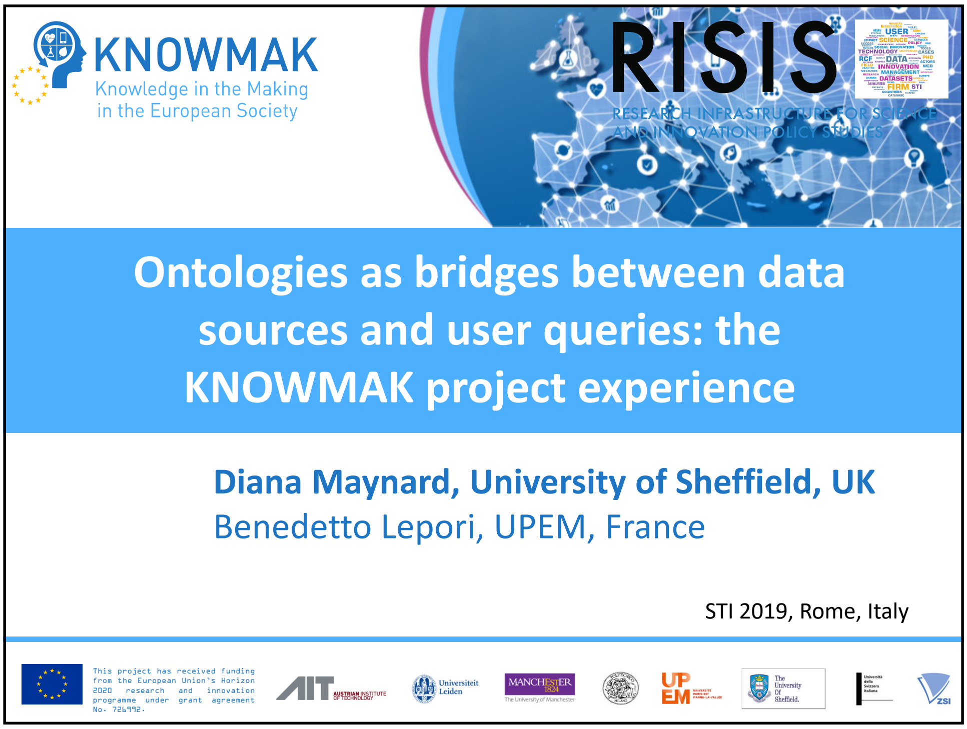


KNOWMAK
Knowledge in the Making
in the European Society

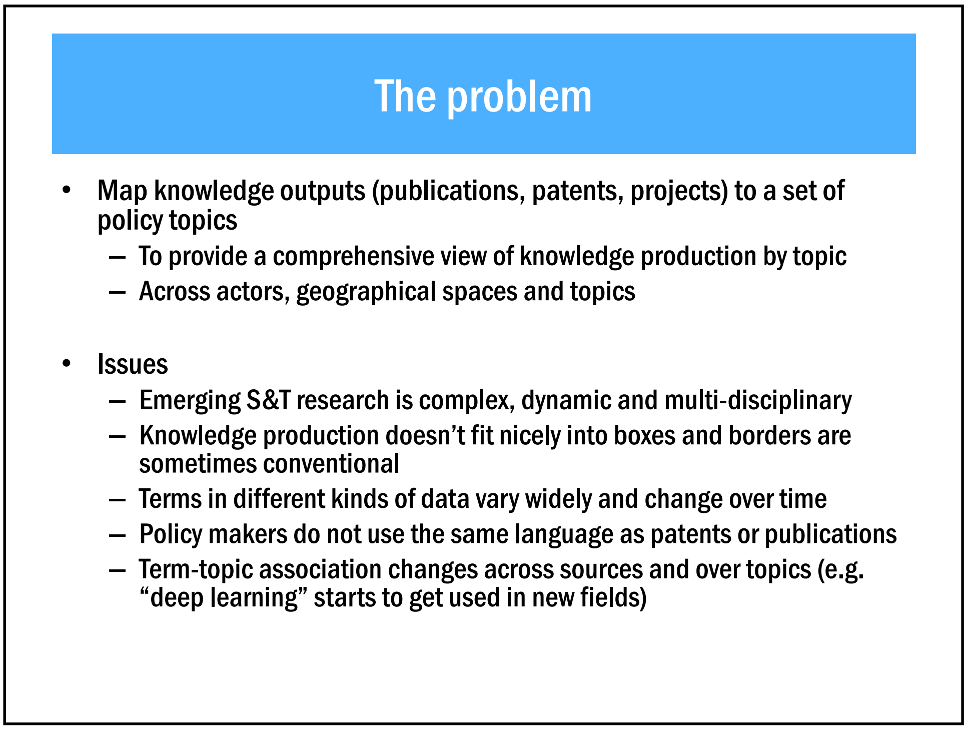
RISIS
RESEARCH INFRASTRUCTURE FOR SCIENCE AND INNOVATION POLICY STUDIES

# Ontologies as bridges between data sources and user queries: the KNOWMAK project experience

**Diana Maynard, University of Sheffield, UK**
Benedetto Lepori, UPEM, France

STI 2019, Rome, Italy

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 726992.

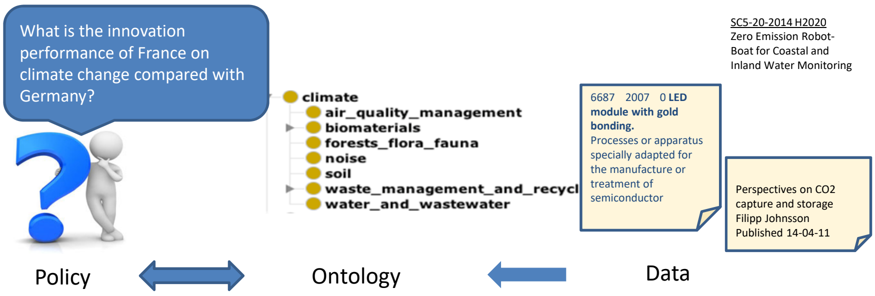


## The problem

- Map knowledge outputs (publications, patents, projects) to a set of policy topics
  - To provide a comprehensive view of knowledge production by topic
  - Across actors, geographical spaces and topics

- Issues
  - Emerging S&T research is complex, dynamic and multi-disciplinary
  - Knowledge production doesn’t fit nicely into boxes and borders are sometimes conventional
  - Terms in different kinds of data vary widely and change over time
  - Policy makers do not use the same language as patents or publications
  - Term-topic association changes across sources and over topics (e.g. “deep learning” starts to get used in new fields)

# Policy questions



What is the innovation performance of France on climate change compared with Germany?

climate
air_quality_management
biomaterials
forests_flora_fauna
noise
soil
waste_management_and_recycl
water_and_wastewater

SC5-20-2014 H2020
Zero Emission Robot-Boat for Coastal and Inland Water Monitoring

6687 2007 0 **LED module with gold bonding.**
Processes or apparatus specially adapted for the manufacture or treatment of semiconductor

