

Digital Twin

Bi-Weekly 3 (11/11/2022)

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Agenda

- Research Framework
- Paper Selection
 - Steps Overview
 - Keywords matching
 - Manually Score & Skimming
- State of the Art
 - statistics
 - Highlights
- Next steps

Key: Digital
Twin

→ DI, System, CP,
→ DT and Sustainability
Quantity

DES

DES | Sync & valid.

→ Data mining;
Process mining;

→ Model generation
→ forecasting / Predict

Academic
(papers)

Clustering

Research Framework

→ Startups
→ Industry trends
→ Big Players

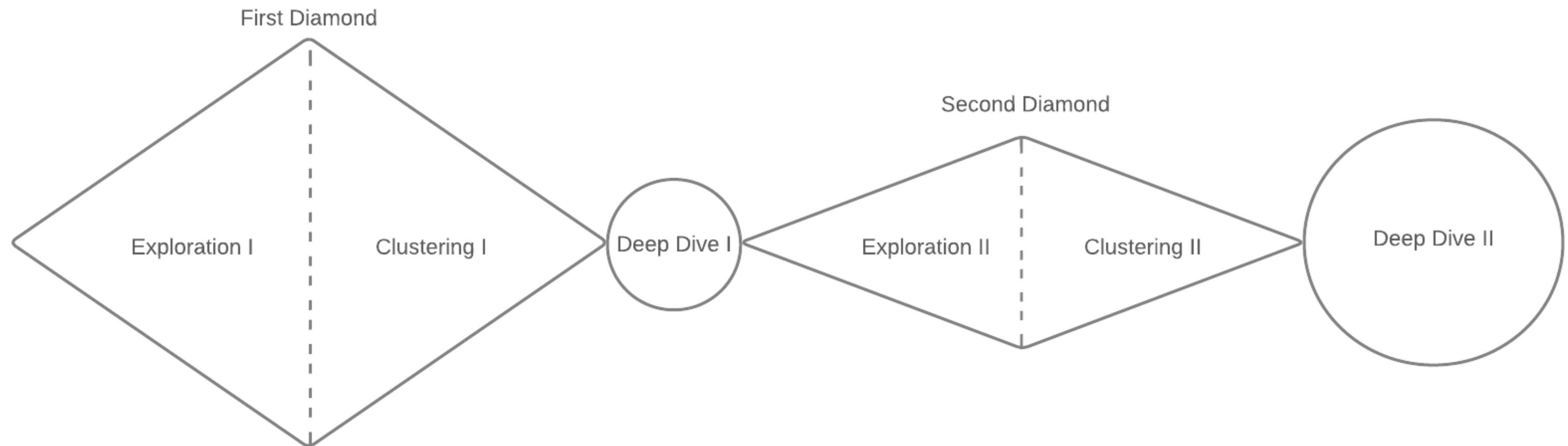
Industrial
(solutions)

→ Financial reports (Investor / Shareholders)

Business

Planning
① 18 hr → Collecting
(~720 paper)

② 6 hr → PdM, SCA



Definitions:
 Exploration: Search for content without getting in detail
 Clustering: Putting contents together and insights
 Deep Dive: Going deep with the selected content

- First Diamond**
- A broad overview of the main topics related to Digital Twin.
 - Trying to create insights from contents that are not specific for Digital Twin applications
 - Key research areas:
 - Digital Twin
 - Discrete Event Simulations
 - Data and Process mining
 - Syncro. / Validations
 - Forecasting / Predictions
 - Model Generations

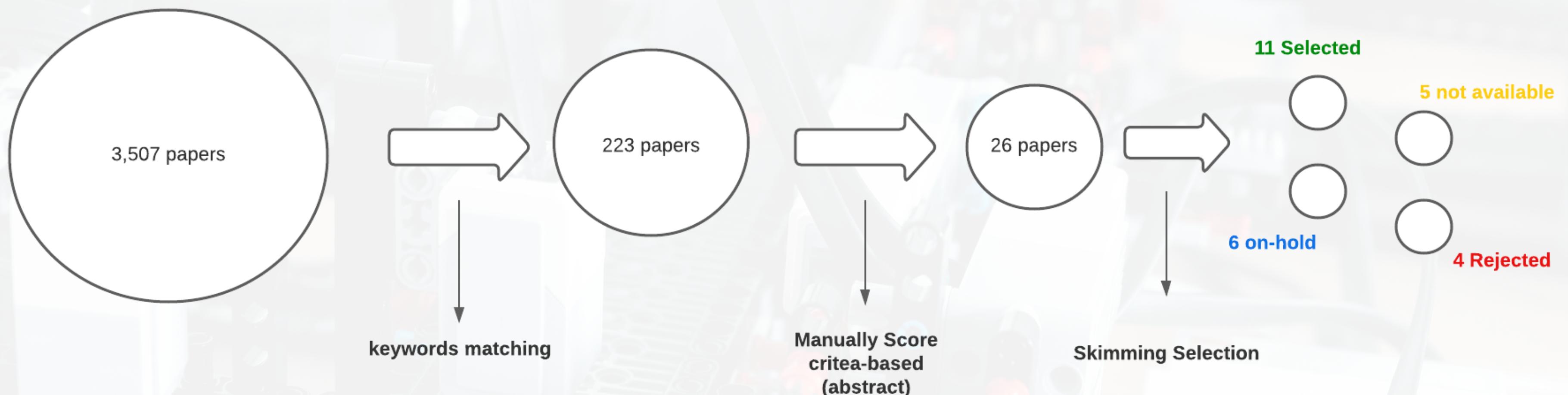
Academic

- Second Diamond**
- Specific overview about the main topics related to Digital Twin and production systems
 - Trying to find what was already done in the same area of Lego Factory
 - Key research areas are the same as the key-words from previous works + new key-words from insights of the first diamond.



Paper Selection

Overview



Base Keywords

(TITLE ("digital twin")

AND

ALL ("manufacturing" OR "production")

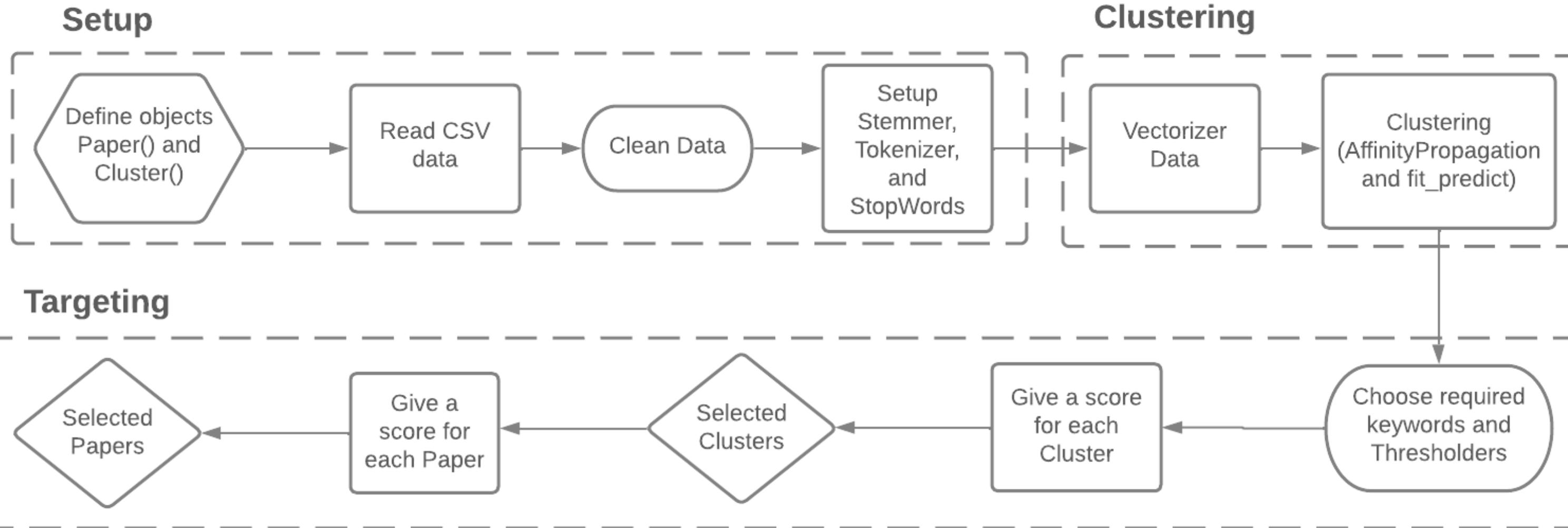
AND

ALL ("applications OR "discrete event simulation" OR "process mining"
OR "model generation" OR sustainability OR types OR categories OR
architecture OR framework OR standards))



