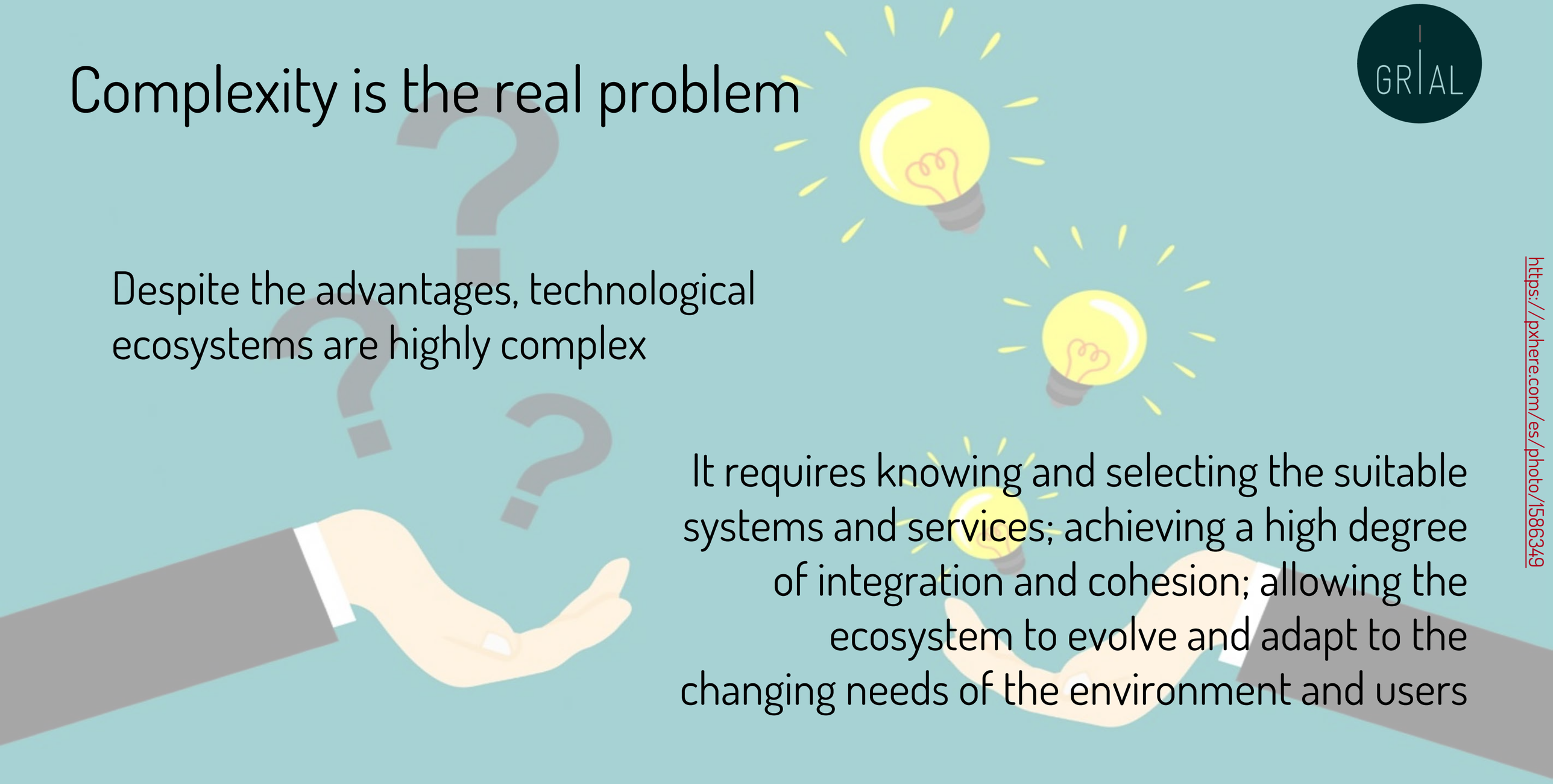
Users are a key component of the technological ecosystems [28]

Complexity is the real problem



Despite the advantages, technological ecosystems are highly complex

It requires knowing and selecting the suitable systems and services; achieving a high degree of integration and cohesion; allowing the ecosystem to evolve and adapt to the changing needs of the environment and users

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Approach

To propose a solution based on software architectures and Model Driven Engineering (MDE) to improve the processes of definition, development and evolution of technological ecosystems for knowledge management in heterogeneous contexts

Based on the previous experiences on developing learning ecologies [29, 30], adaptive systems [31, 32], service-oriented architectures [33, 34]

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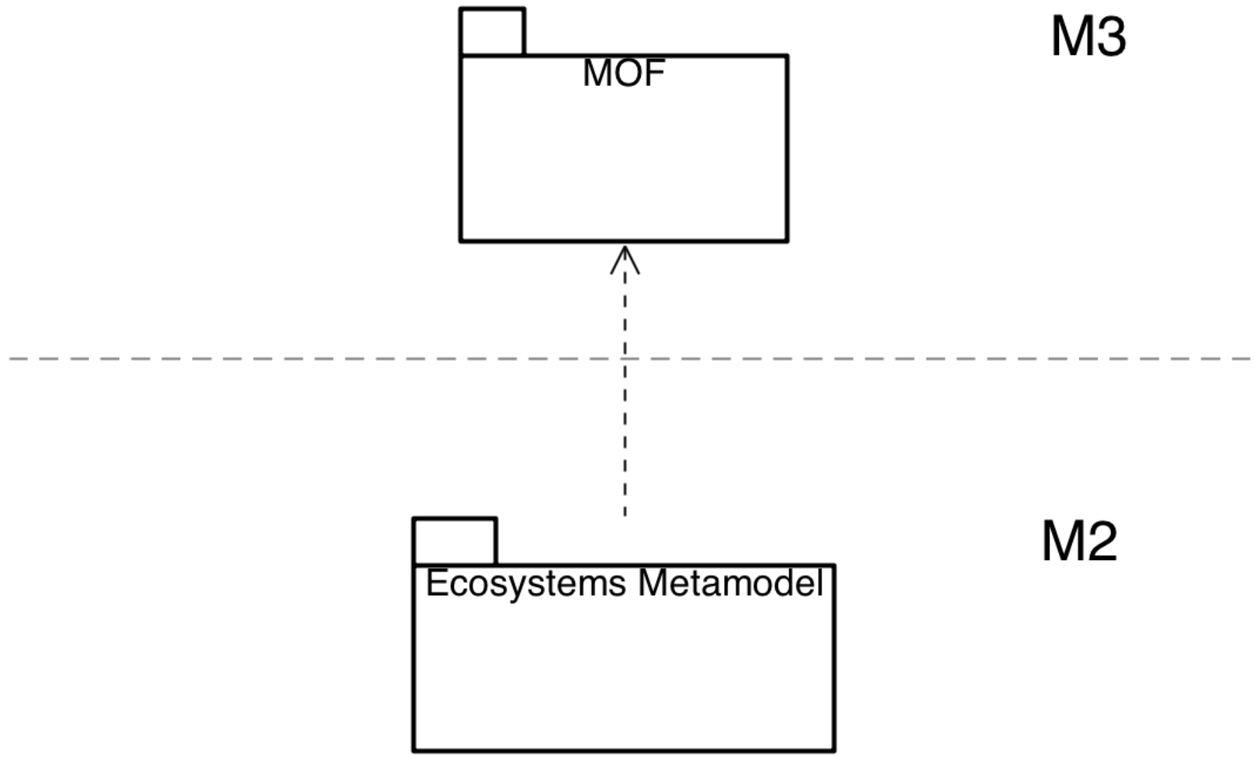
Defining and validating a technological ecosystem metamodel [35-37]

- The metamodel is an M2 model in the four-layer stack
- The technology ecosystem metamodel is an instance of the MOF meta-metamodel (M3 model)
- The metamodel is a platform-independent model, i.e., a PIM (Platform-Independent Model)



Metamodel high-level requirements

- The metamodel will capture the high-level description of the components of the learning ecosystem
- The metamodel will capture the human factor as part of the learning ecosystem
- The metamodel shall allow capturing the information flows between the components of the learning ecosystem
- The metamodel shall allow capturing the configurations of the software components