Perspectives on CO2 capture and storage
Filipp Johnsson
Published 14-04-11

Policy
Ontology
Data

**In a nutshell:**

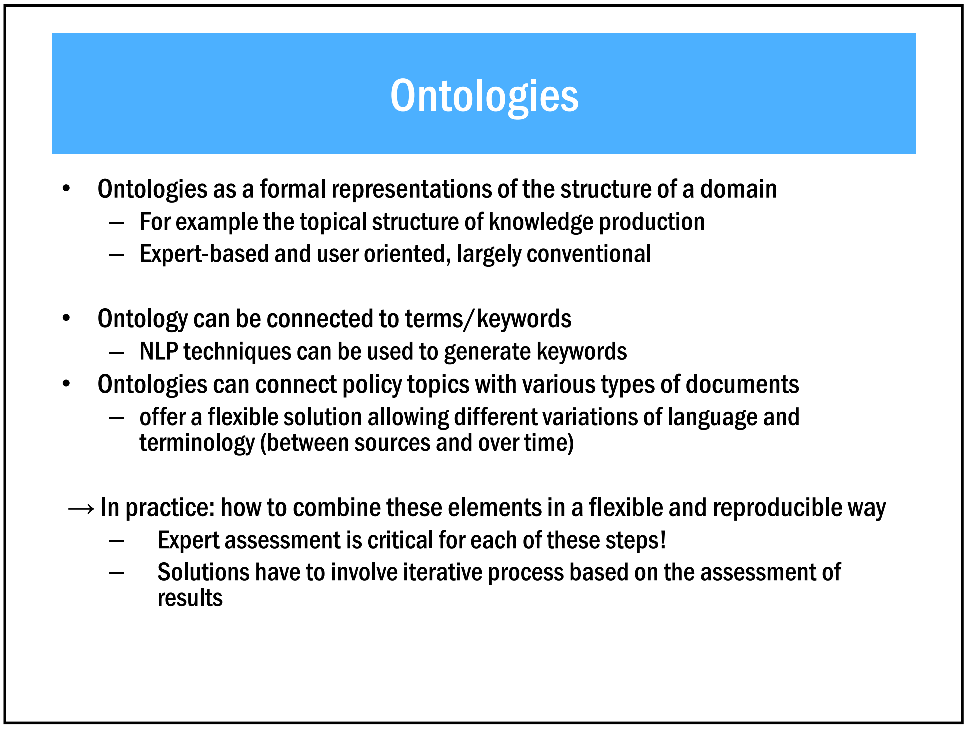
- We need to know which topics each document is talking about (multi-class classification)
- But we have to connect these topics together coherently

*Implemented within the KNOWMAK EU-FP project and further extended under the RISIS EU infrastructure project (risis.eu)*

# Usual approaches

- Link classifications to topics
  - For example IPC classes for patents or Fields of Science
  - Straightforward, but sometimes arbitrary and time-consuming
  - rigid and difficult to employ across different sources / publications vs. patents)
- Use NLP techniques to create maps of knowledge production
  - Very flexible, but sometimes too much detail, link with high-level topics unclear
  - Difficult to connect to policy language and across data sources with very different vocabularies

→ Need for an approach that combines expert-based classification and NLP techniques in a flexible manner

