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From Observation, Detection to Design of Innovative Research and Technology

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Abstract

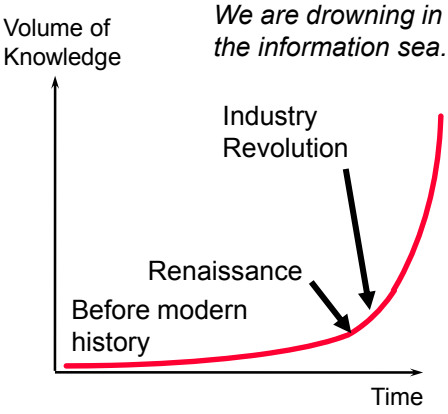
Citation network analysis is a powerful approach to illustrate science map and therefore has been utilized for R&D planning and science and technology policy. However, observation of research trends based on publications and science map lags behind cutting-edge research front. Currently, much effort is devoted to develop methodology to detect emerging research front. In this paper, we develop further and propose an approach to design innovative research and technology and to assess industrial opportunities in addition to traditional observation and detection methods. Citation network was used to illustrate science map and to detect emerging research fronts. Then, text analysis was used to measure relatedness between papers and patents and also papers in different research domains to design innovative research and technology. Results of case studies in energy technologies are shown to demonstrate the effectiveness of proposed approach. Our results showed that proposed approach to integrate citation network analysis and text analysis can find plausible and promising research target and evaluate industrial opportunity.

INTRODUCTION: Issues in R&D Planning

Fundamental Challenges We Face

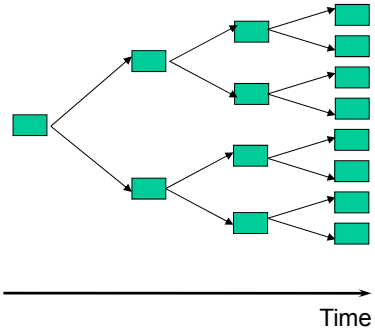
•Exponential growth of knowledge

We are drowning in the information sea.



•Segmentation & Specialization

Prerequisite to catch up with the pace of development



•Complexity of Social Issues.

Ex) Sustainability, Aging Society

Role of Computational Intelligence

Non-structured Information

Vast amount of
- **Paper**
- **Patent**
- **Researcher**
- **Organization**

etc.

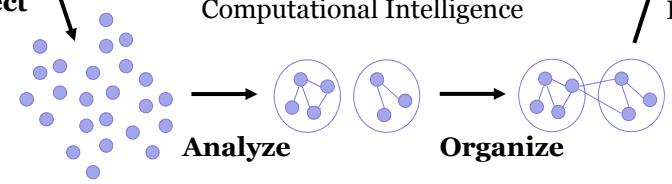
Structured Information

Observation of …
- **Complex Industrial Structure**
- **Collaboration Network**
- **Trend of Science and Technology**
- **Emerging Research Field**

etc.

Collect → **Analyze** → **Organize** → **Present**

Computational Intelligence



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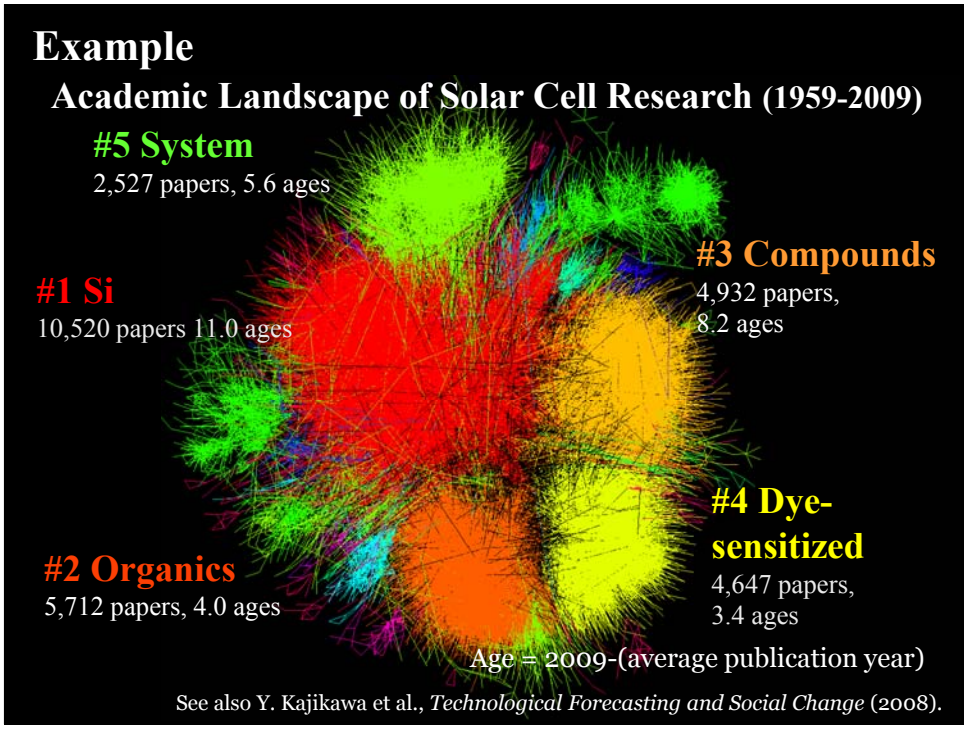