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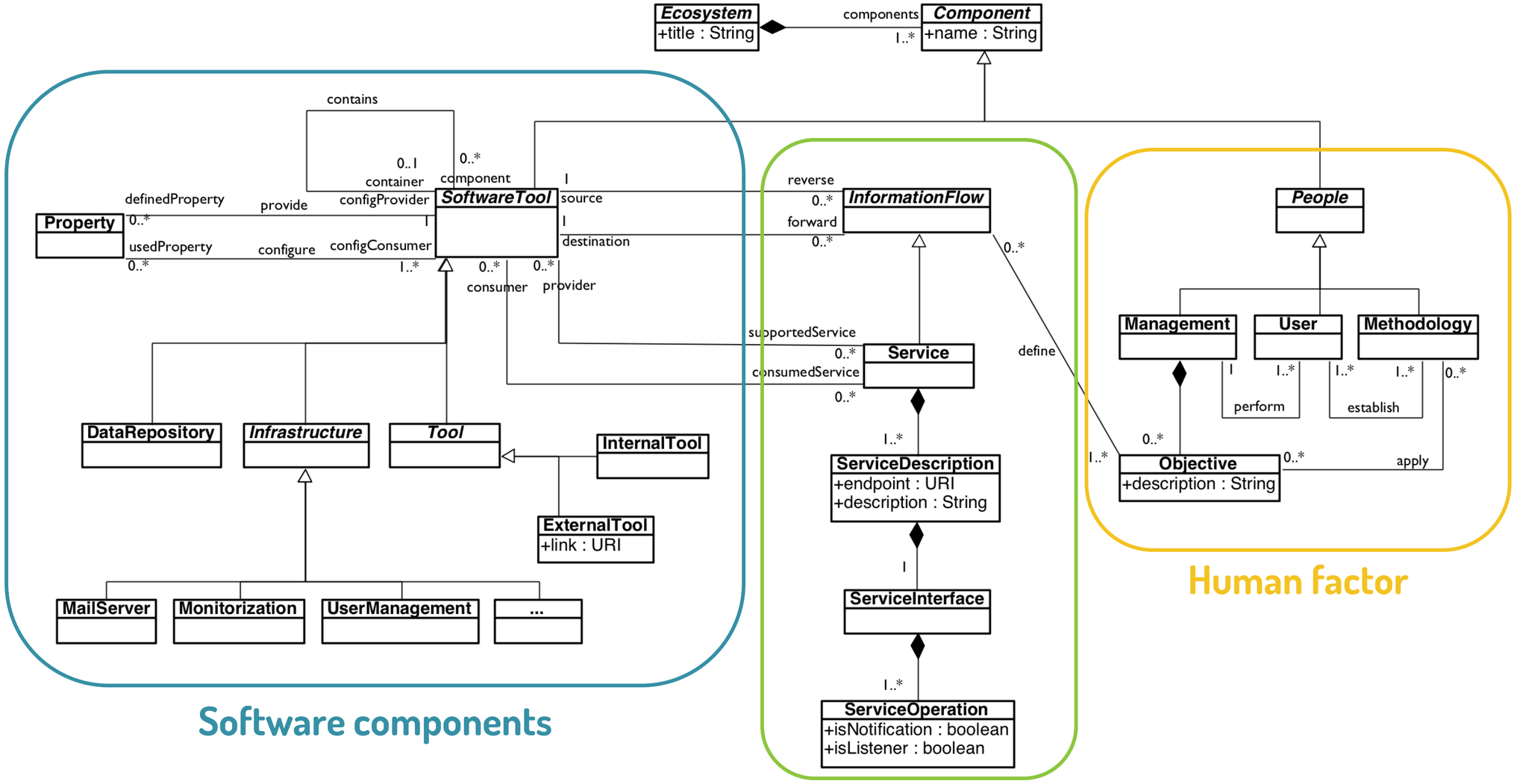
Technological ecosystem metamodel [27, 37]



Technological ecosystem metamodel achievements

- The metamodel makes it possible to define models corresponding to real software ecosystems
- The models instantiated from the metamodel serve as a guide for developing the corresponding technology ecosystem
- In combination with ATL transformation rules, it allows translating learning ecosystem models into platform-specific models

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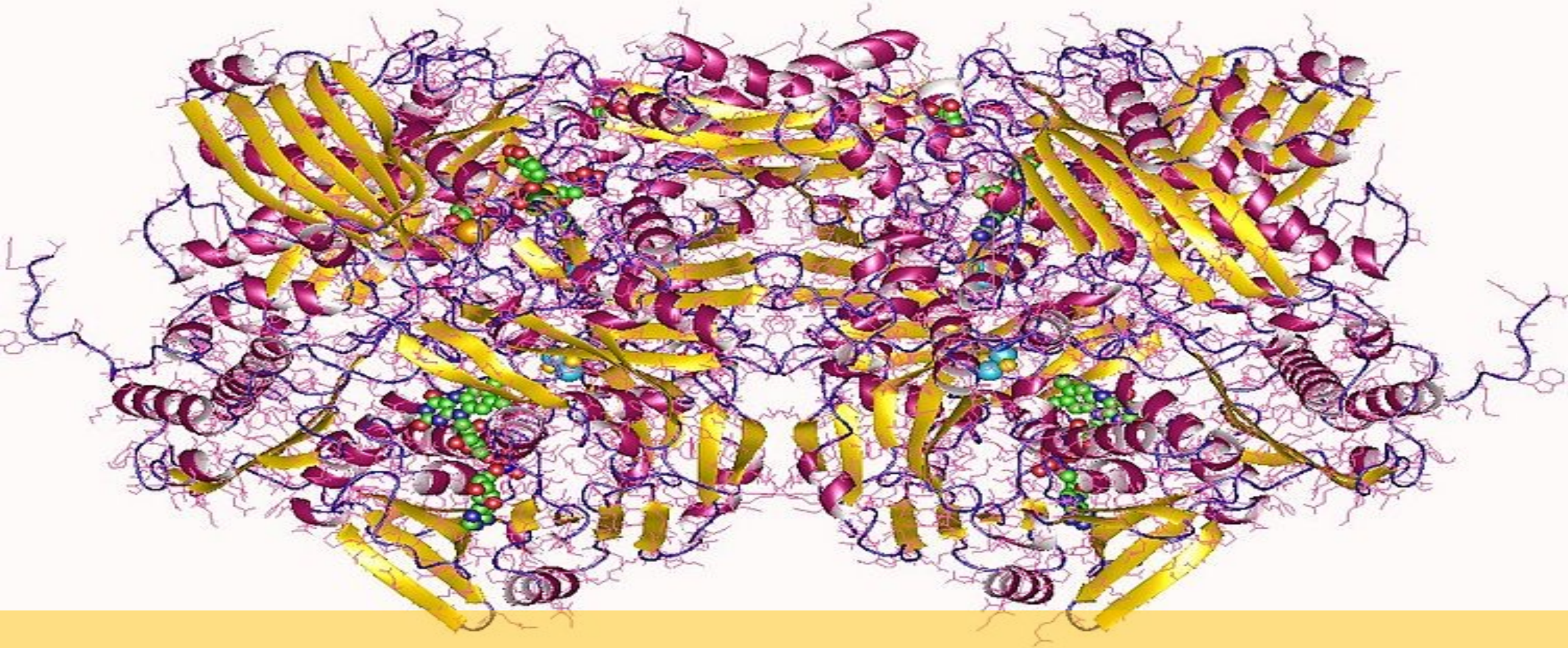
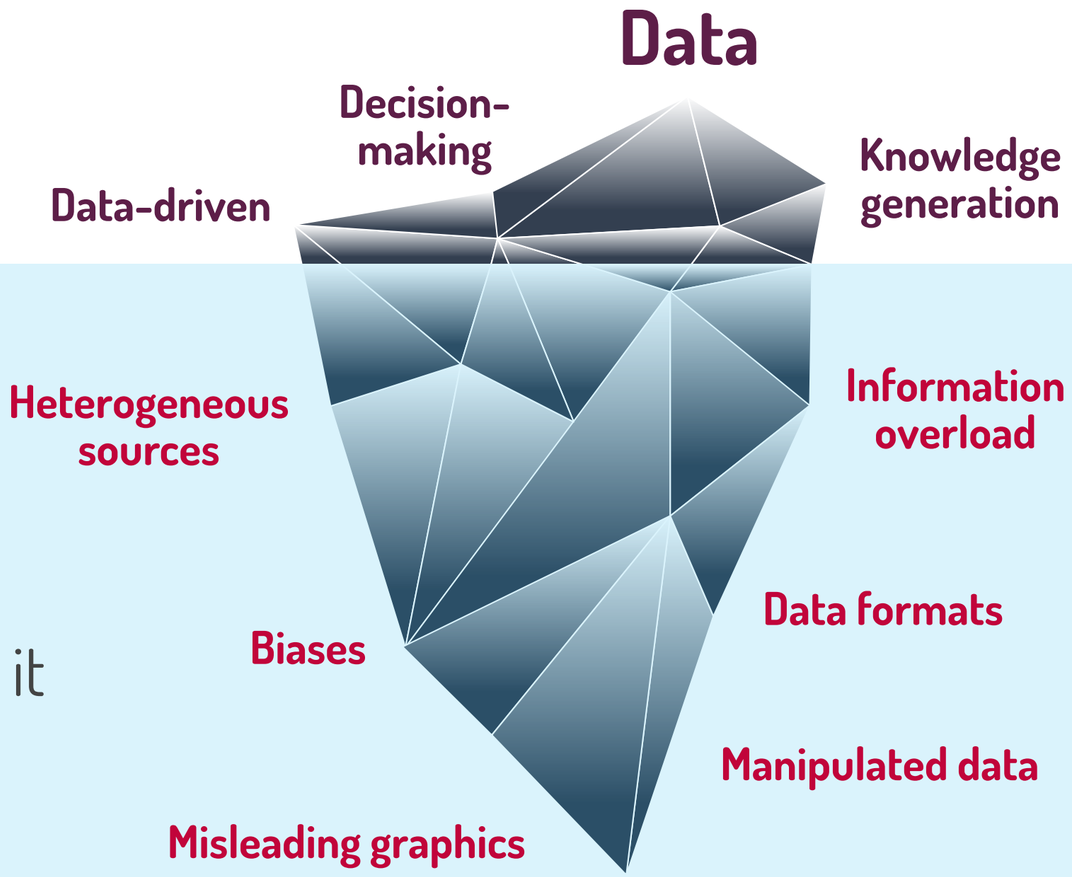