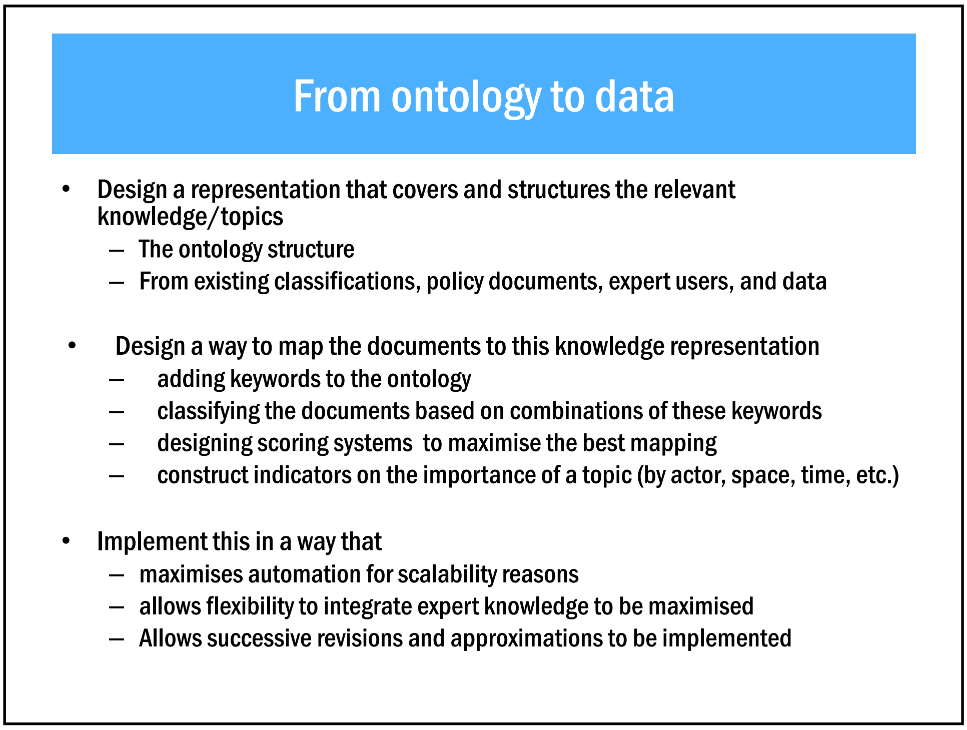


## Ontologies

- Ontologies as a formal representations of the structure of a domain
  - For example the topical structure of knowledge production
  - Expert-based and user oriented, largely conventional
- Ontology can be connected to terms/keywords
  - NLP techniques can be used to generate keywords
- Ontologies can connect policy topics with various types of documents
  - offer a flexible solution allowing different variations of language and terminology (between sources and over time)

→ In practice: how to combine these elements in a flexible and reproducible way

- Expert assessment is critical for each of these steps!
- Solutions have to involve iterative process based on the assessment of results



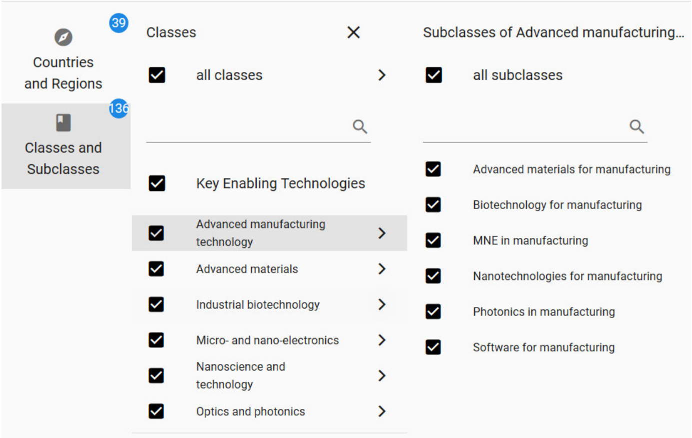
## From ontology to data

- Design a representation that covers and structures the relevant knowledge/topics
  - The ontology structure
  - From existing classifications, policy documents, expert users, and data
- Design a way to map the documents to this knowledge representation
  - adding keywords to the ontology
  - classifying the documents based on combinations of these keywords
  - designing scoring systems to maximise the best mapping
  - construct indicators on the importance of a topic (by actor, space, time, etc.)
- Implement this in a way that
  - maximises automation for scalability reasons
  - allows flexibility to integrate expert knowledge to be maximised
  - Allows successive revisions and approximations to be implemented

# Ontology structure

- There aren't any suitable ontologies already out there
  - The amount of data is too big to build them manually
  - But automated methods are problematic too
- Solution: create the initial structure manually based on existing representations
  - Nature.doc for technology
  - EU policy documents for SGCs
- Reducing the complexity: 2-level ontology, 13 KETs/SGCs and 135 subclasses
- Assessing  the structure
  - Reducing overlap between classes
  - Dropping 'rare' classes
  - Adding classes from data sources (social innovation)
- Expert knowledge is needed for fine-tuning

# Ontology structure



Classes ✕

☑ all classes >

☑ Key Enabling Technologies

☑ Advanced manufacturing technology >

☑ Advanced materials >

☑ Industrial biotechnology >

☑ Micro- and nano-electronics >

☑ Nanoscience and technology >

☑ Optics and photonics >

Subclasses of Advanced manufacturing...