Identifying Emerging Research Domains

1st layer	2nd layer			3rd layer		
Cluster name	Cluster name	Ages	Nodes	Cluster name	Ages	Nodes
Si	a-Si	8.53	2905	Degradation of a-Si	15.33	785
				Microcrystalline	4.93	705
				H dilution effect in a-Si:H	7.27	573
				Textured ZnO	5.57	432
	Modeling	21.78	2477	Modeling of recombination	20.37	747
				Compounds	25.24	584
				Shottokky	19.10	537
				Resistance	23.20	359
	High efficiency	7.05	2196	Tandem-type	9.56	581
				Band structure	5.82	478
	c-SI	6.13	2151	Metal-induced crystallization	6.63	481
				Surface passivation	5.75	475
				Metal impurities	7.61	409
				HIT	3.71	231

Identifying Emerging Research Domains

Organics	Organics	6.46	2023	Double-hetero structure	2.63	679
				phthalocyanine	11.89	552
				Photodiode	5.99	527
				Plastic solar cell	3.00	521
	New materials and processes	2.31	1570	Narrow bandgap	2.05	517
				Liquid process	1.62	423
	Complexes with Nanoparticles	2.49	1263	Nanopartciels/polymer	2.26	427
				Conjugated polymer	2.15	402
				TiO_2 nanotube/polymer	2.94	322
	Complexes with Nanocarbons	3.56	667	nanotube/polymer	2.33	177
				fullerene/olygomer	3.95	168
				fullerene/ polyfiline	3.44	106
Dye-sensitized	Electrode	2.97	1467	Modeling	4.23	520
				TiO_2 nanotube	2.27	399
				Nano-structured ZnO	2.08	387
	Electrolyte	3.28	1427	Semi-solid electrolyte	2.73	488
				Solid-electrolyte	4.45	412
				Impedance measurement	2.86	374
	Photosensitizer	3.69	1245	Ru-based dyes	4.56	4.88
				Molecular design	2.00	327

Previous Research

Science map

H. Small, Update on science mapping: Creating large document spaces. Scientometrics, 38 (1997) 275–293.

K.W. Boyack et al., Domain visualization using VxInsight for science and technology management. Journal of the American Society for Information Science and Technology 53 (2002) 764–774.

C. Chen, Searching for intellectual turning points: progressive knowledge domain visualization. Proceedings of the National Academy of Sciences 101 (2004) 5303–5310

Extraction of research front

H. Small, Tracking and predicting growth areas in science, Scientometrics 68 (2006) 595–610.

Y. Kajikawa et al., Tracking emerging technologies in energy research: toward a roadmap for sustainable energy, *Technological Forecasting and Social Change* 75 (2008) 771-782.

N. Shibata et al., Detecting emerging research fronts based on topological measures in citation networks of scientific publications, *Technovation* 28 (2008) 758-775.

N. Shibata et al., Comparative study on methods of detecting research fronts using different types of citation, *Journal of the American Society for Information Science and Technology* 60 (2009) 571-580.

K. Fujita et al., Detecting research fronts using different types of weighted citation networks, Journal of Engineering & Technology Management, in press.

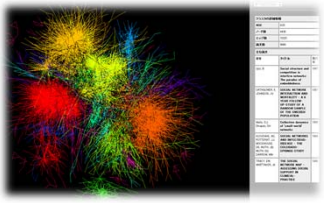
Link prediction

N. Shibata et al., Topological analysis of citation networks to discover the future core papers, *Journal of the American Society for Information Science and Technology* 58 (2007) 872-882.

N. Shibata, Y. Kajikawa, and I. Sakata, Link prediction in citation networks, Journal of the American Society for Information Science and Technology 63 (2012) 78-85.