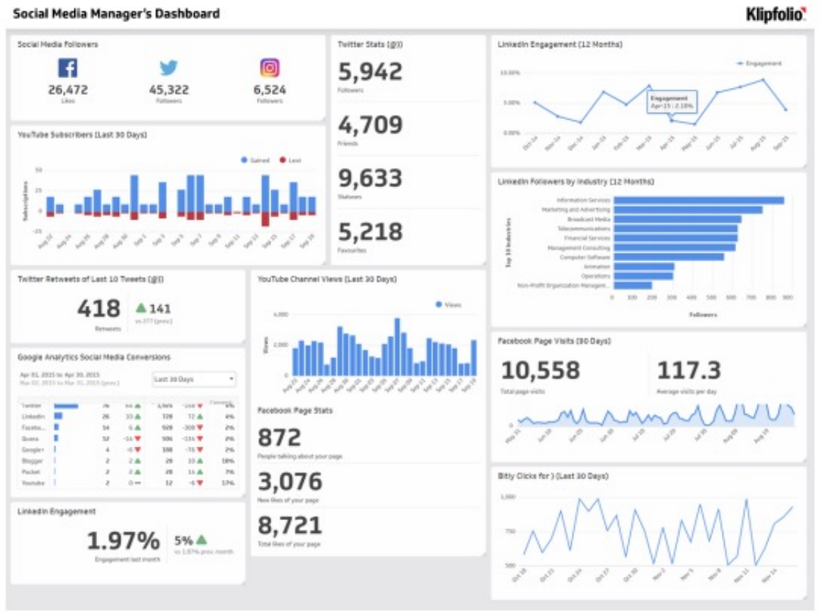
Visualizing and interacting with data in the ecosystems

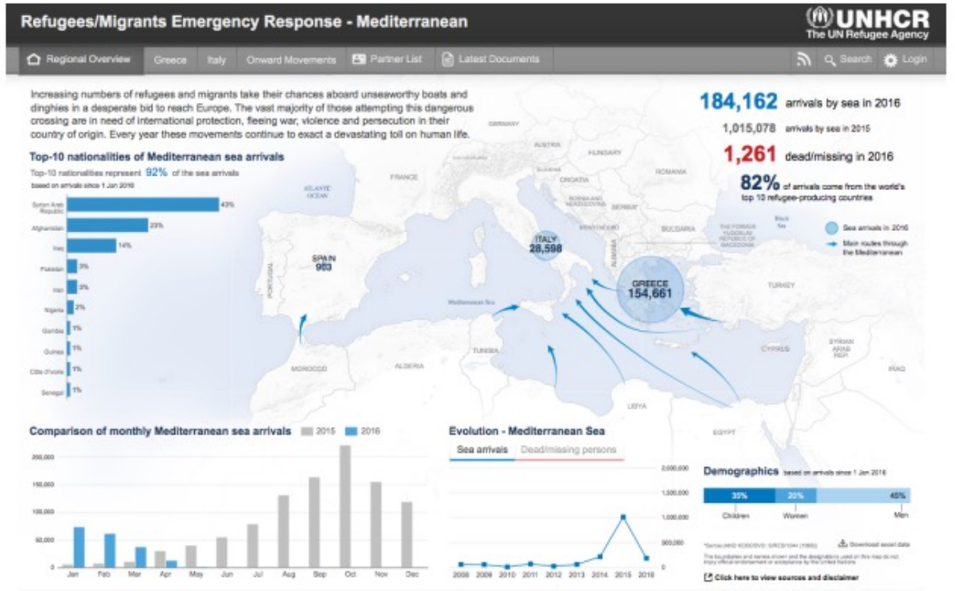
The data iceberg



Data visualizations and information dashboards are powerful allies when it comes to understanding complex datasets

Dashboards





Dashboards are one of the most use cases for data visualization, and their design and contexts of use are considerably different from exploratory visualization tools [38]

Dashboards

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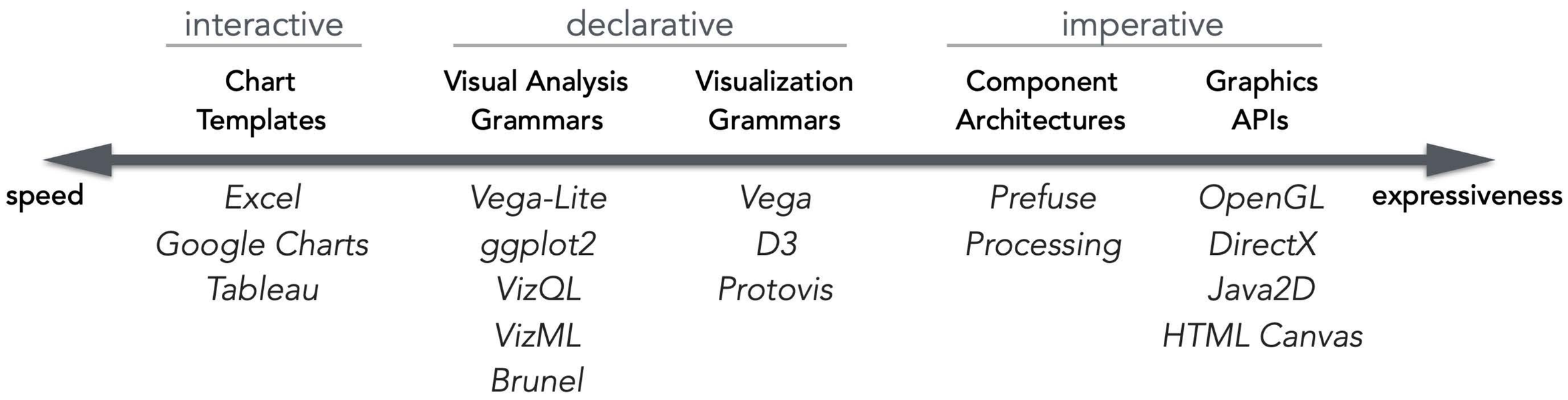
Powerful but also **complex** tools with

+ Different characteristics
+ Different audiences
+ Different components
+ Necessity of expert knowledge

=

Costly development processes

Spectrum of data visualizations and dashboards creation tools [39]

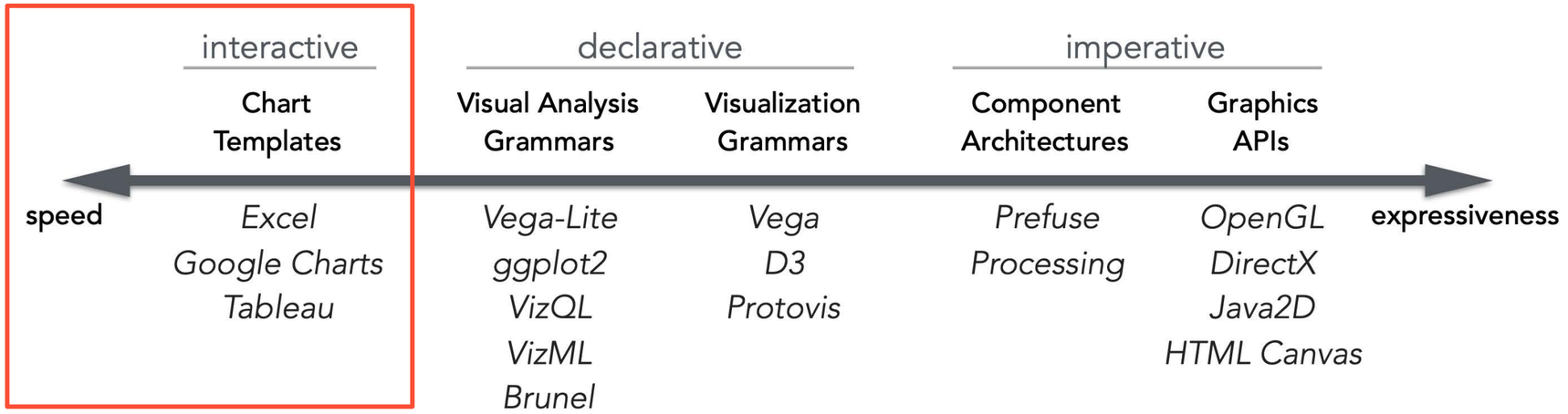


Spectrum of data visualizations and dashboards creation tools [39]