☑ all subclasses

☑ Advanced materials for manufacturing

☑ Biotechnology for manufacturing

☑ MNE in manufacturing

☑ Nanotechnologies for manufacturing

☑ Photonics in manufacturing

☑ Software for manufacturing

http://demos.gate.ac.uk/knowmak/faceted-search/

http://demos.gate.ac.uk/knowmak/filter-search/

## Ontology population

- Source data comprises policy documents, topic descriptions, links to other knowledge sources etc.
  - For example the IPC patent vocabulary
- Apply NLP tools
  - Generate lists of terms associated with each class (gazetteers)
- Linguistic variants: more sophisticated NLP
  - “Similar” terms: word embeddings, additional info sources (DBpedia, terminologies, policy documents)

## Pitfalls and issues

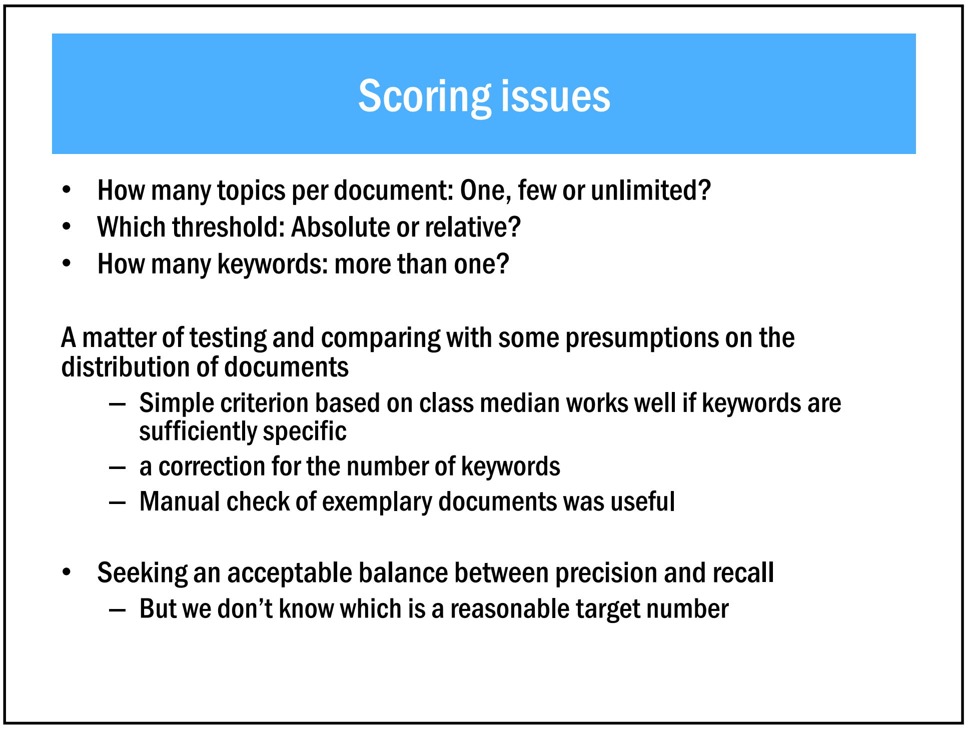
- Overlaps between classes lead to issues with automatic keywords generation
  - Manual cleaning needed
- Generic keywords creep in through automatic generation
  - List of stopwords critical and manual check ex-post from the scoring
  - But very specific keywords might lead to low recall if these are too few
- Very unequal number of keywords by class
  - Need to take into account in the scoring

## Keyword occurrences in patents

| | | |
|---|---|---|
| macromolecular | 58’772.00 | dna nantechnology |
| scaffold | 16’373.00 | dna nantechnology |
| dna | 15’226.00 | dna nantechnology |
| rna | 13’101.00 | dna nantechnology |
| macromolecule | 10’751.00 | dna nantechnology |
| surface | 345’986.00 | nanobiotechnology |
| interface | 49’989.00 | nanobiotechnology |
| concentration | 37’631.00 | nanobiotechnology |
| molecule | 30’961.00 | nanobiotechnology |
| array | 22’340.00 | nanobiotechnology |
| assay | 14’160.00 | nanobiotechnology |
| microorganism | 4’088.00 | nanobiotechnology |
| neural | 2’513.00 | nanobiotechnology |

## Annotating Data with Ontologies

- Data sources are annotated against the ontologies
  - each document is associated with one or more topics
- NLP matching of keywords in the documents (from titles, abstracts etc) with ontology
- Based on linguistic pre-processing, term recognition, frequency and some weighting mechanisms
- Higher priority (weights) allocated to a topic for that document if:
  - Multi-word term (vs single-word term)
  - It belongs to a more specific ontology class
  - It comes from a particular trusted source (e.g. IPC patent codes)
  - more matching terms associated with that class