Source Database: Scopus
Query Date: 28/10/2022

Keywords matching



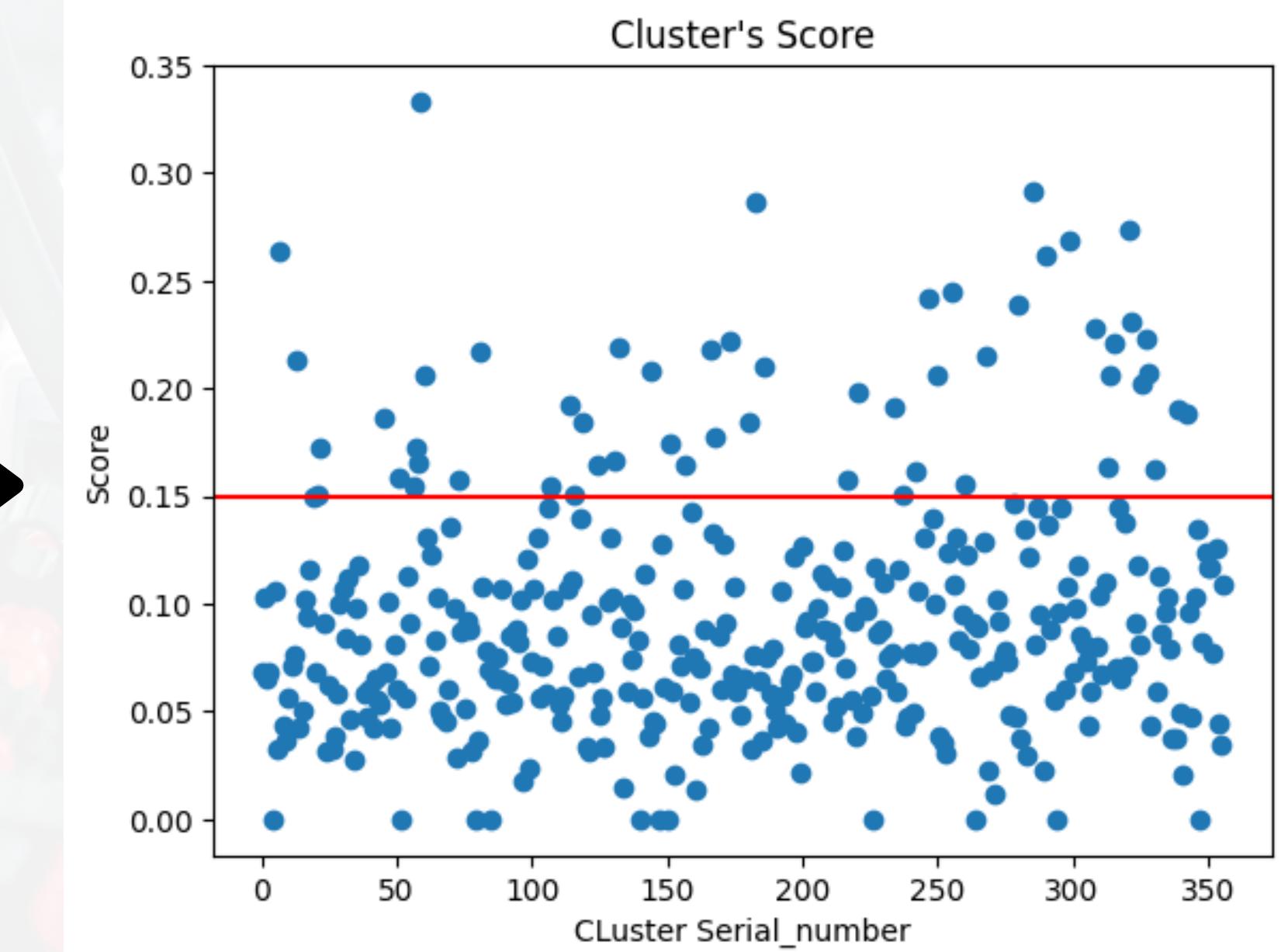
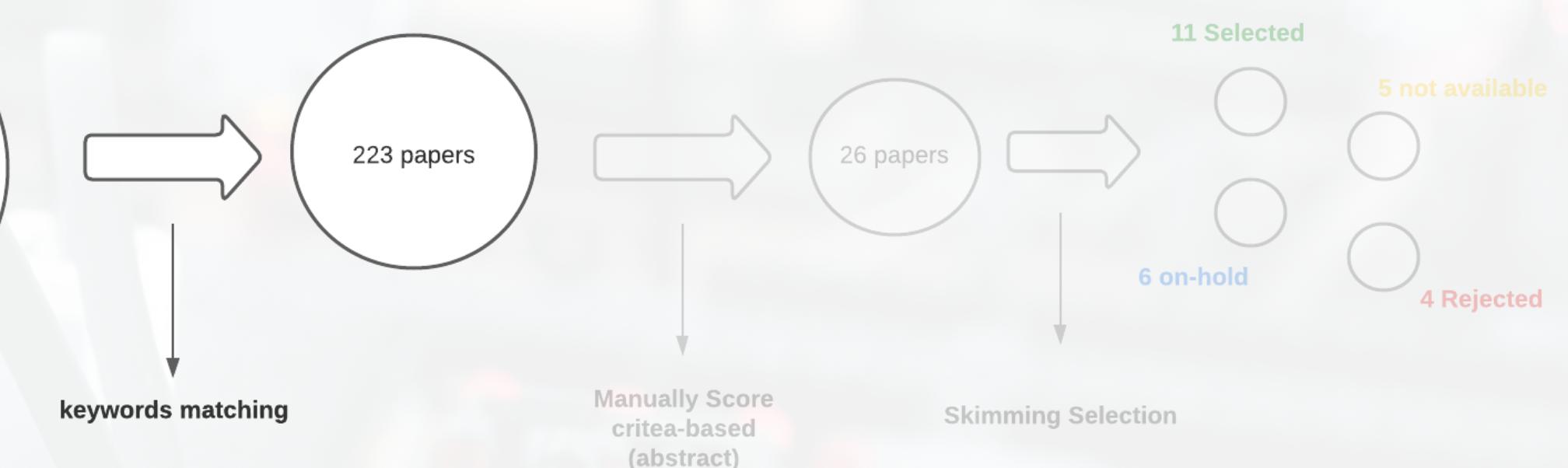
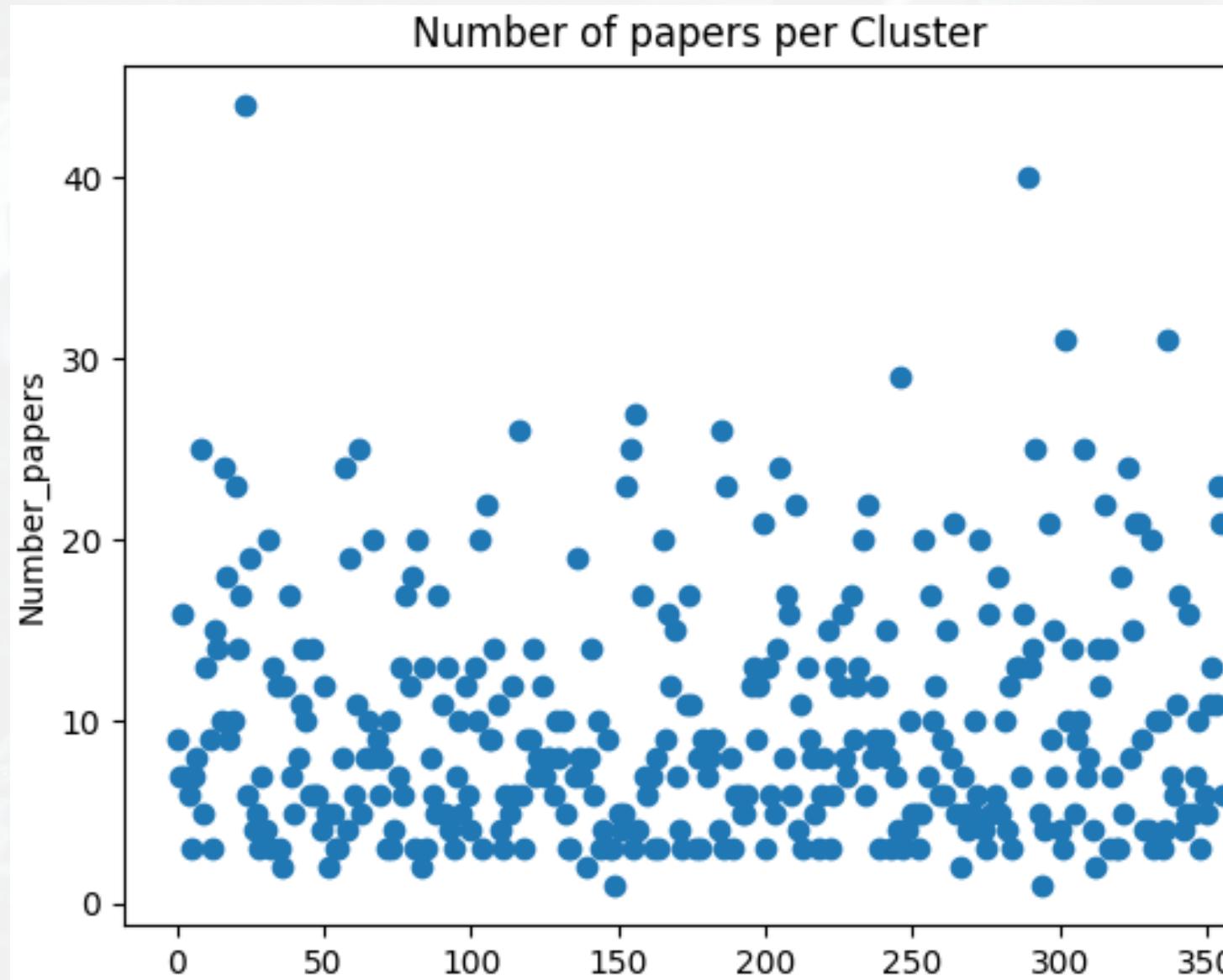
Keywords matching