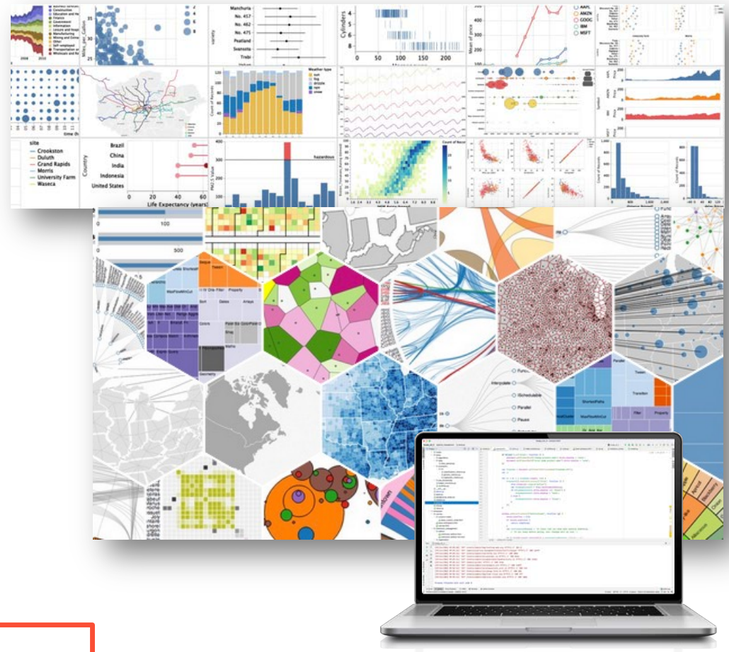
Interactive tools try to assist the user and adapt the displays depending on the context

Issue

-Expressiveness of the obtained visualizations



Spectrum of data visualizations and dashboards creation tools [39]

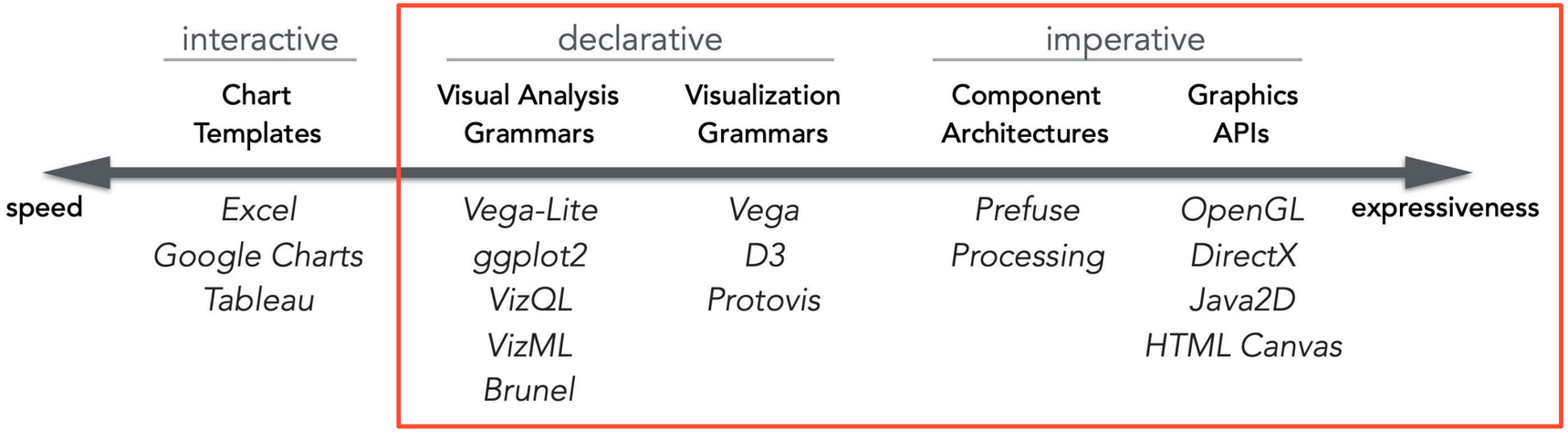


Declarative and imperative programming libraries

can improve expressiveness

Issue

-Steep learning curve



How can we efficiently automate the development of these tools?

A generative dashboard pipeline should merge the best of **interactive systems** and **programming languages**

- Good experience for **non-expert** users
- Fine-grained specification to improve **expressiveness**

Dashboard metamodel [40-46]