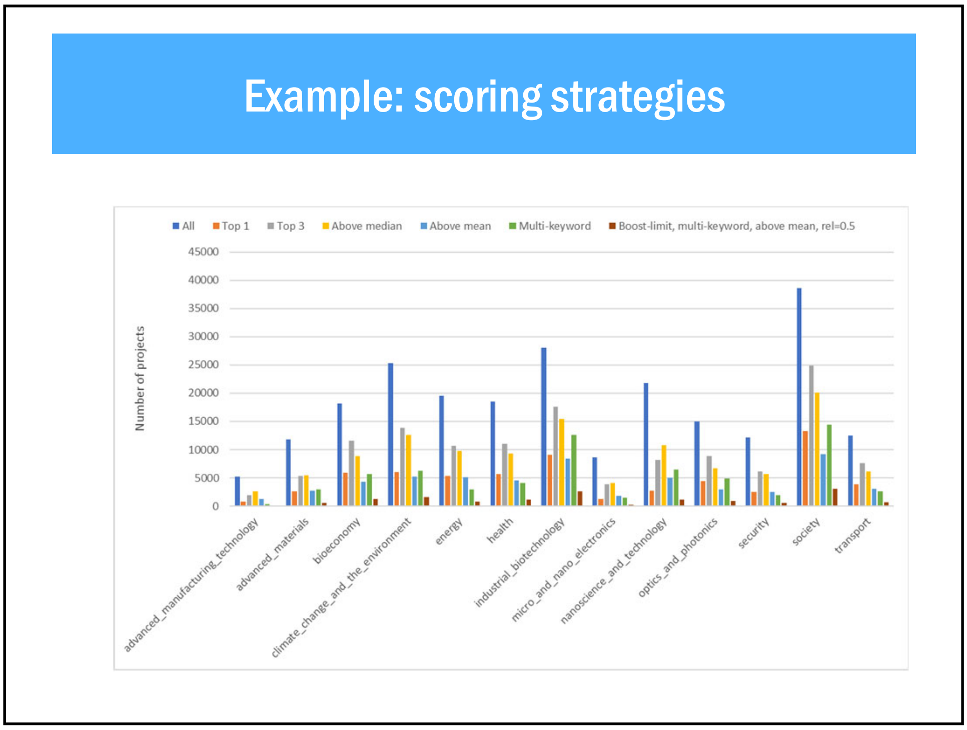
# Scoring issues

- How many topics per document: One, few or unlimited?
- Which threshold: Absolute or relative?
- How many keywords: more than one?

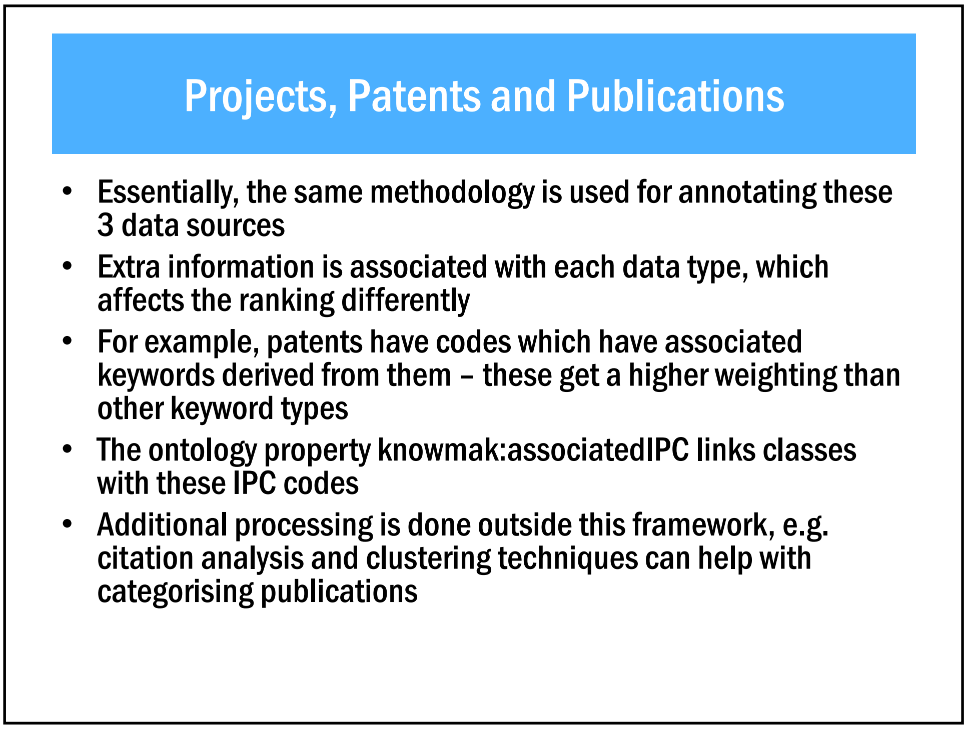
A matter of testing and comparing with some presumptions on the distribution of documents