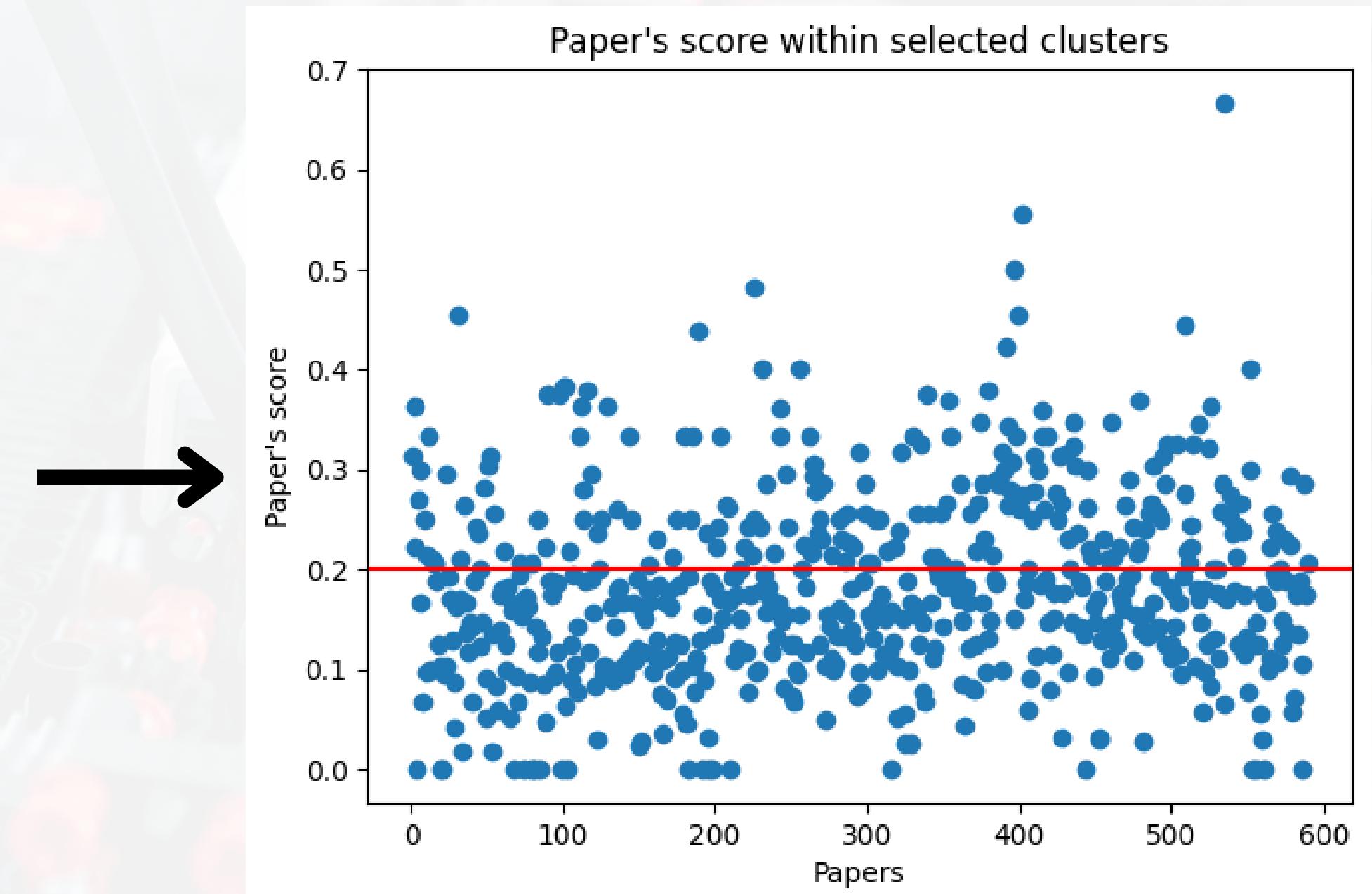
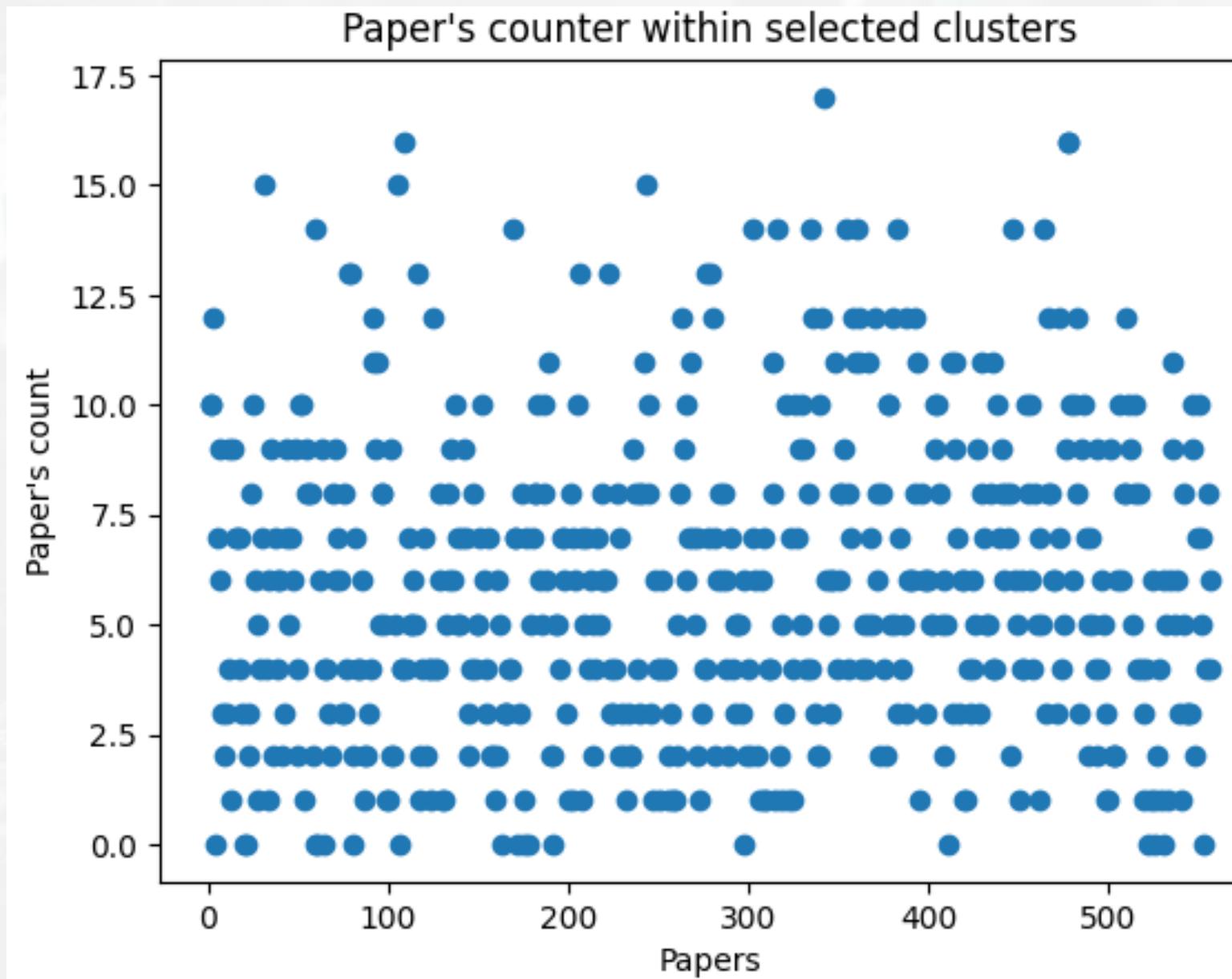
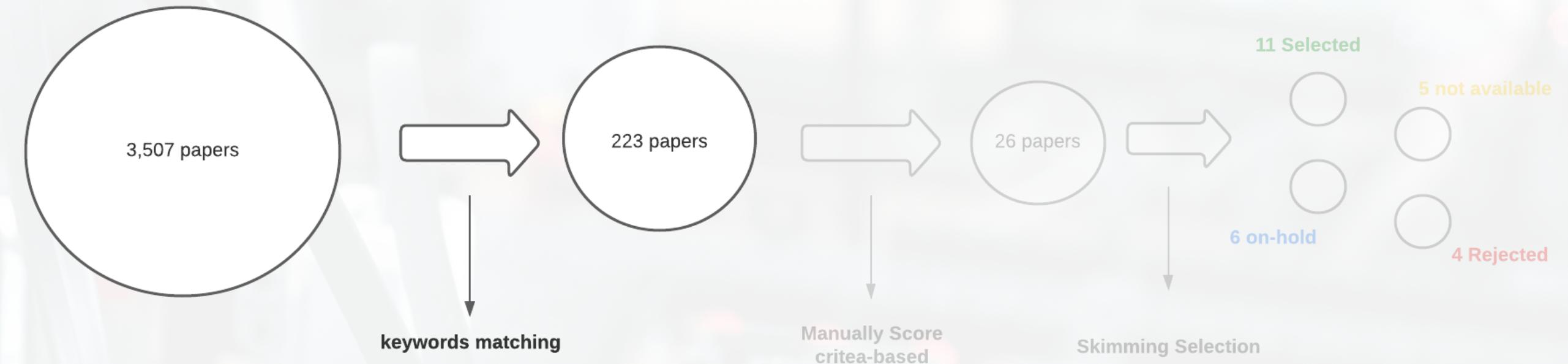
Vectorizing the Keywords

	A	B	C	D	E	F
A, B, D, E	1	1	0	1	1	0
A, C, F, M,	1	0	1	0	0	1
B, E, G, N	0	1	0	0	1	0
H, C, F, M	0	0	1	0	0	1

Keywords matching

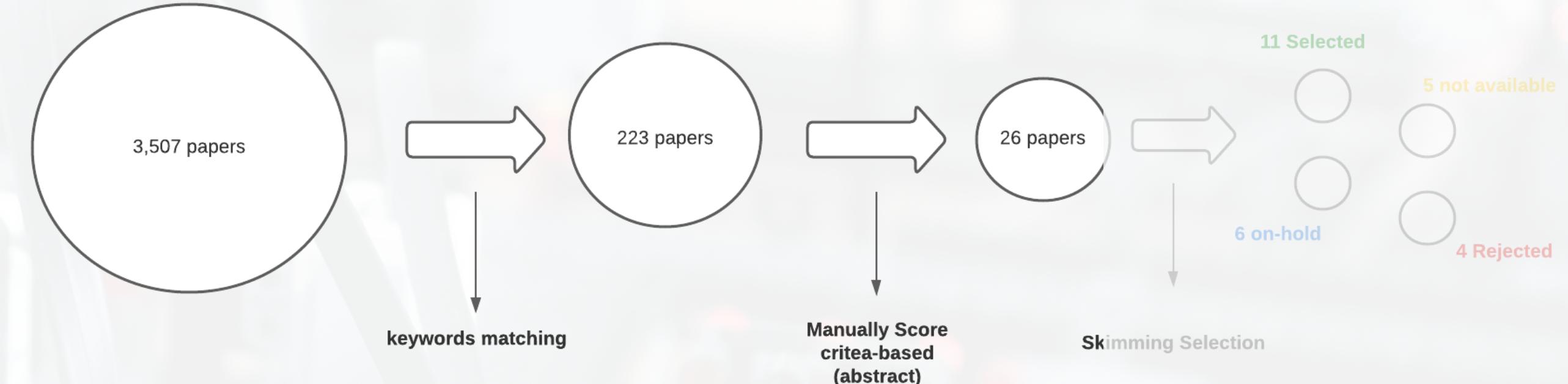


Keywords matching



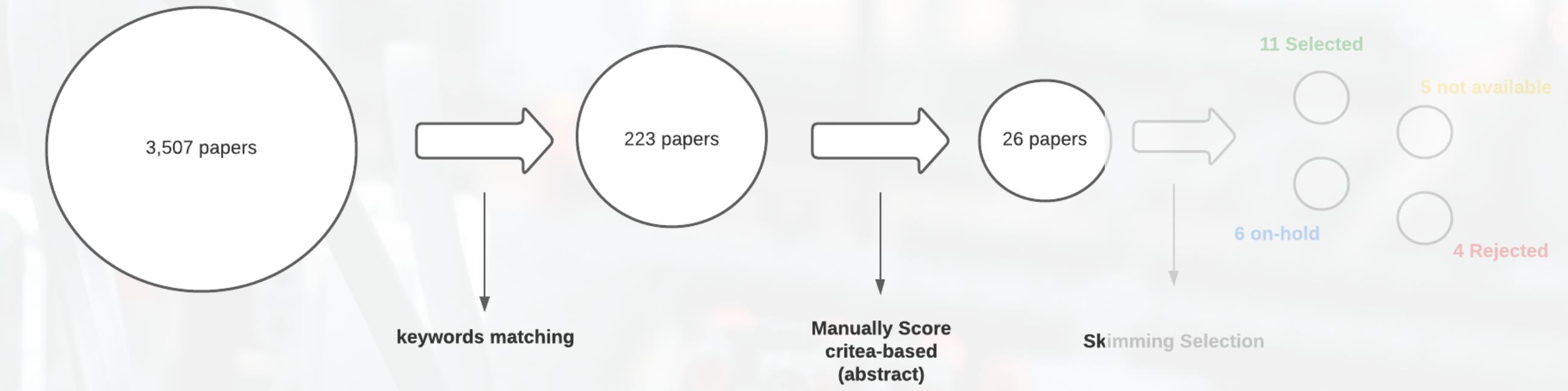
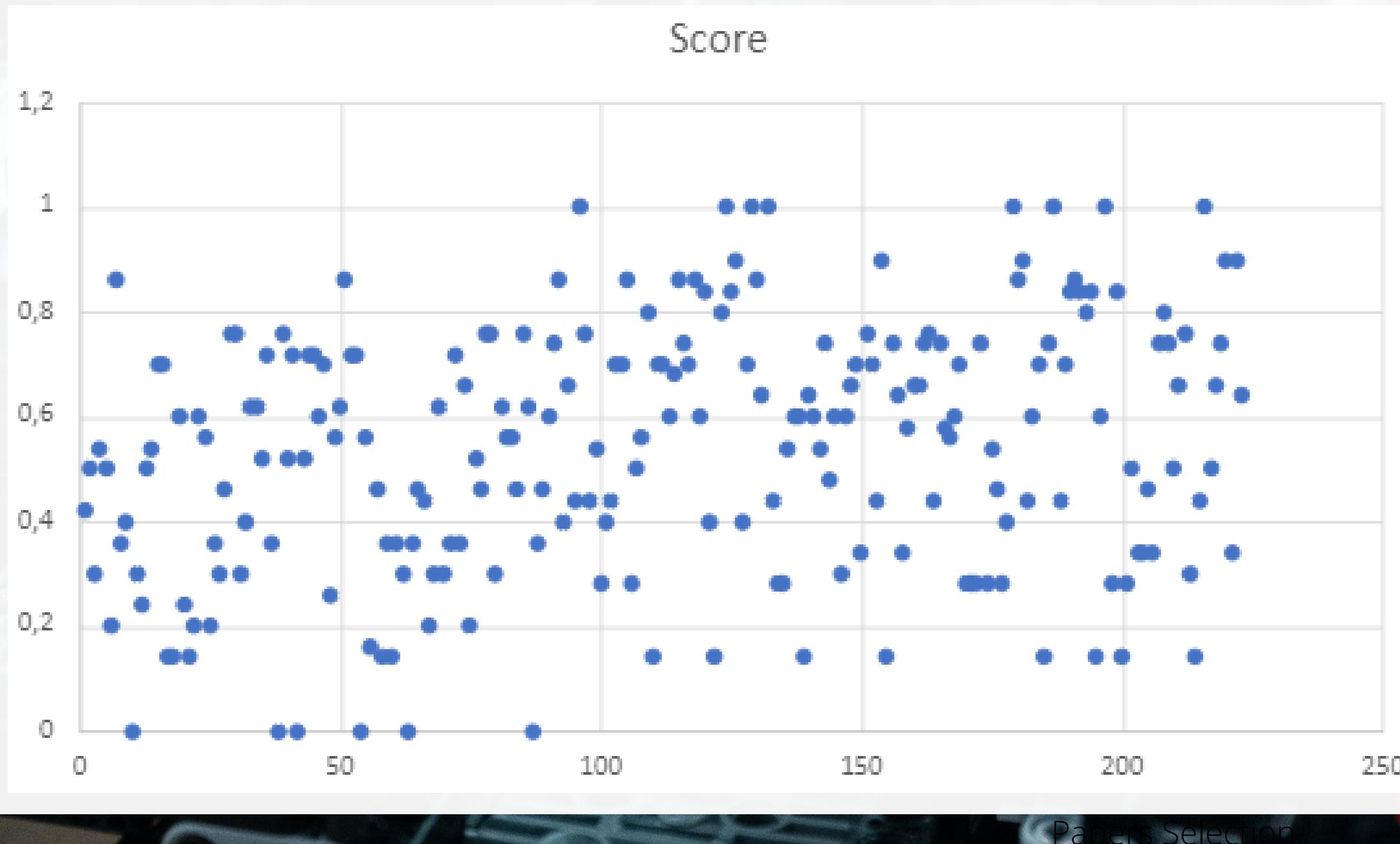
Papers Selection