MOF/ECORE

M3

Defined by

Dashboard Meta-model

M2

Defined by

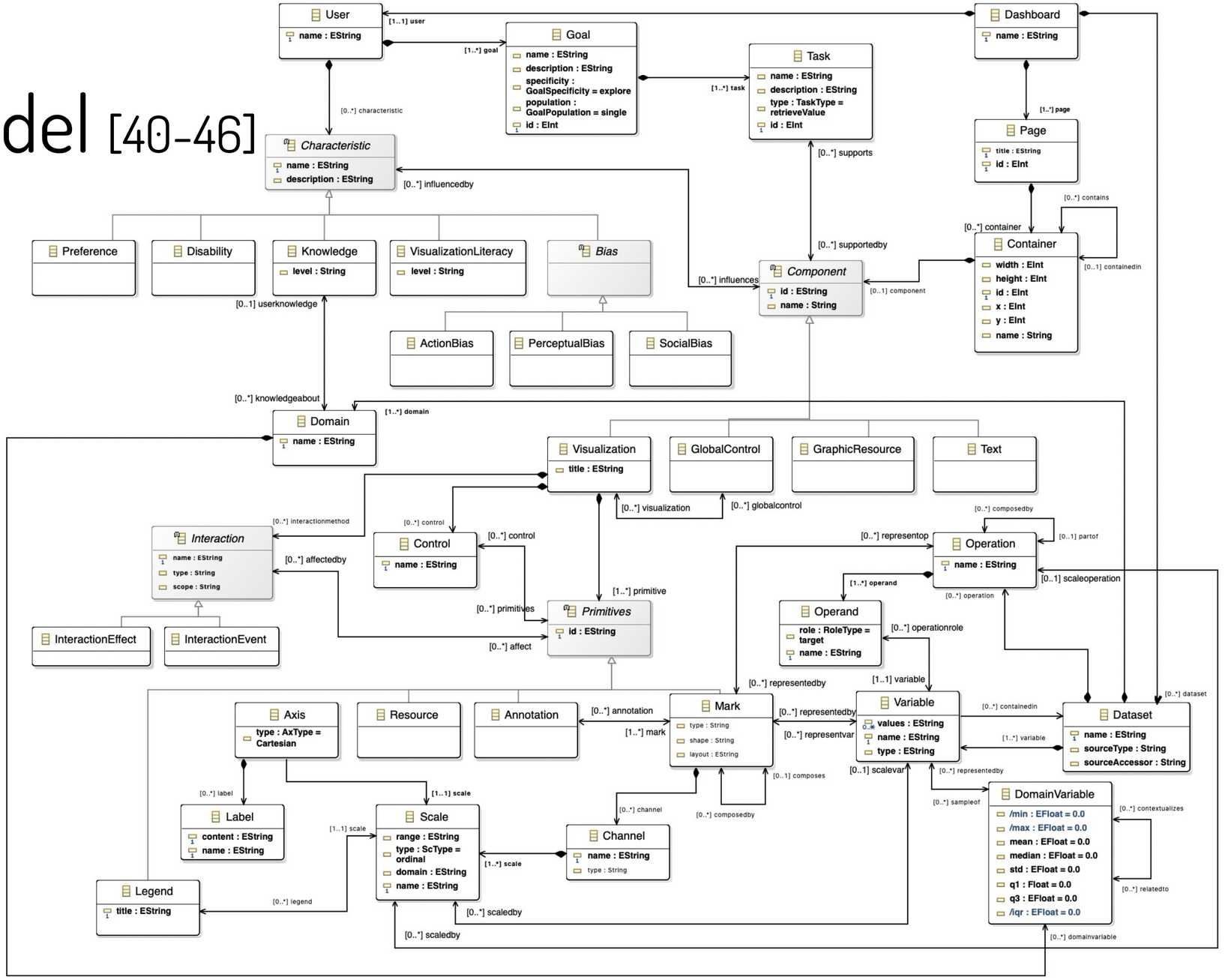
System (dashboard) model

M1

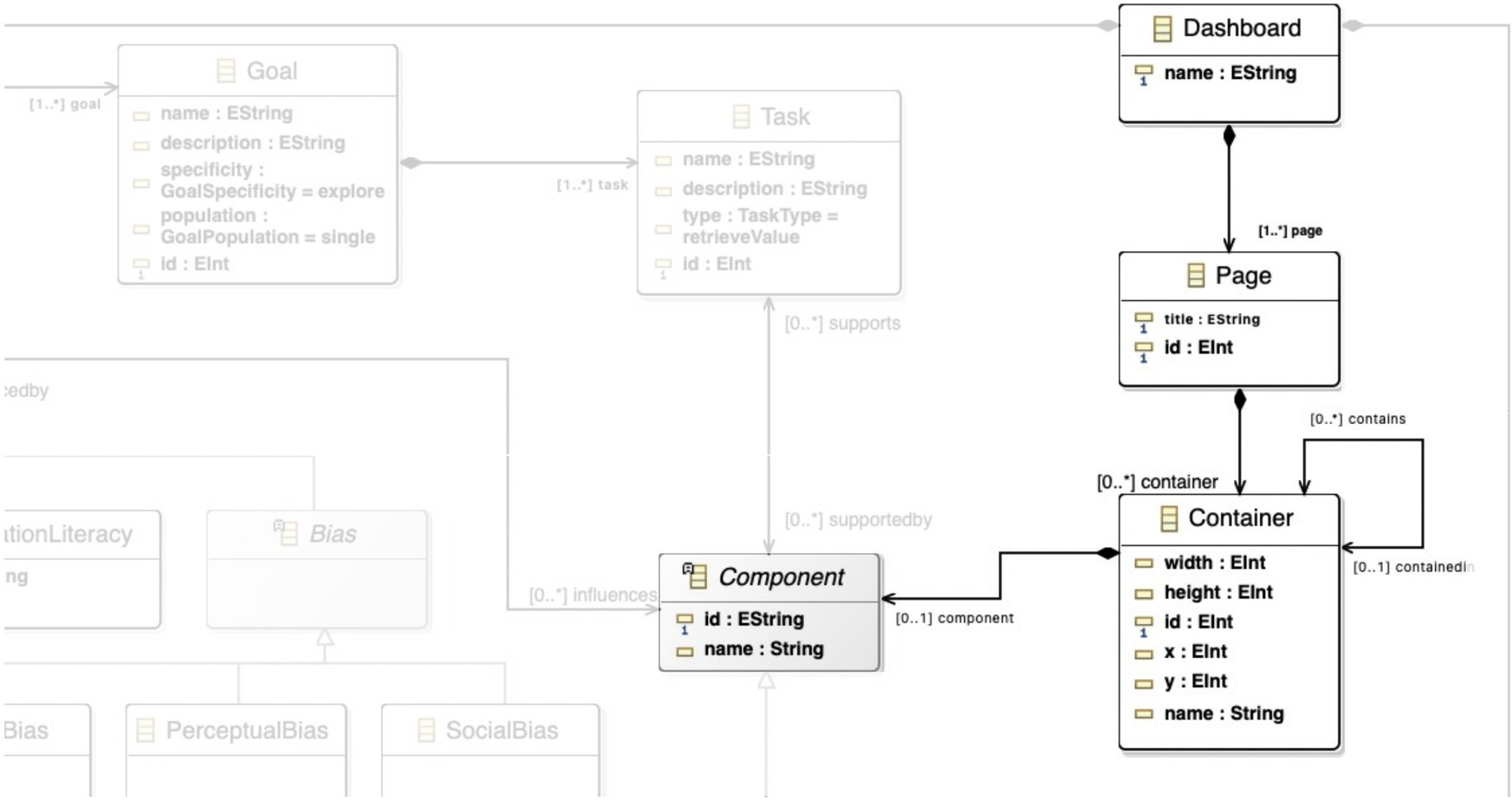
Generated through

Final system (dashboard)