- – Simple criterion based on class median works well if keywords are sufficiently specific
- – a correction for the number of keywords
- – Manual check of exemplary documents was useful

- Seeking an acceptable balance between precision and recall
  - – But we don't know which is a reasonable target number

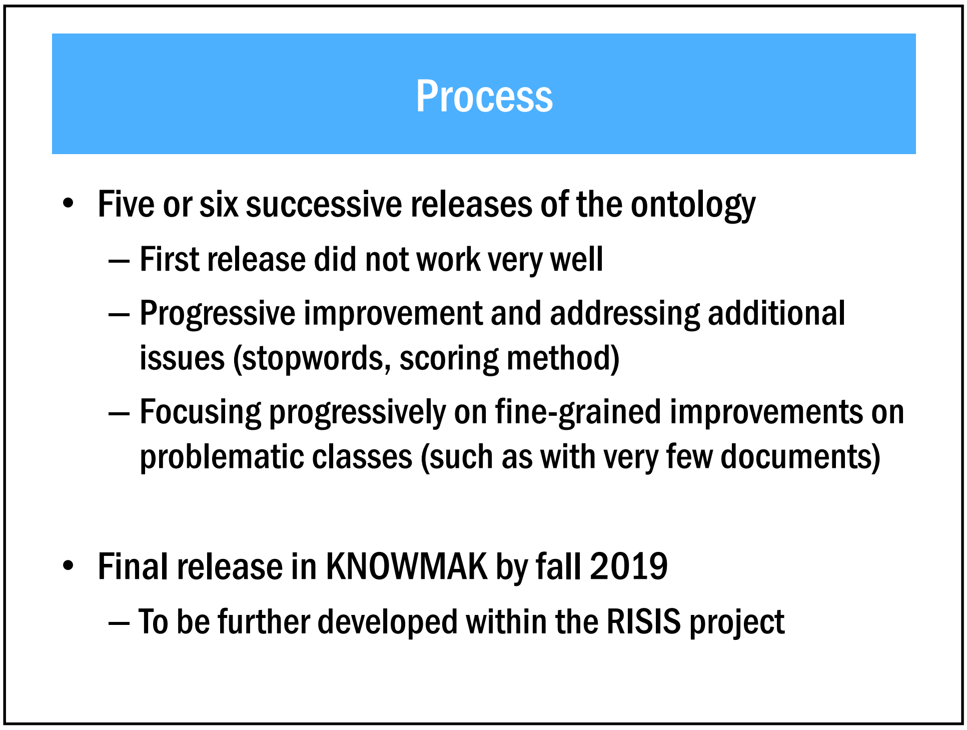


# Example: scoring strategies



## Projects, Patents and Publications

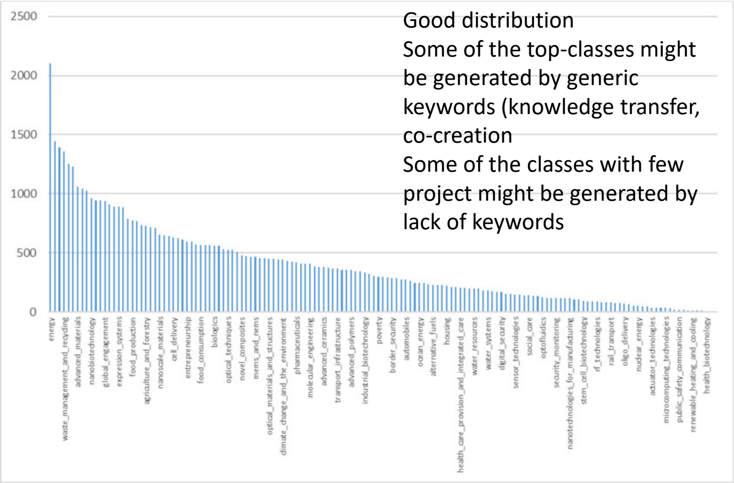
- Essentially, the same methodology is used for annotating these 3 data sources
- Extra information is associated with each data type, which affects the ranking differently
- For example, patents have codes which have associated keywords derived from them – these get a higher weighting than other keyword types
- The ontology property knowmak:associatedIPC links classes with these IPC codes
- Additional processing is done outside this framework, e.g. citation analysis and clustering techniques can help with categorising publications



## Process

- Five or six successive releases of the ontology
  - First release did not work very well
  - Progressive improvement and addressing additional issues (stopwords, scoring method)
  - Focusing progressively on fine-grained improvements on problematic classes (such as with very few documents)
- Final release in KNOWMAK by fall 2019