Manually Scoring



CRITERIA	Weightage	Score range
Digital twin quality (DTQ)	20%	1 - Complete definition; 0.5 - incomplete development; 0 - wrong definition
Application/Area (AA)	20%	1 - related to manufacturing/production; 0 - others
Single or Multiple Machines/Assets (SM)	16%	1 - Multiple asset/ system level DT; 0 - Single asset/ individual machine level DT
Specific DT or Generic DT (SG)	16%	1 - Generic application/scenario; 0 - Specific application/scenario
Year (Y)	14%	1 - year ≥2021; 0 - year <2021
New or existing Methods/Tools (NM)	14%	1 - New/Unknown; 0 - Existing/Known

Manually Scoring



- There isn't an explicit correlation between the 2 approaches - as it was supposed to be
- 4 papers from Polimi were selected in the end. This indicate that the result is aligned with the Lab

Skimming

11 Selected



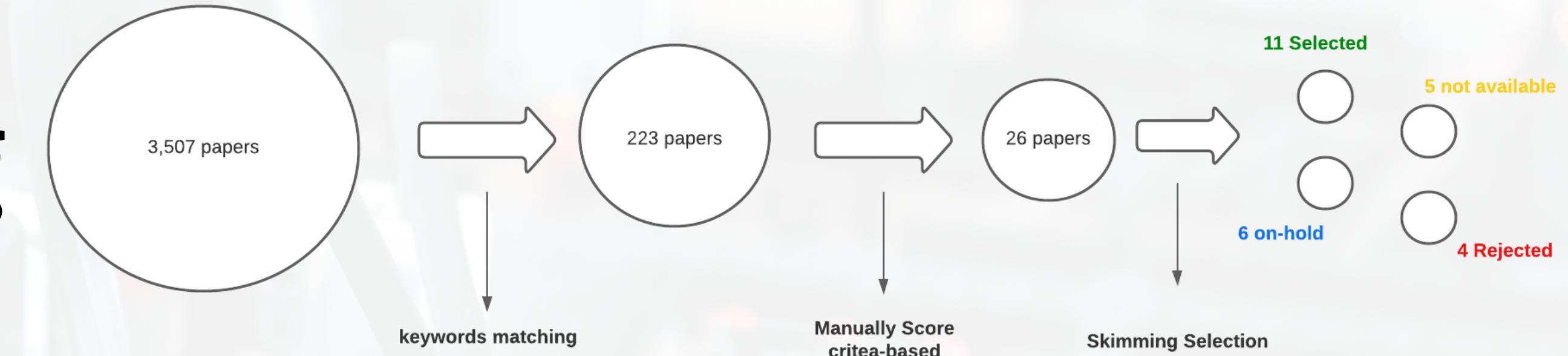
5 not available



6 on-hold



4 Rejected



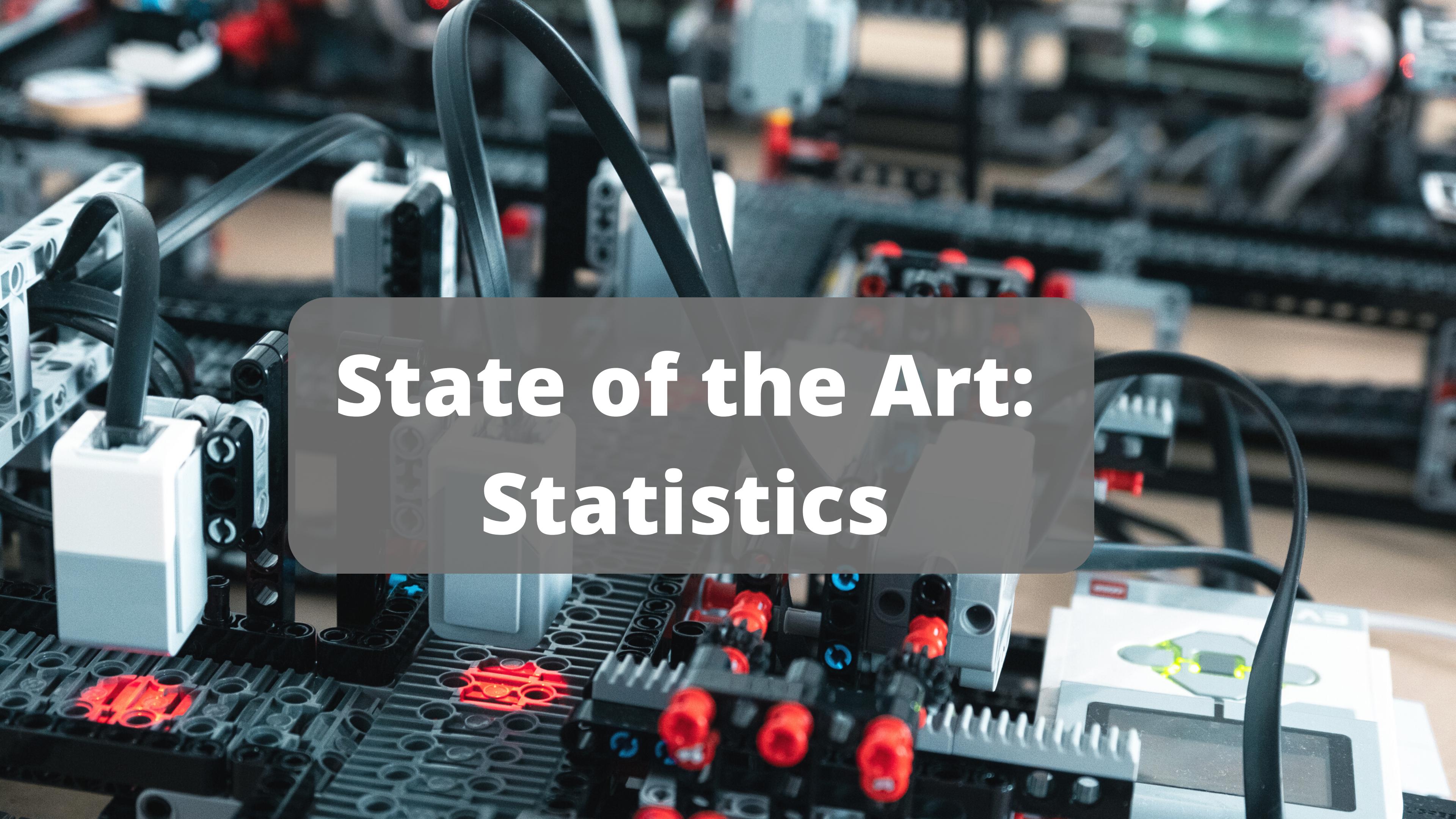
Automated digital twins generation for manufacturing systems:
A case study

Digital twins: Representation, Replication, Reality, and
Relational (4Rs)

Unifying digital twin framework: Simulation-based proof-of-
concept

Digital twins-based flexible operating of open architecture
production line for individualized manufacturing