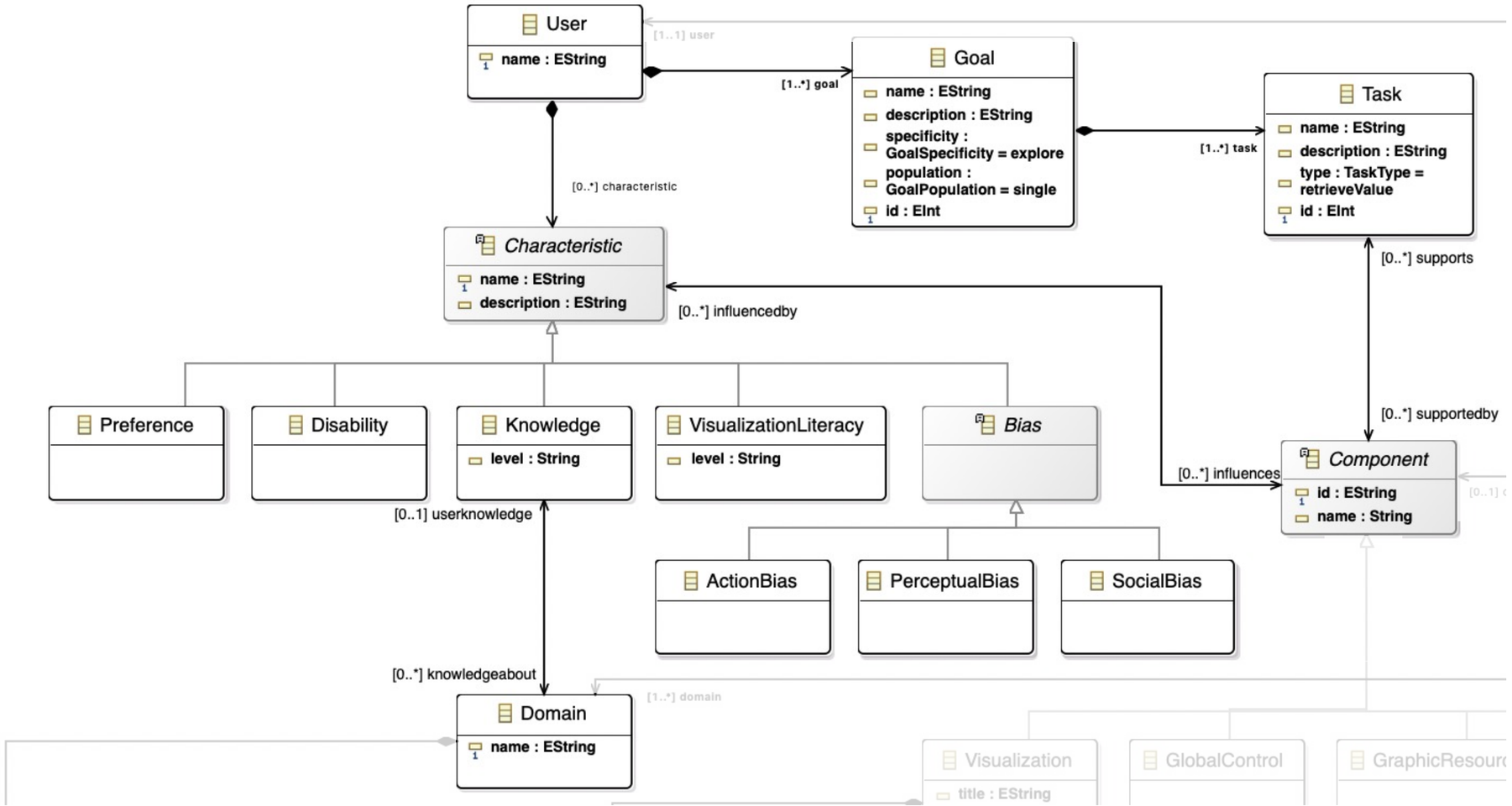
M0



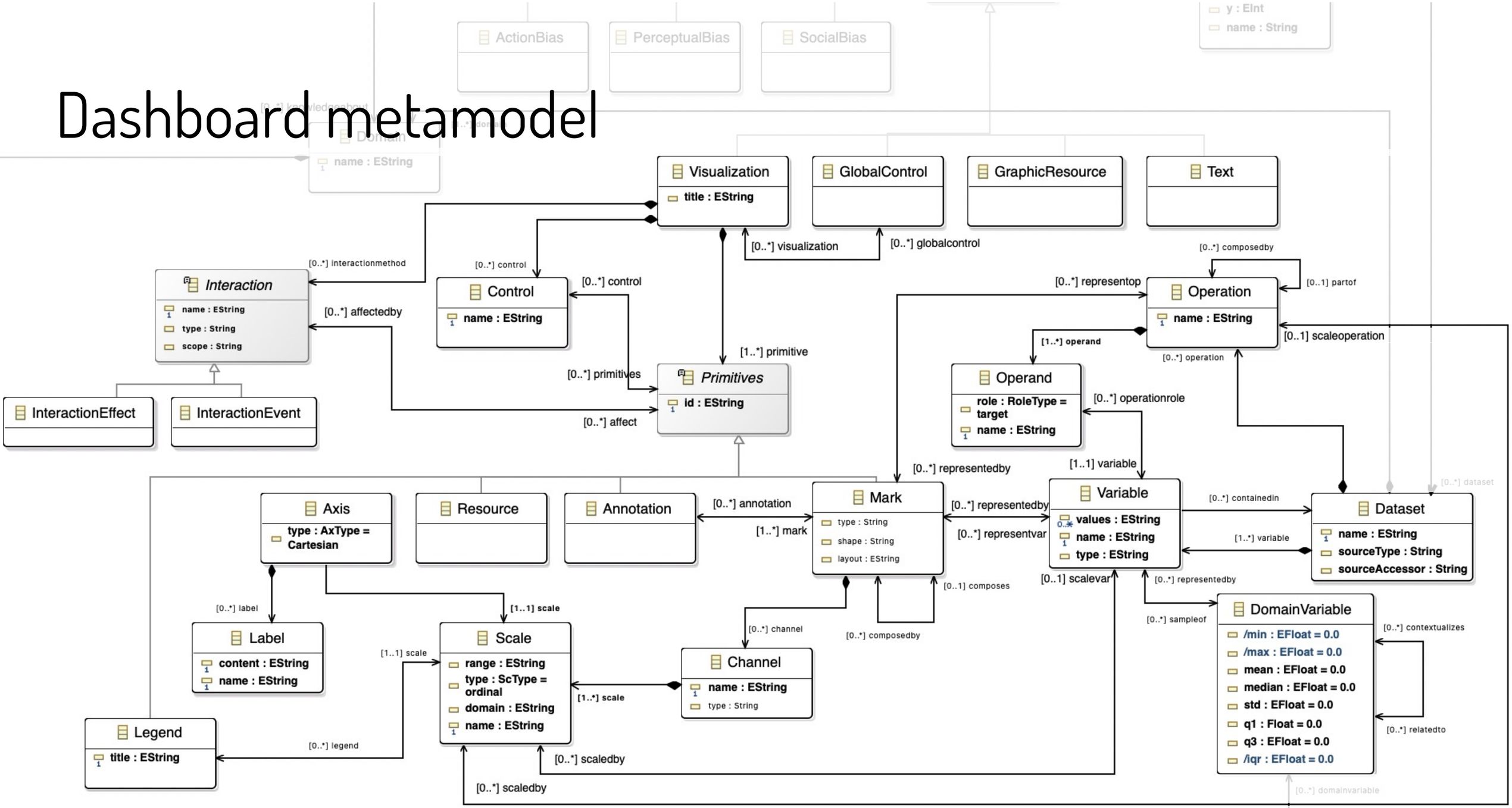
Dashboard metamodel



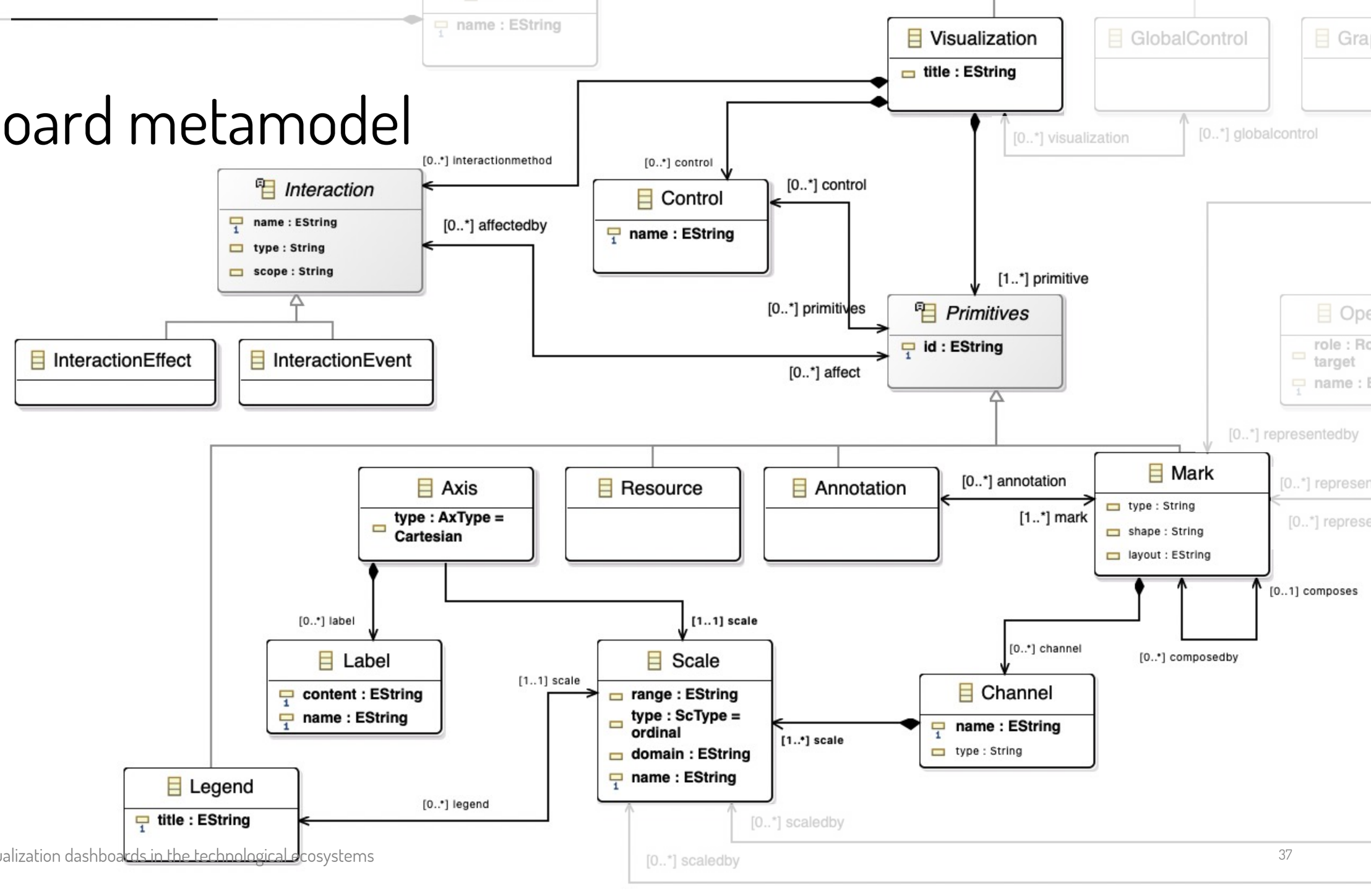
Dashboard metamodel



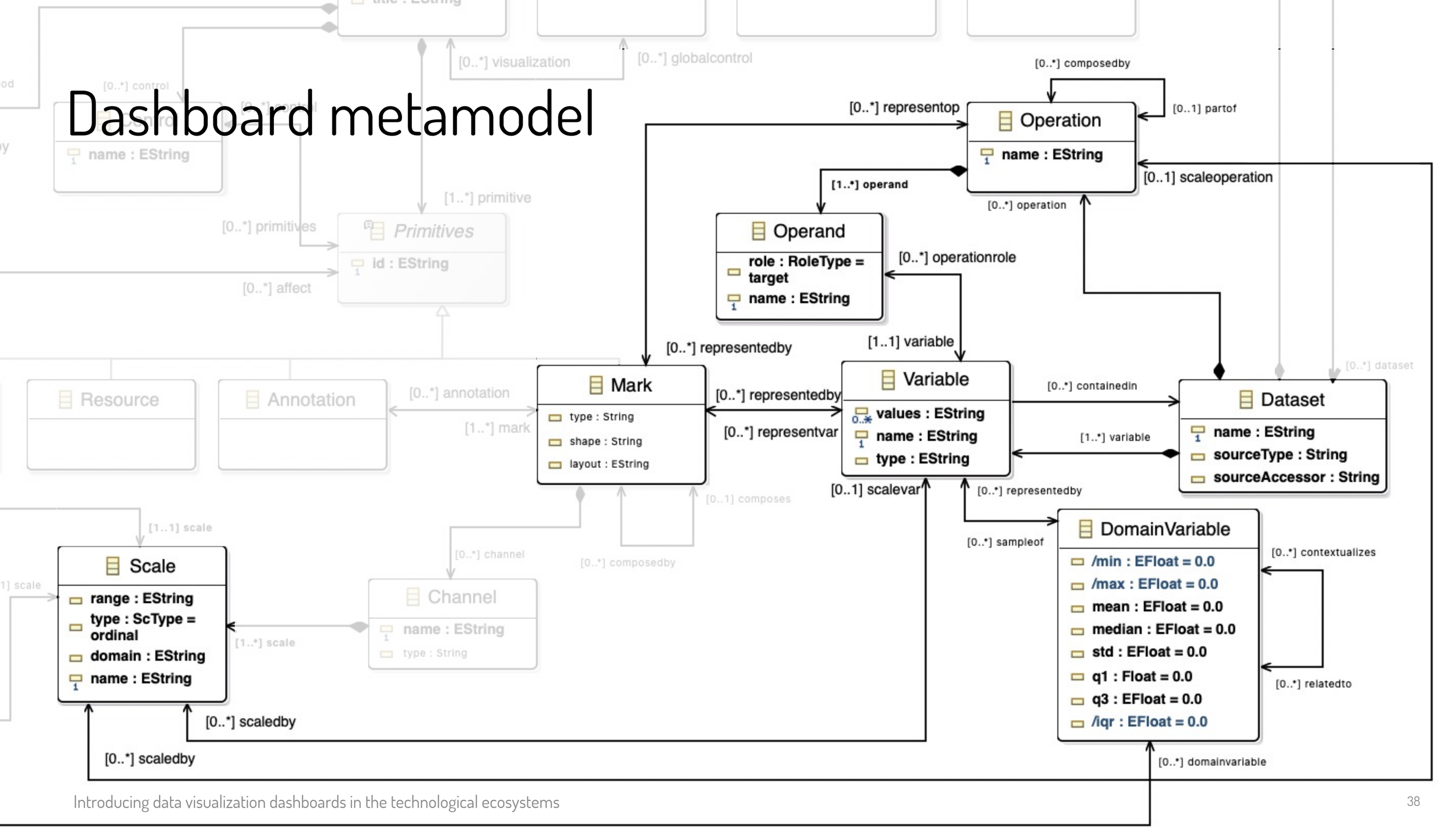
Dashboard metamodel



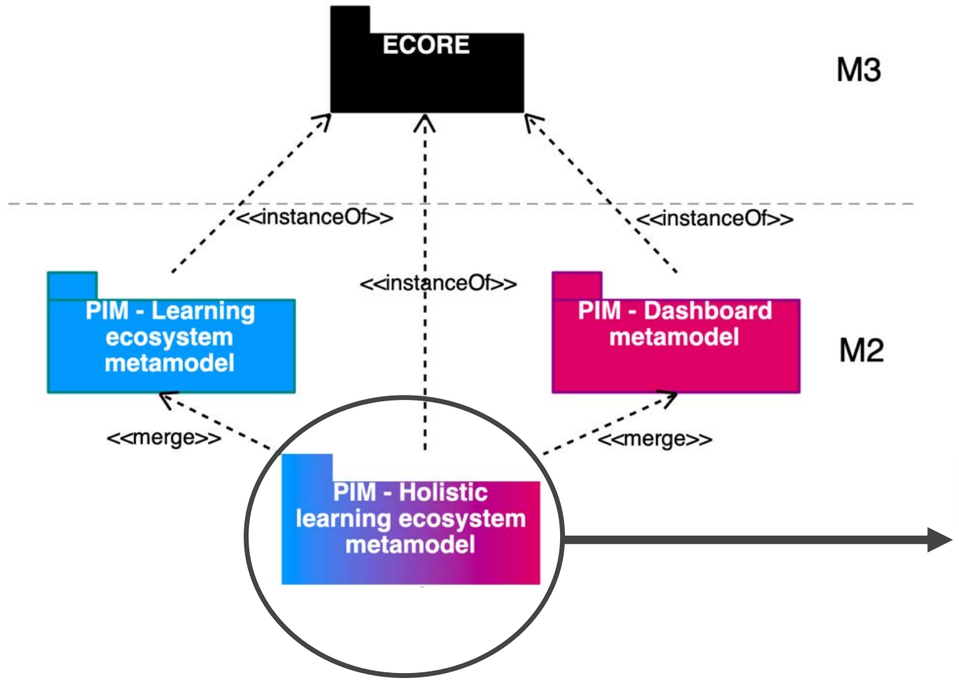
Dashboard metamodel

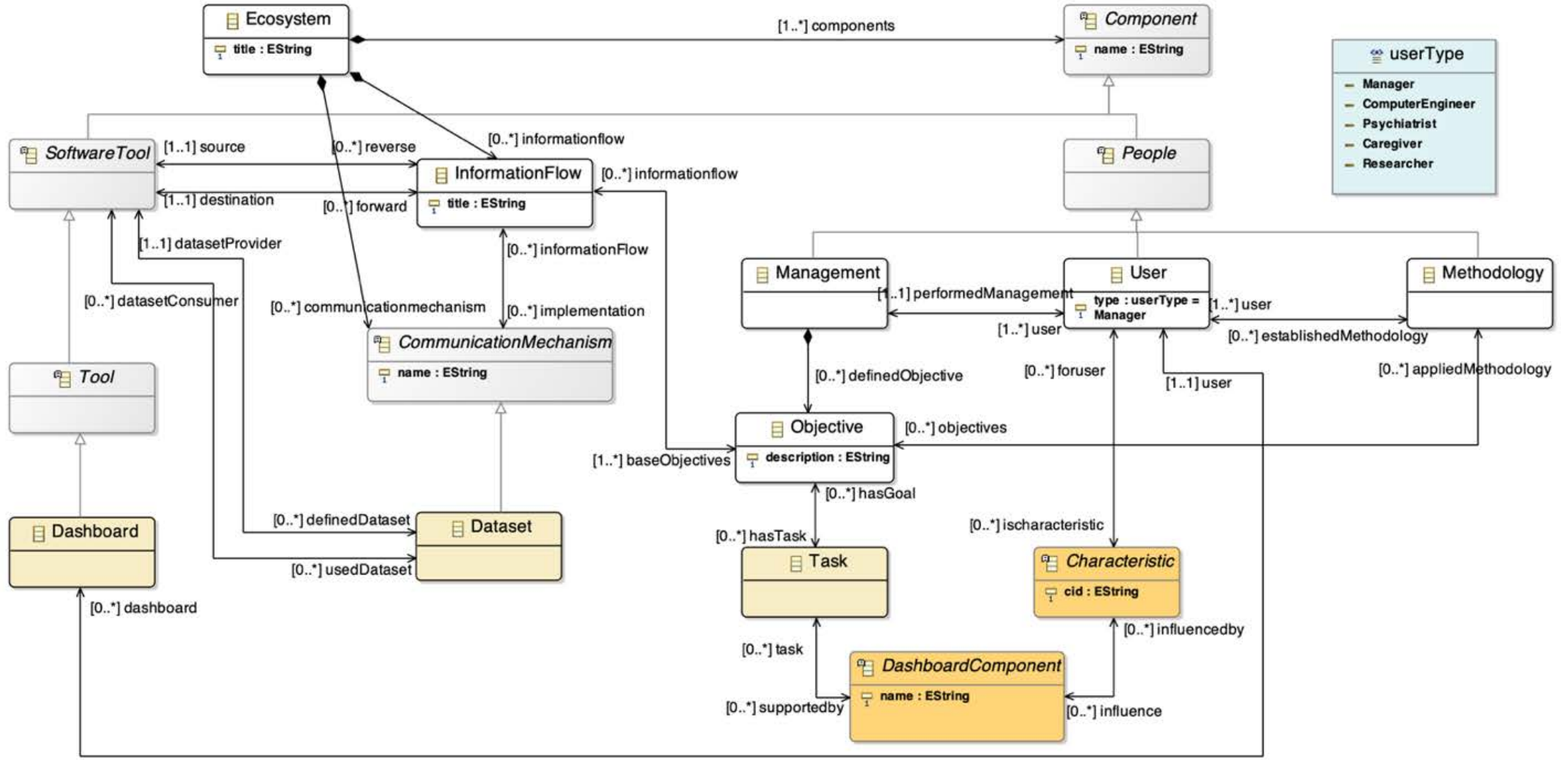


Dashboard metamodel

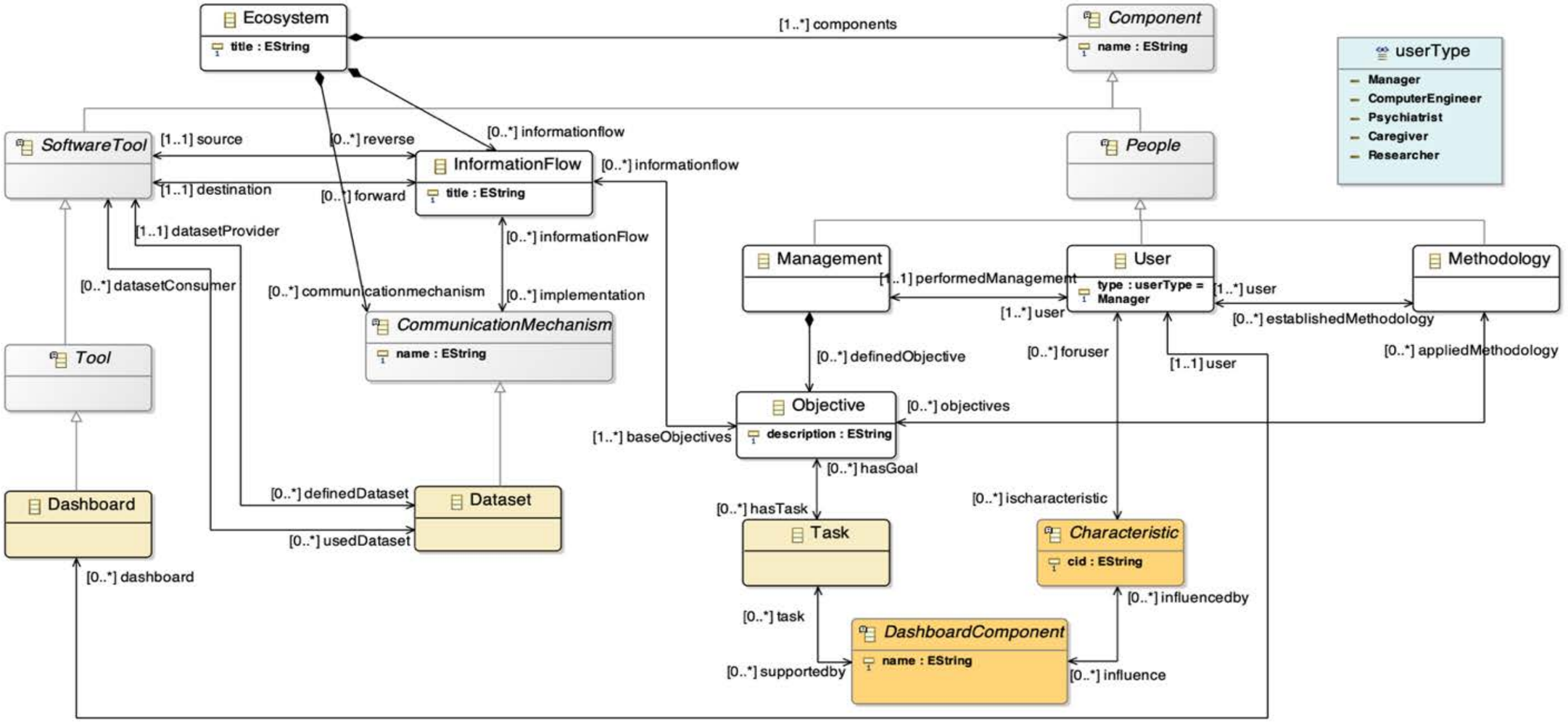


Integration with the M2 technological ecosystem metamodel [47-49]





Integration with the M2 technological ecosystem metamodel



Conclusions

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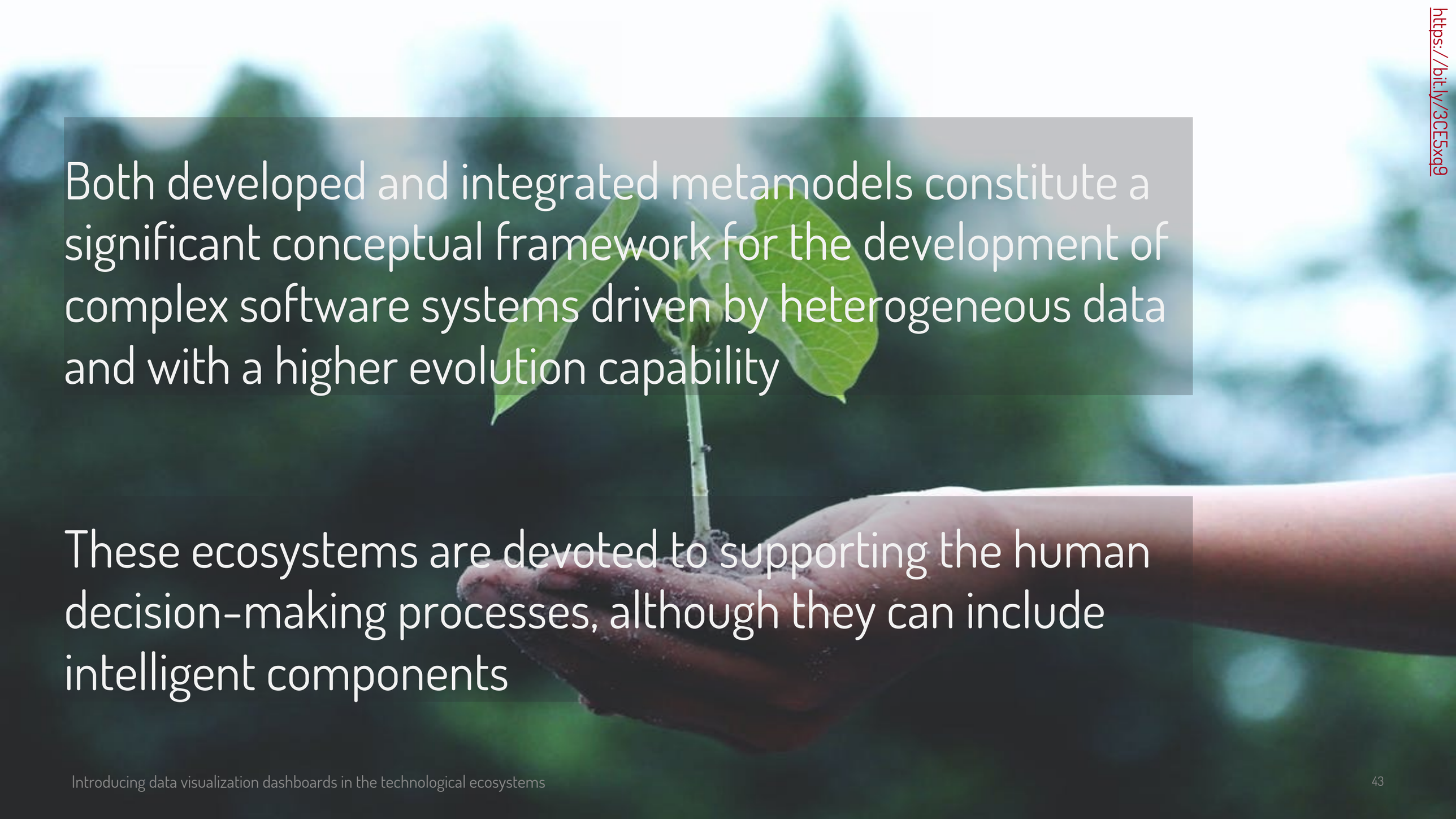
Model Driven Development and Software Product Lines

allow us to face the development of complex ecosystems in specific domains with feasibility thanks the support of fine-grained features



Both developed and integrated metamodels constitute a significant conceptual framework for the development of complex software systems driven by heterogeneous data and with a higher evolution capability

These ecosystems are devoted to supporting the human decision-making processes, although they can include intelligent components

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The inclusion of artificial intelligent mechanisms in the proposed conceptual framework

has been highly beneficial in capturing expert knowledge automatically

but training artificial intelligent models can lead to **biased results** if there is a lack of domain expertise or if input data are not interpreted correctly

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- Generative pipelines can be **dangerous** if not controlled
- Software systems can assist the design of data visualizations, but the honest endeavor in this context is to train **critical thinking** through these tools and their design process
- Knowing that data visualization can be affected by biases, it is important for the user to **be aware** of what they are doing and take action to convey or generate knowledge from raw data

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Introducing data visualization dashboards in the technological ecosystems

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