  - To be further developed within the RISIS project

## Current distribution by classes for EU-FP projects

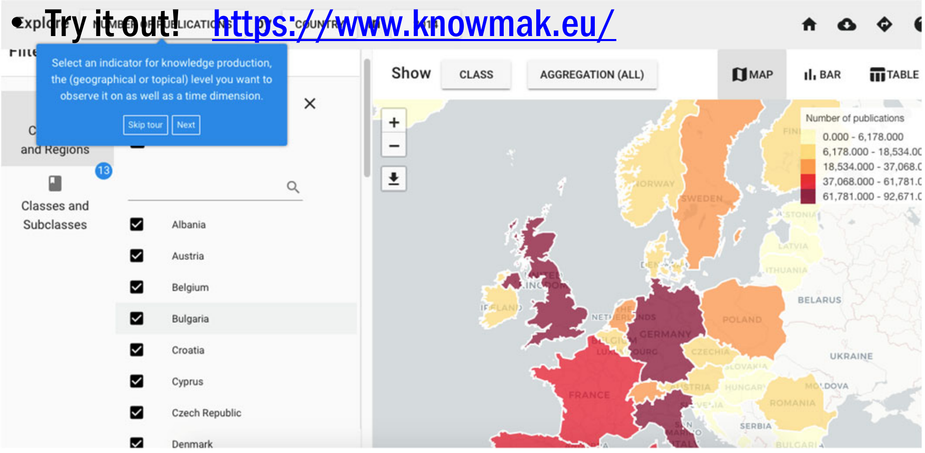


Good distribution
Some of the top-classes might be generated by generic keywords (knowledge transfer, co-creation
Some of the classes with few project might be generated by lack of keywords

## Work ahead in RISIS2

- Systematic evaluation of precision and recall
  - By scoring manually a sufficiently large number of documents
  - Needed for validity of the ontology
- Investigate better methods for automatically generating topic keywords that are both relevant and representative of a class
  - factoring in negative as well as positive feedback mechanisms
  - Adjustment of similarity thresholds and investigation of scoring metrics based on gold standard data
- Potential incorporation of new topics with minimal human expert intervention for a more sustainable approach long-term

- Try it out! https://www.knowmak.eu/


Select an indicator for knowledge production, the (geographical or topical) level you want to observe it on as well as a time dimension.

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USER
SCIENCE
TECHNOLOGY
DATA
INNOVATION
MANAGEMENT
DATASETS
FIRM
STI

## THANK YOU FOR LISTENING!

Main project website
Sheffield's KNOWMAK work
RISIS project
GATE tools

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