Existing Tools

- Academic Landscape (Kajiawa@Tokyotech, Univ. Tokyo)
- Sci2 Tool (Börner@Indiana U)
- Cite space (Chen@Drexel U)
- Vantage Point (Porter@Gerogia Tech)
- SciVal (Boyack@SciTech Strategy)



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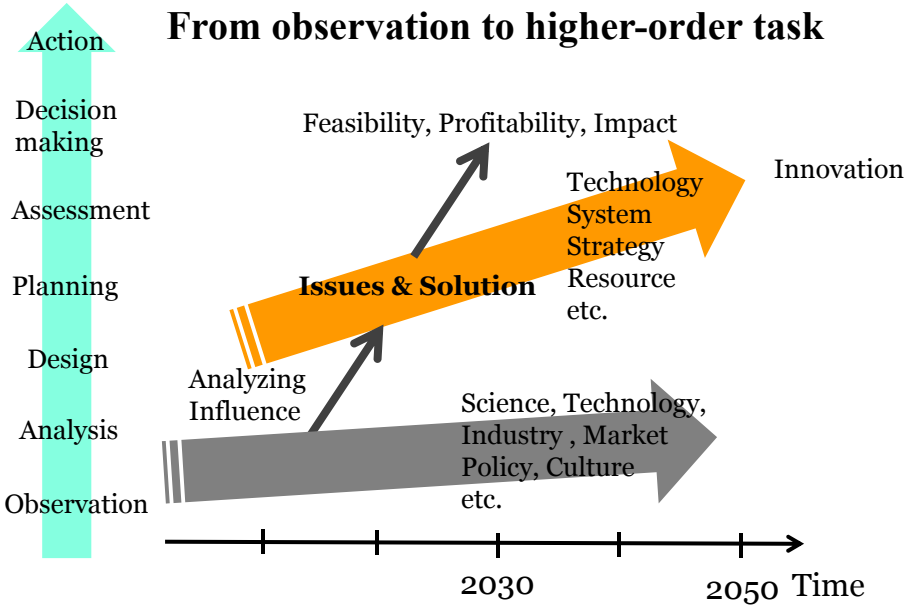
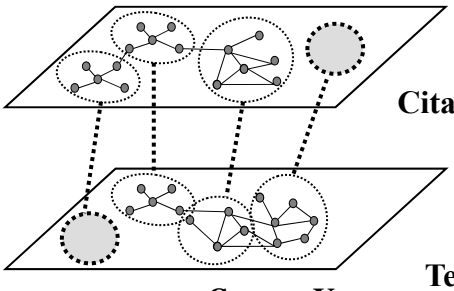
Unresolved Issue for Computational Intelligence



METHODOLOGY: Multi-Layered Approach

Integration of citation analysis and text analysis for multi-layered corpus

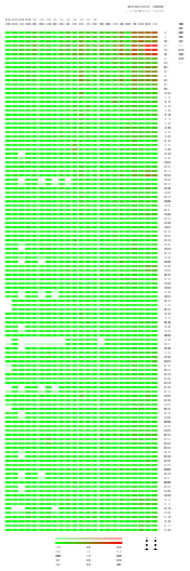


Citation Analysis

- Direct citation
- Modularity Maximization

Text Analysis

- TFICF
- Cosine similarity



Corpus Y

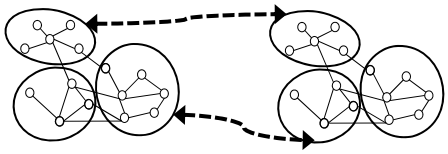
Corpus X	Exist	Not-exist
Exist	A	B
Not-exist	C	D

Science-Technology Linkage

Recommendation of uncommercialized research front

•Approach

Academic papers



Patents

•Case Secondly battery (-2009)