-
-
-



State of the Art:
Statistics

Statistics

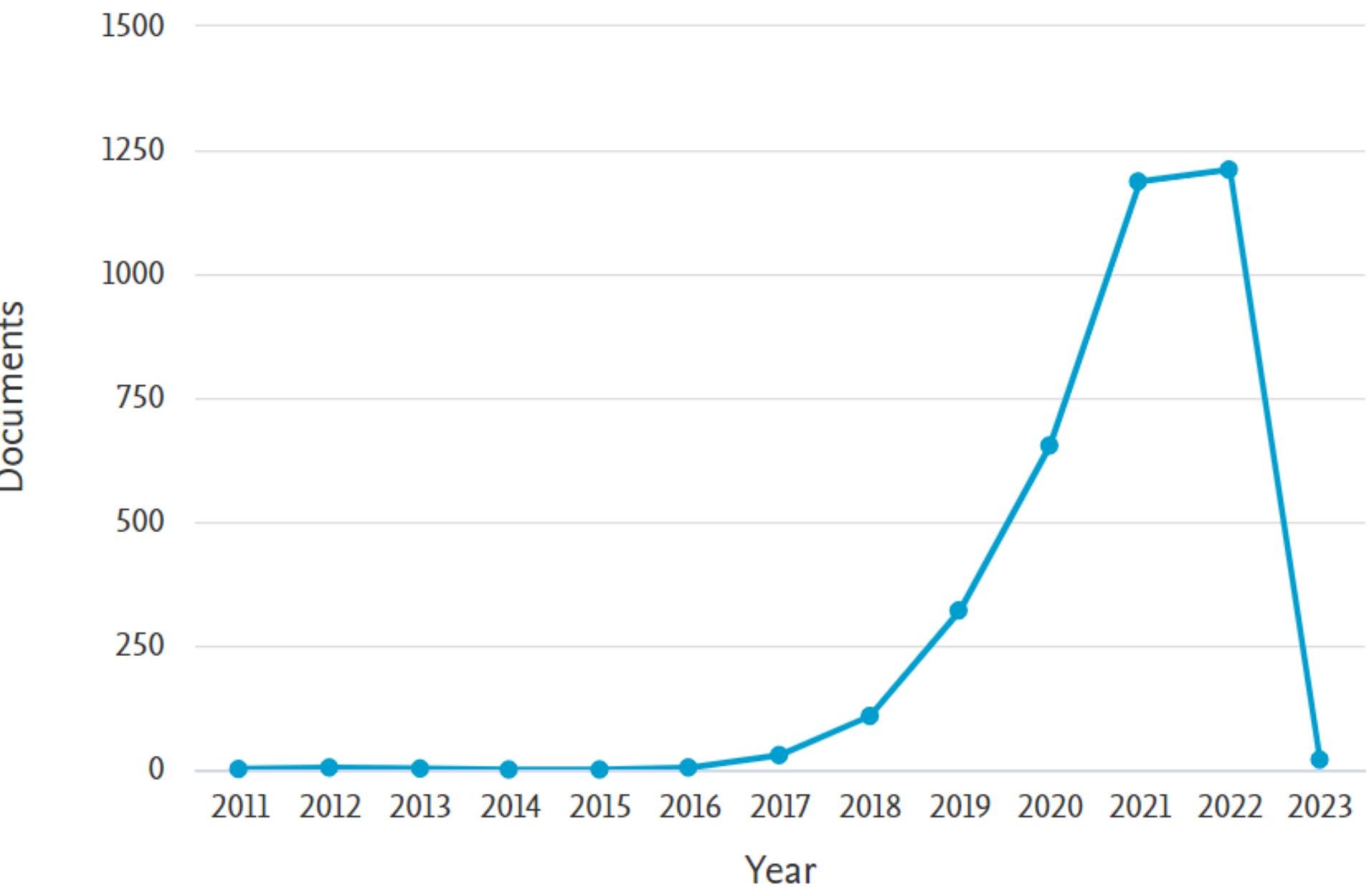


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Academic Articles

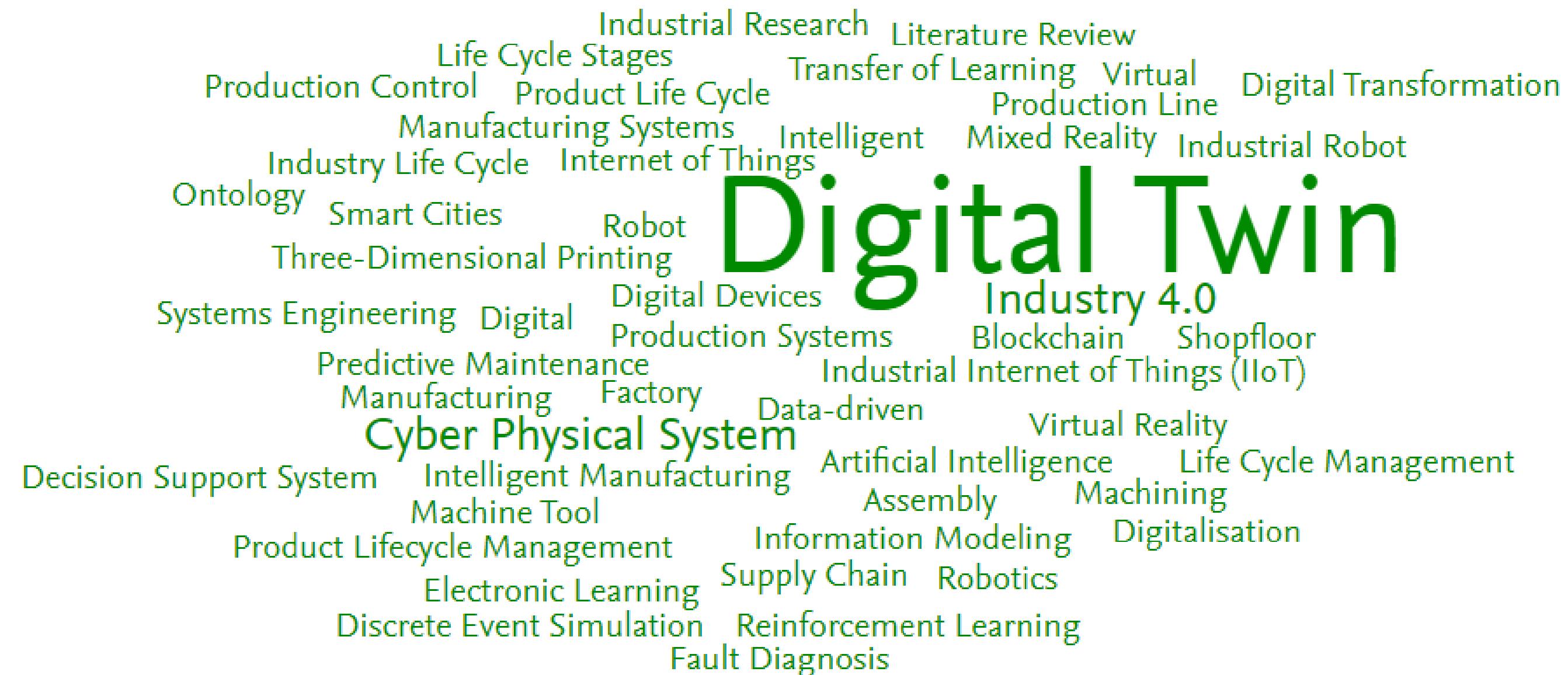
Source: Scopus

Documents by year



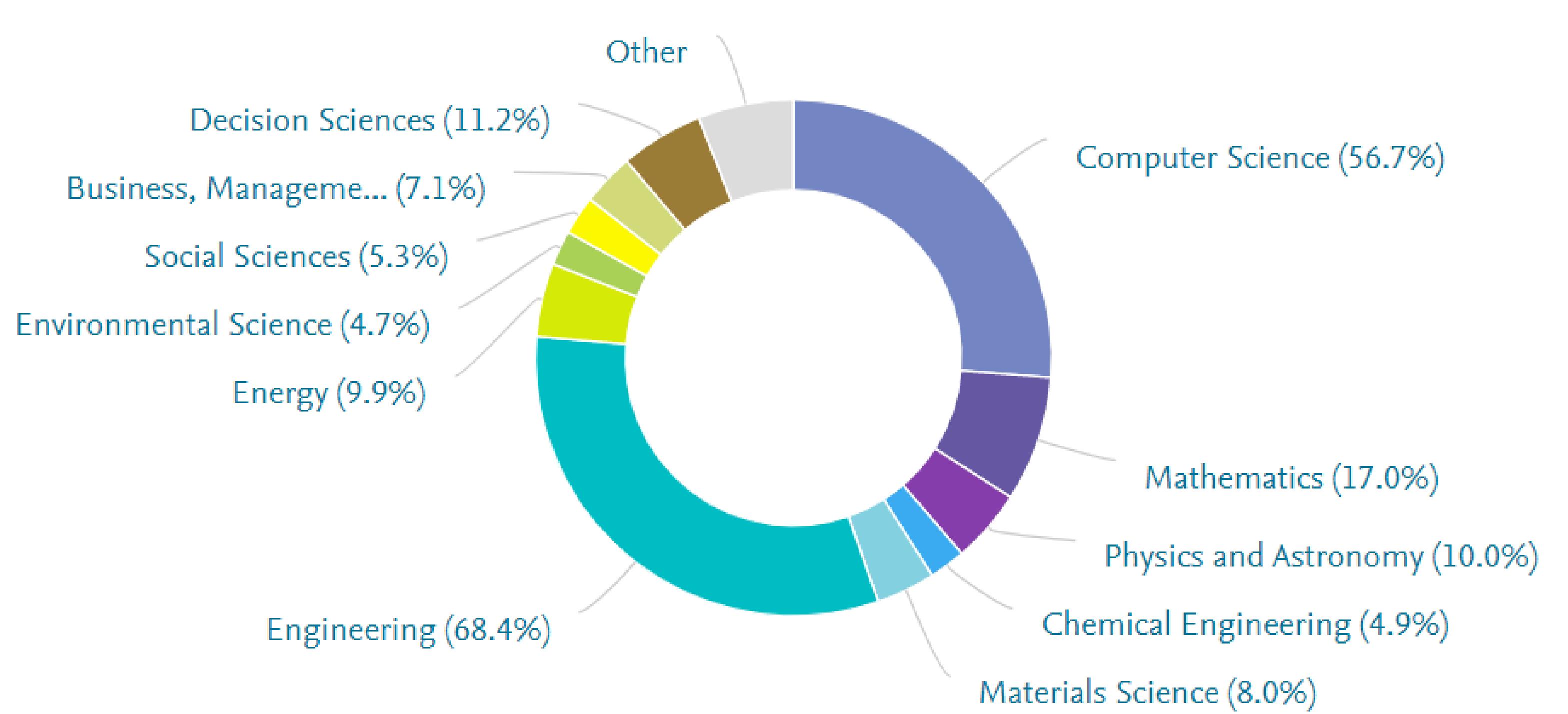
Statistics

Major Keyphrases



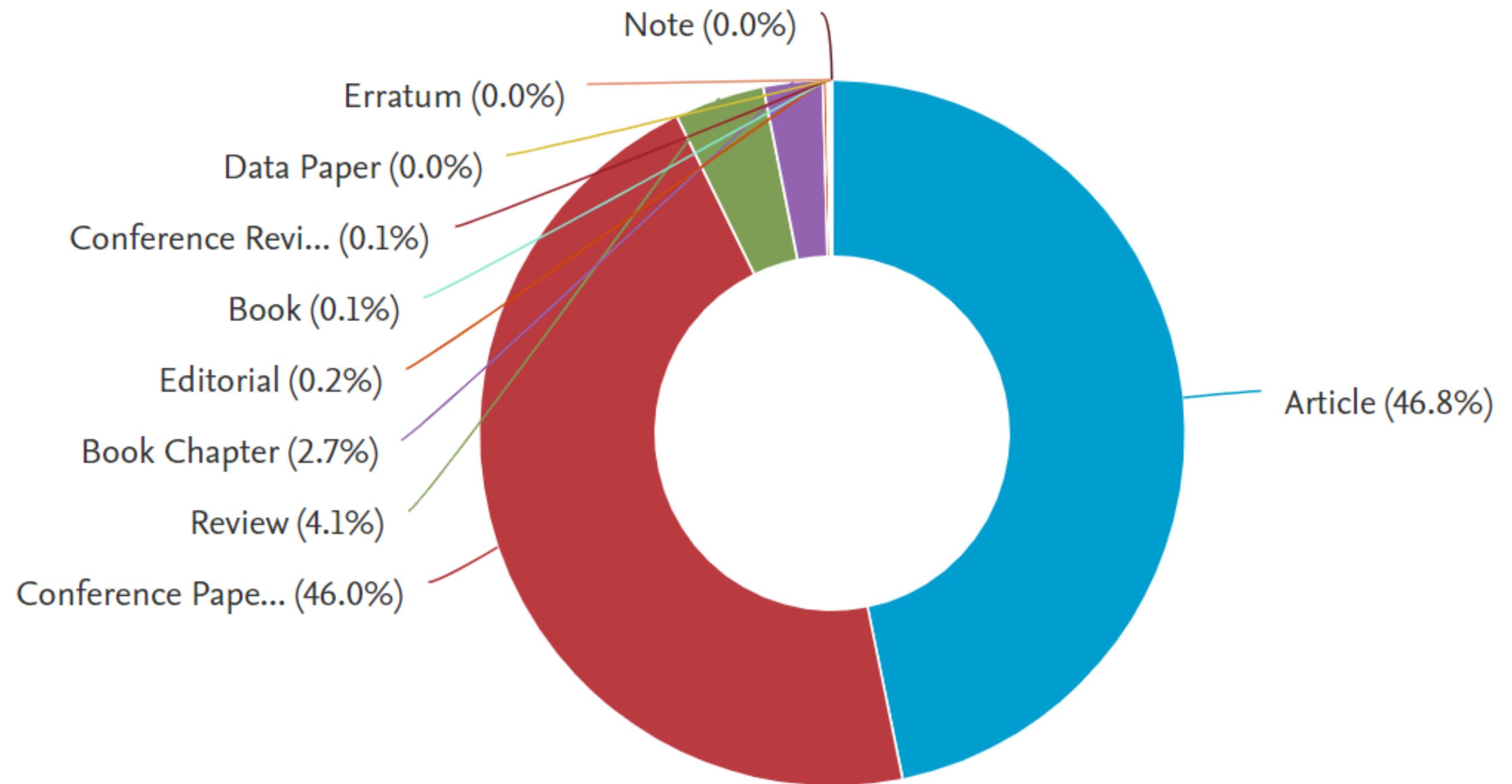
Statistics

Publication share by Subject Area



Statistics

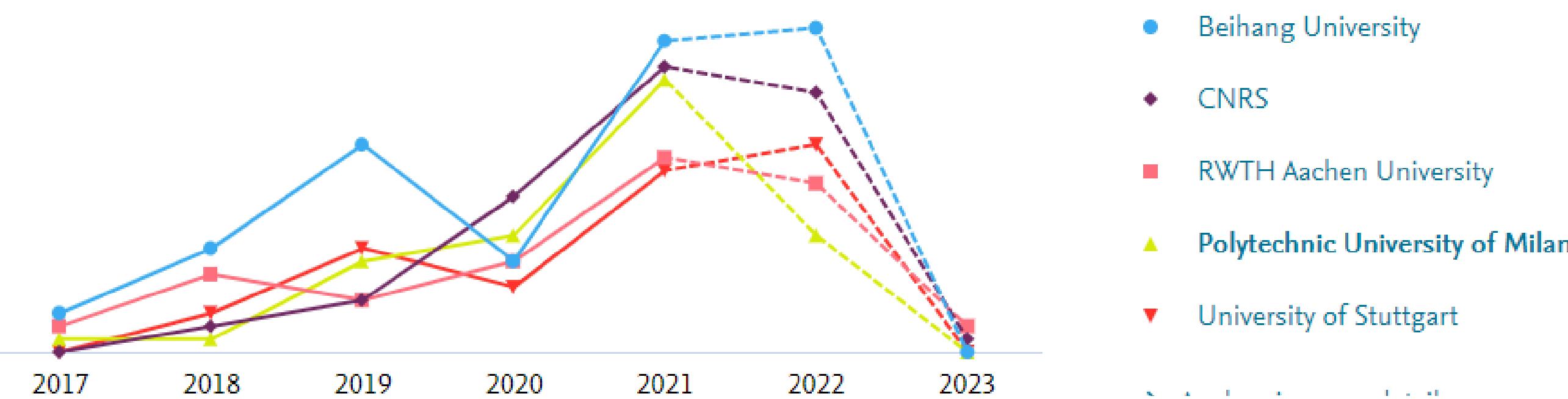
Documents by Type



Statistics



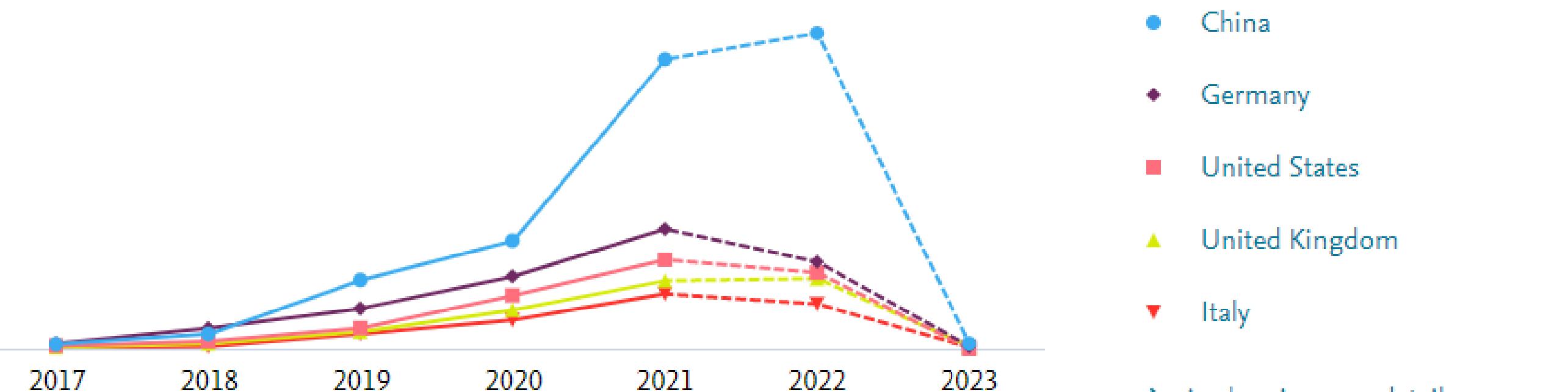
Most active Institutions



Top 5 by Scholarly Output

83
61
49
48
46

Most active Countries/Regions

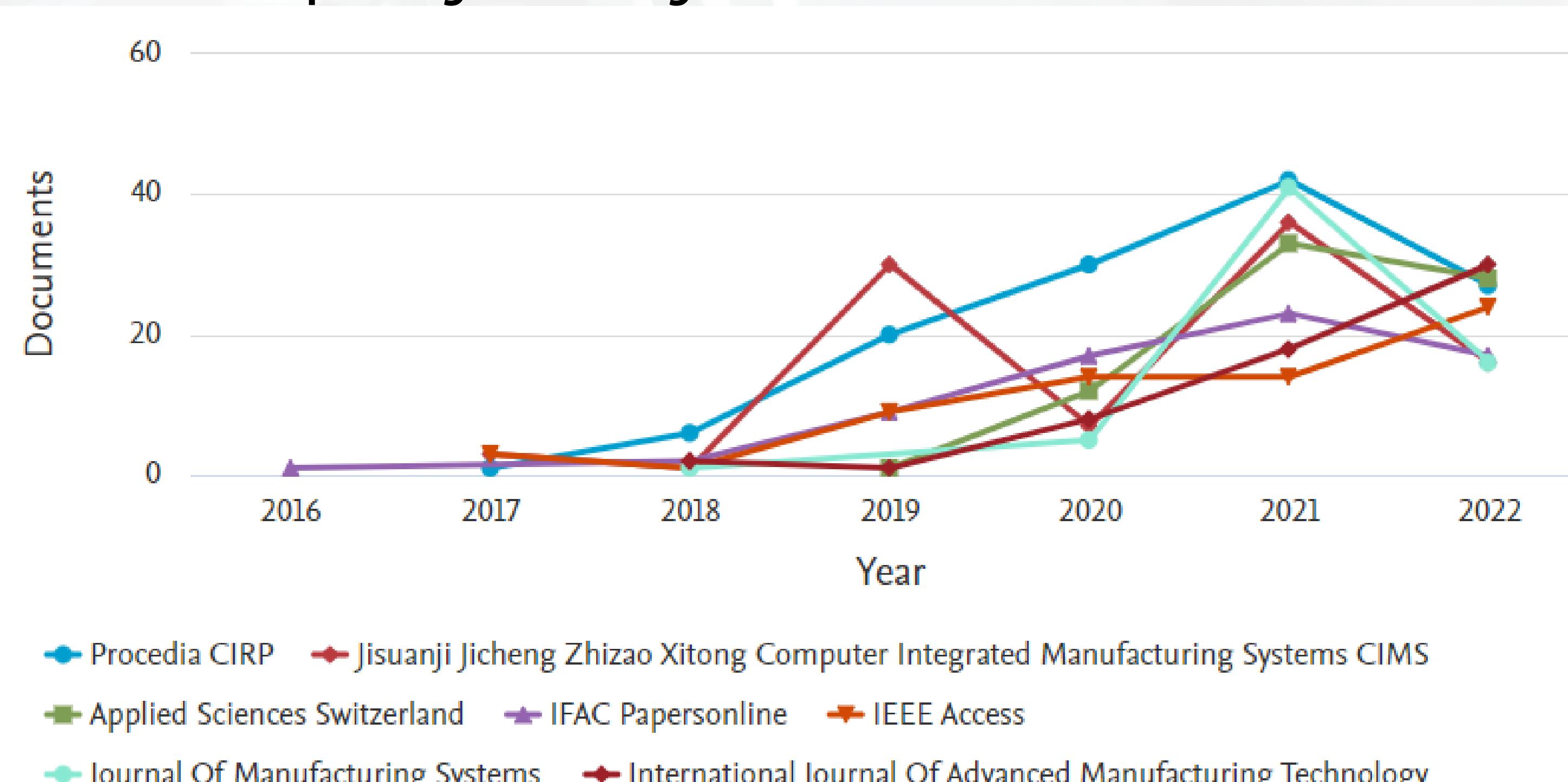


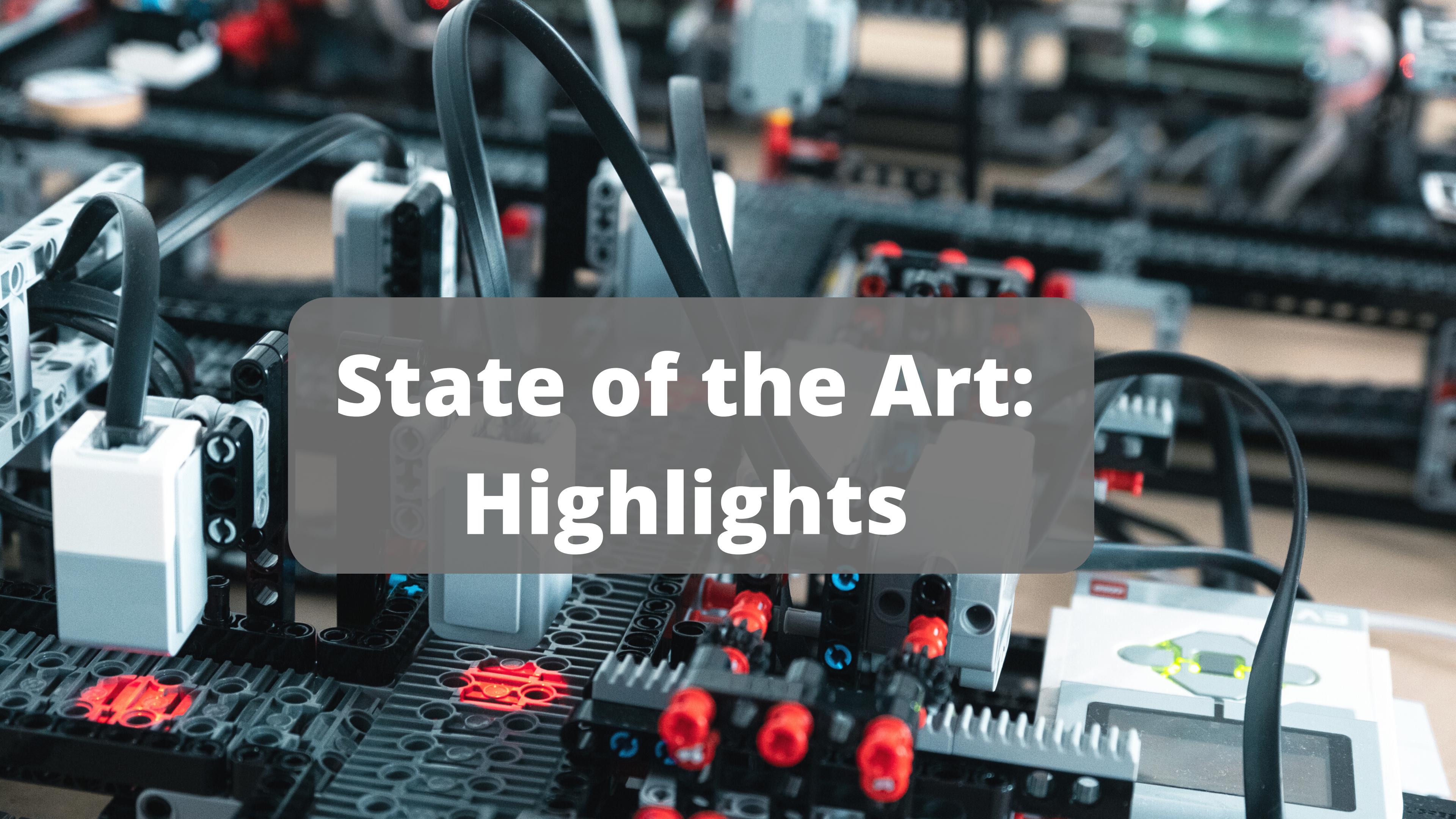
Top 5 by Scholarly Output

1,105
475
341
277
202

Statistics

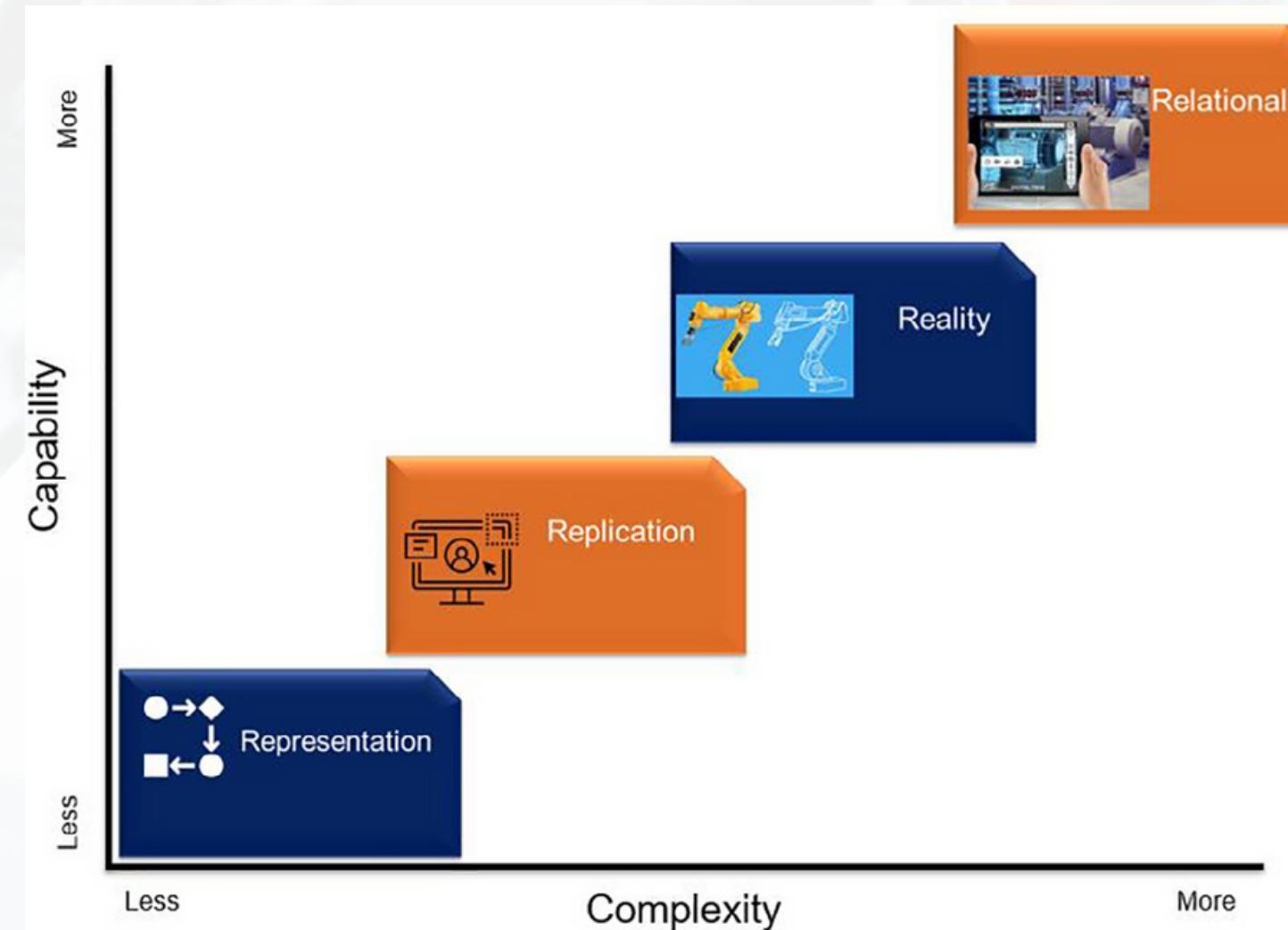
Documents per year by source





State of the Art: Highlights

Highlights



Representation

- Create digital representation of a physical object
- Data flows from the physical device to the virtual device
- Data used for visualization, validation & control of the virtual model, and analysis
- Used to capture and verify data against generated data from the original system

Replication

- Use data to create a digital system in a virtual environment
- The digital system is replicating the chosen components/variables from the Representation level of the cyber-physical system
- The DT is capable of reproducing outputs of the physical system given the same inputs

Reality