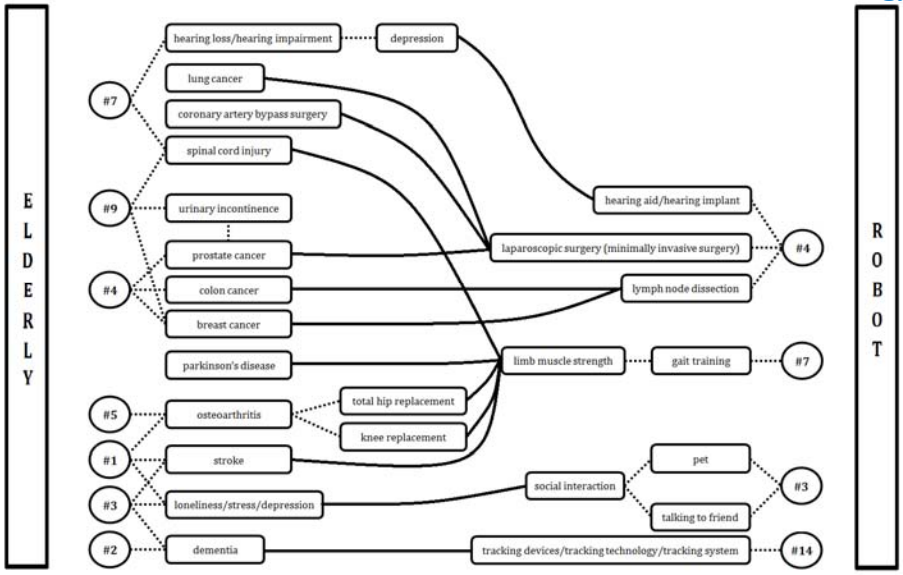
•Result

Papers \ Patents	Exist	Not Exist
Exist	Science-linkage Li-ion battery Cell design Metal-hydride	Chances for industry or basic research Solid electrolyte
Not Exist	Too applied or lack of science Application to EV	

Cf. The first presentations on solid electrolyte by TOYOTA at Japan Society of Electrochemistry (March, 2010)
See also N. Shibata et al., *Technological Forecasting and Social Change* 77 (2010).

Science-Society Linkage

(Social Issue) (Science and Technology)

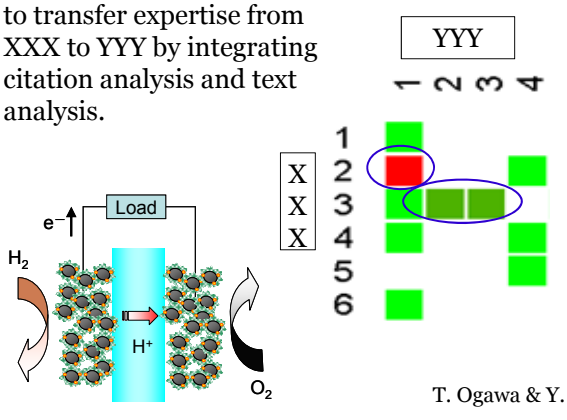


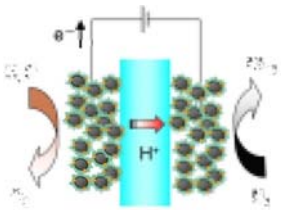
See also, V. Ittipanuvat et al., *Journal of Engineering & Technology Management*, in press.

Science-Science Linkage

Rapidly developing research field XXX
X
Matured research field YYY

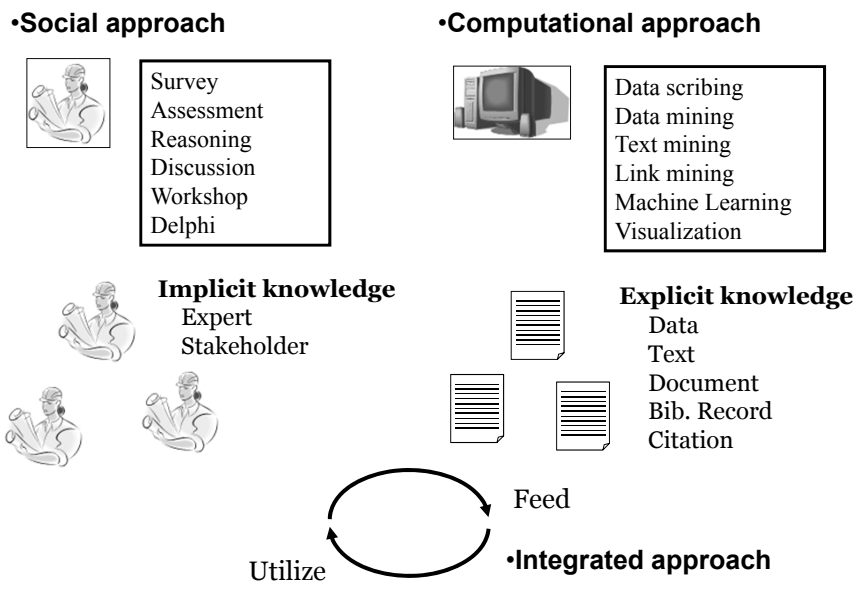
We explored opportunity to transfer expertise from XXX to YYY by integrating citation analysis and text analysis.





T. Ogawa & Y. Kajikawa, unpublished work.

Discussion



SUMMURY

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- Citation network was used to illustrate science map and to detect emerging research fronts. Then, text analysis was used to measure relatedness between papers and patents and also papers in different research domains to design innovative research and technology.
- Examples in energy technologies and robotics are shown to demonstrate the effectiveness of proposed approach.
- Our results showed that proposed approach to integrate citation network analysis and text analysis can find plausible and promising research target and evaluate industrial opportunity.