- Has the capability of independently providing outcomes given a set of inputs that are validated by the system
- The virtual device can work independent of the physical device
- The DT can predict the outcome if how the physical system will operate and produce with a given set of inputs

Relational

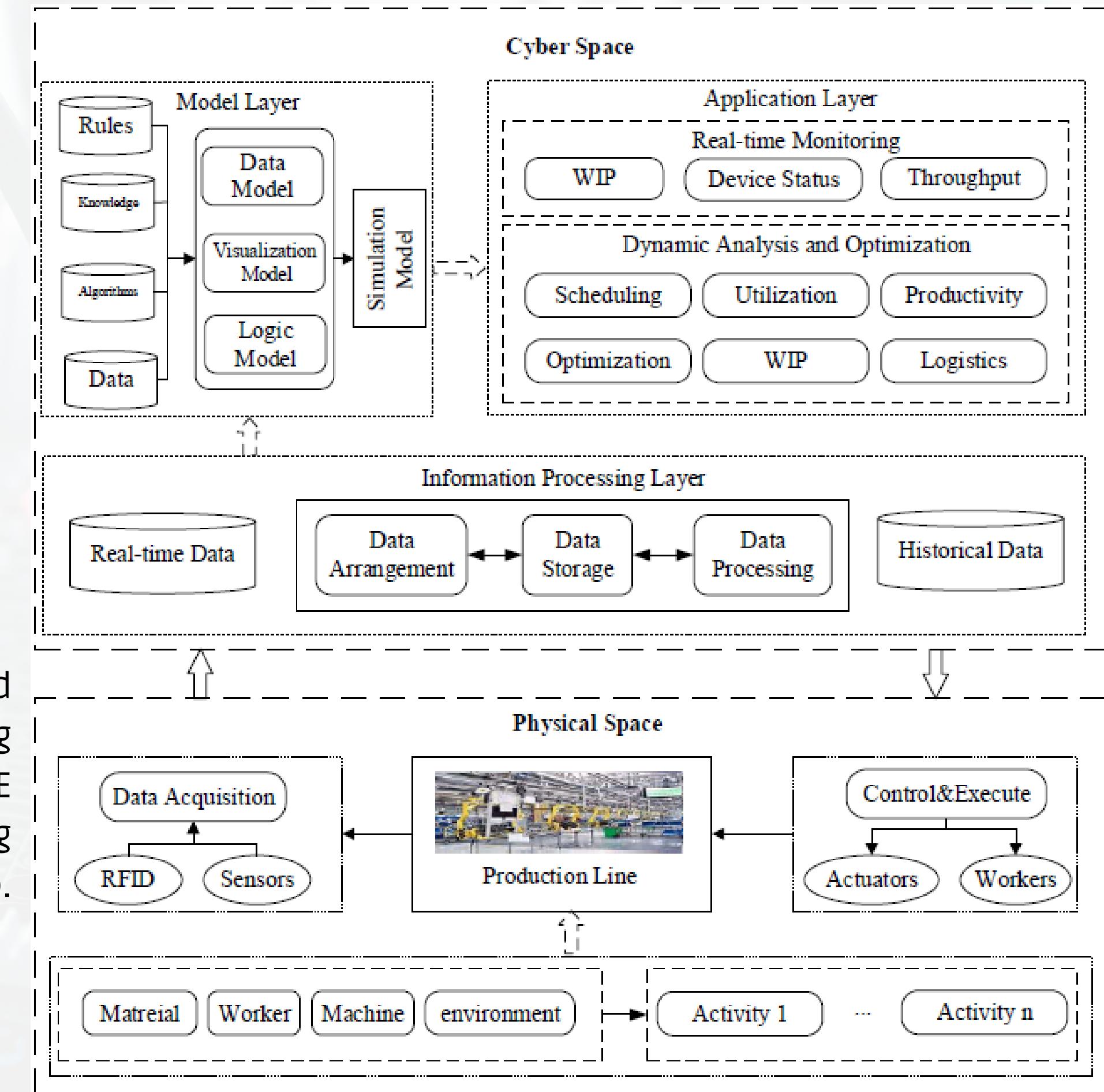
- The DT is applying technology such as machine learning and AI to perform decision making
- The DT has a level of autonomy not found in previous levels
- The DT can self-adjust, identify an optimal strategy depending on sensor data and calibrate itself

Hyre, A. et al. (2022) 'Digital twins: Representation, Replication, Reality, and Relational (4Rs)', Manufacturing Letters, 31, pp. 20–23. doi: 10.1016/j.mfglet.2021.12.004.

Highlights

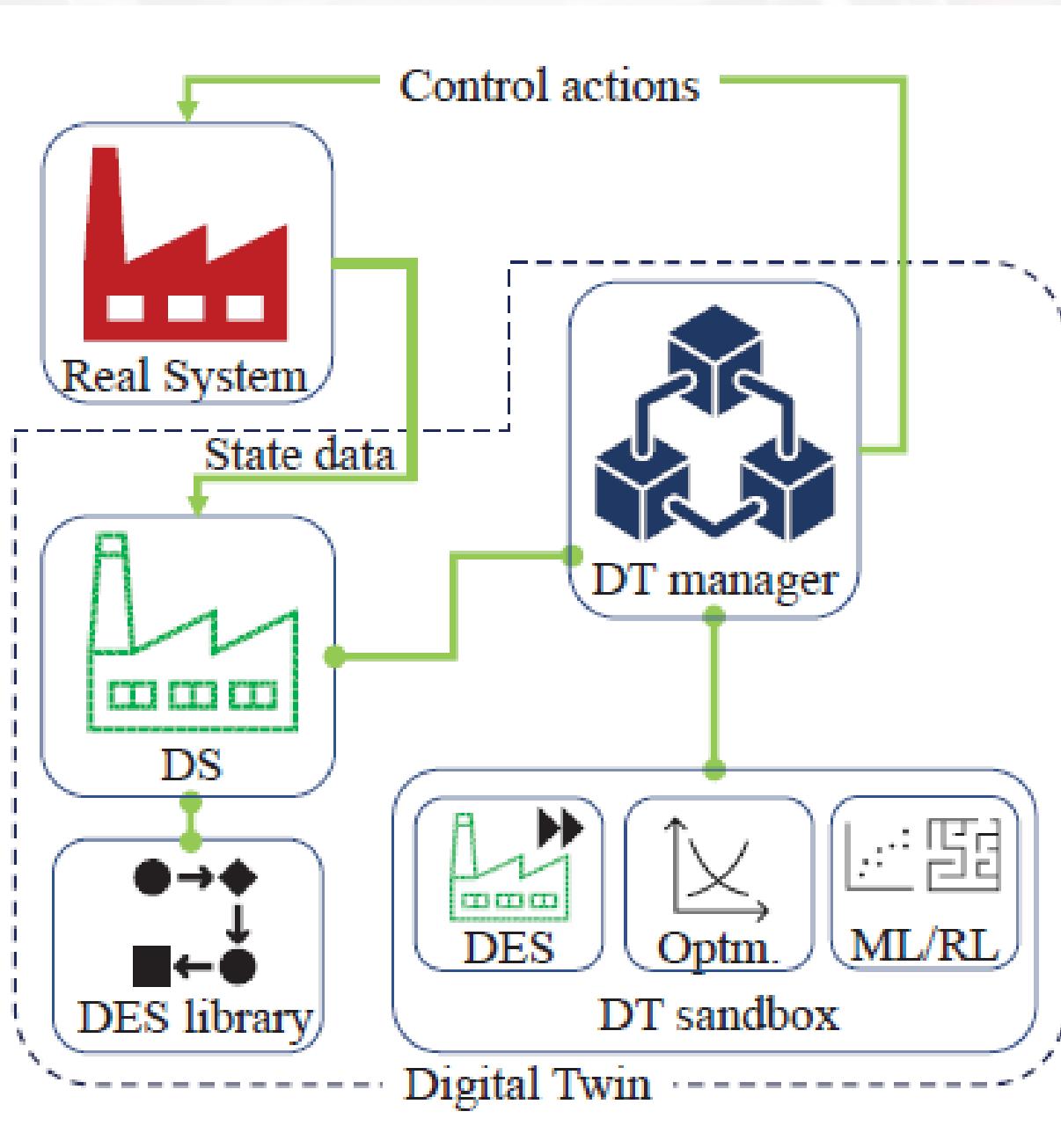
"formalize the construction workflow of the production performance digital twin from data, logic and visualization aspects"

Zhang, Y. F. et al. (2020) 'Digital twin-based production simulation of discrete manufacturing shop-floor for onsite performance analysis', IEEE International Conference on Industrial Engineering and Engineering Management, 2020-Decem, pp. 1107–1111. doi: 10.1109/IEEM45057.2020.9309928.

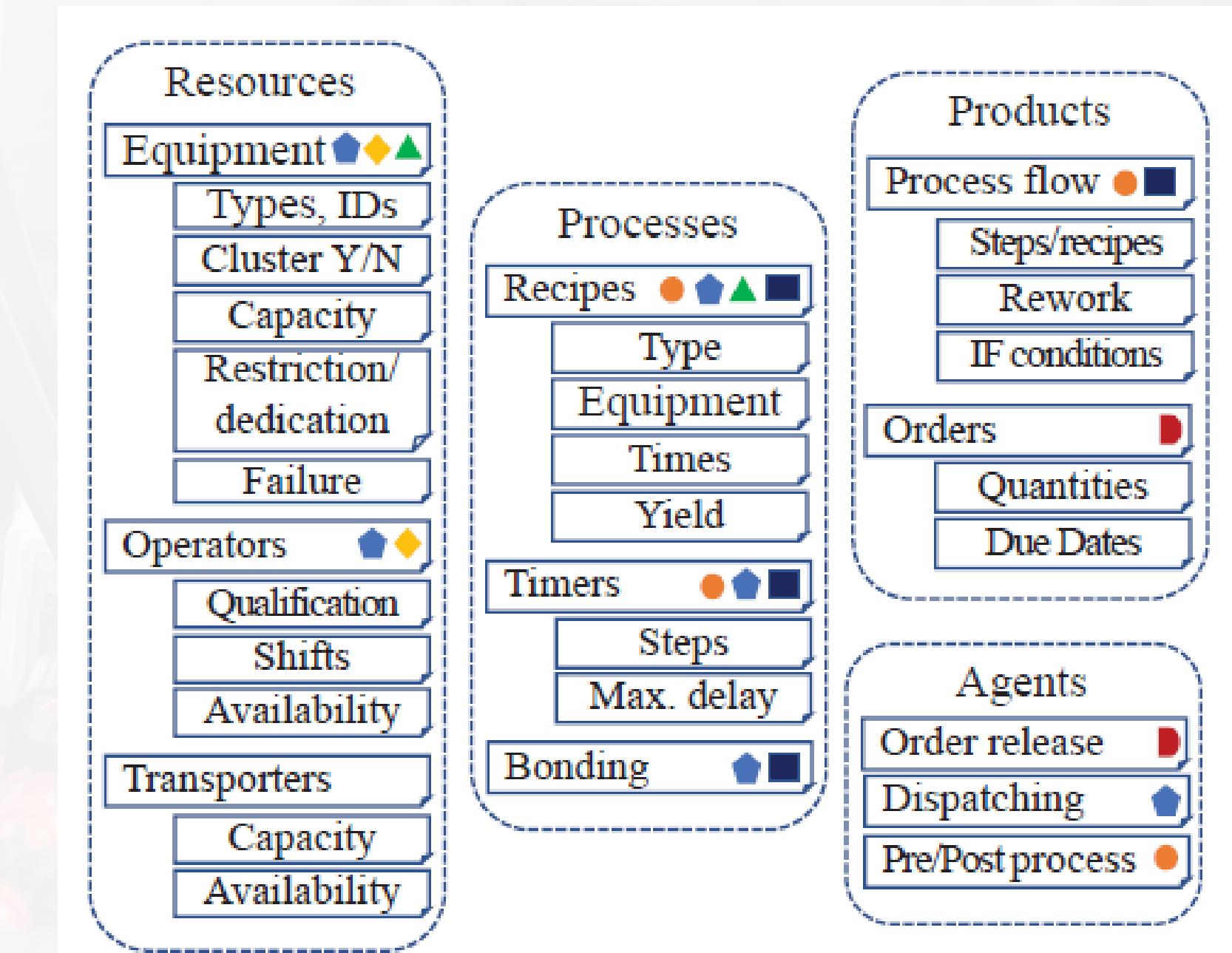


Highlights

Sakr, A. H. et al. (2021) 'Building Discrete-Event Simulation for Digital Twin Applications in Production Systems', IEEE International Conference on Emerging Technologies and Factory Automation, ETFA, 2021-Sept.
doi: 10.1109/ETFA45728.2021.9613425.



Digital Twin Framework



Database Structure



Next Steps

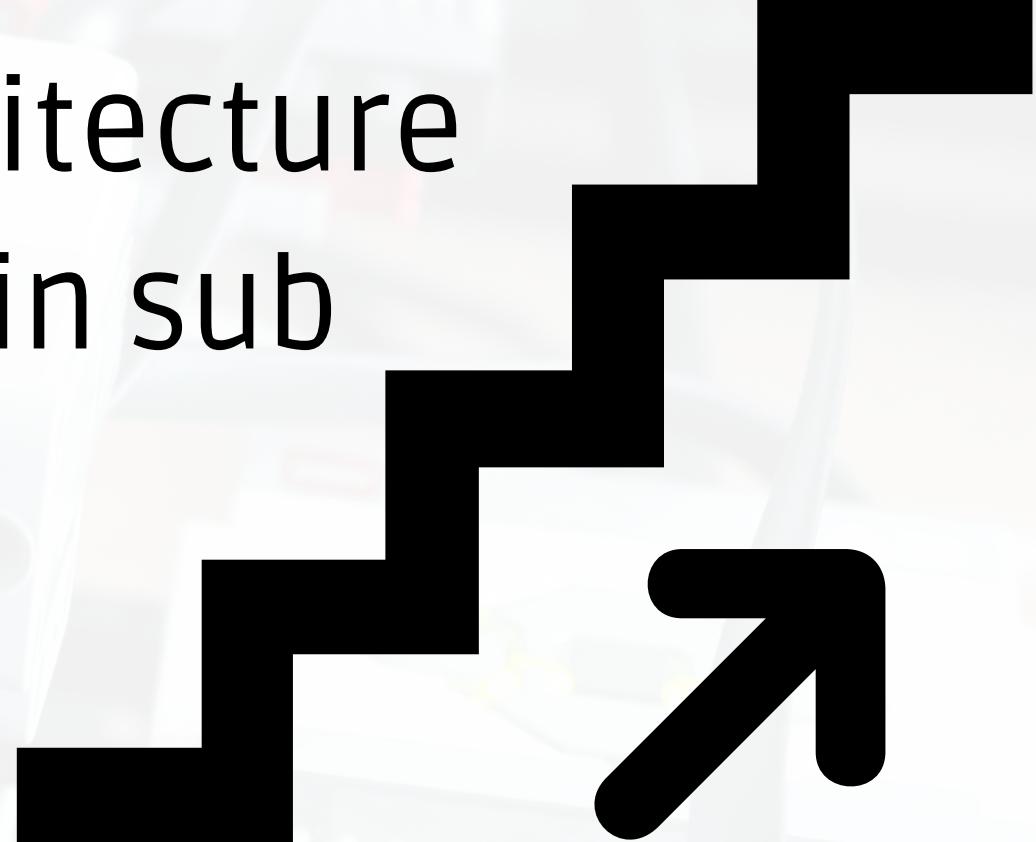
Next Steps

- Refresh State-of-Art
 - Continue reading remaining selected articles



Next Steps

- Refresh State-of-Art
 - Continue reading remaining selected articles
- Alignment
 - with the present digital twin architecture
 - with already developed digital twin sub components





Thank You