How the analysis of structural holes in academic discussions helps in understanding genesis of advanced technology

Konstantin Fursov
Alina Kadyrova
Background

- Continual emergence and dissemination of new technologies

- Importance of certain technology groups for intensive economic growth (next industrial revolution)

- Widespread and increasing interest in developing of statistical indicators explaining evolution and predicting growth of new (emerging) S&T areas

- Lacking conventional definitions and taxonomies for “promising” technology areas against a growing number of umbrella concepts (advanced, emerging, enabling, converging, disruptive, critical and other technologies)
Why advanced technologies (AT)?

**Web of Science**

AT seems to be the oldest...

**Factiva**

... less conceptualized (vs. emerging – see Rotolo et al., 2015) and still valid group of technologies

Query: TS="advanced technolog**" or TI="advanced NEAR technolog**" and similar to other categories
Research question

Do studies in AT constitute a separate research field or with the category we have another ‘endless frontier’?

In other words, in professional scientific discourse on advanced technology can we identify a communication core that set up conceptual framework and/or research agenda for a certain period?
Methodology

0. *Identification of relevant academic papers* in the corps of professional literature

1. Analysis of *publication dynamics* in order to identify relevant periods of sustainable growth for in-depth exploration

2. *Keyword analysis* to highlight main research topics in each of the periods

3. *Co-citation analysis* to single out networks that had set up research agenda for each of the periods
   - as invisible colleges (Gmür, 1973) or clusters of science (Small, 1999)
   - as sources of inspiration for emerging topics (Small et al., 2014)
   - as ‘knowledge base’ of certain fields (Fagerberg & Verspagen, 2009; Fagerberg et al., 2012)

4. Application of *betweenness centrality* to identify core elements of the networks
   - optimally positioned actors that can accumulate information flows from dislocated parts of a network (Bavelas, 1948, 1950)
   - structural holes that provide opportunities for mediating knowledge flows in a wider community of actors (Burt, 2002)

5. *Comparing betweenness centrality* of papers cited in two consecutive periods with papers cited in one period only
publication dynamics

Query TS="advanced technolog*" or TI="advanced NEAR technolog*".

Source: WoS Core Collection (all types of publications in all indices)
Keyword analysis before 1990: homogeneity of discussions

Top 5 domains
1. Engineering
2. Business/economics
3. Other topics of science and technology
4. Material science
5. Optics

Key issues:
- role of technologies in economic development
- engineering education and skills
- human resource management
Keyword analysis 1991-2000: primary specialization (manufacturing)
Keyword analysis 2001-2010: AT beyond manufacturing

- Medical technologies
- Communication, design
- Knowledge management, innovations
- Energy technologies
- Geosystems
- Optics
- Lithography, surfaces
- Manufacturing materials
Keyword analysis 2011-2015: focus on implementation & management

- Knowledge flows, education
- Design, architecture and materials
- Manufacturing practices
- Policy, energy efficiency
- Manufacturing equipment and materials
- Medical technologies

- Knowledge flows, education: innovation, research, communication, student, learning, development, cost, education, knowledge, information, technology
- Design, architecture and materials: design, architecture, material, construction, system, engineering, building, city, cityscape, green building, solar, energy, efficient, sustainable, green, urban, infrastructure, design
- Manufacturing practices: manufacturing, practices, process, management, quality, efficiency, production, automation, flexibility, supply, chain, agile, lean, sustainable, design, architecture, material, manufacturing, equipment, materials
- Policy, energy efficiency: policy, energy, efficiency, transformation, lifecycle, assessment, sustainability, governance, regulation, technology, innovation, efficiency, solar, wind, energy, conservation, efficiency, renewable, green, carbon, footprint, energy, audit, energy, saving, energy, efficiency, energy, audit, energy, management
- Medical technologies: medical, technology, diagnosis, treatment, therapy, medicine, healthcare, biotechnology, nanotechnology, genomics, proteomics, imaging, care, patient, health, wellness, research, drug, delivery, drug, discovery, drug, development, drug, delivery, drug, discovery, drug, development
- Manufacturing equipment and materials: manufacturing, equipment, materials, automation, robotics, machinery, tool, design, architecture, material, construction, engineering, city, cityscape, green building, solar, energy, efficient, sustainable, green, urban, infrastructure, design

This diagram illustrates the key areas of focus in the analyzed period, highlighting the interconnections and evolution of these topics over time.
Co-citation networks: key parameters

**before 1990**

- $N = 1268$
- Threshold = 1
- Connected nodes = 128

**1991-2000**

- $N = 18827$
- Threshold = 1
- Connected nodes = 2606

**2001-2010**

- $N = 66533$
- Threshold = 2
- Connected nodes = 1658

**2011-2015**

- $N = 79484$
- Threshold = 2
- Connected nodes = 2376

**Key issues:**

- **before 1990**: role of AT in changing social and economic structure
- **1991-2000**: technology and innovation management
- **2001-2010**: management of tech, innovation, globalization
- **2011-2015**: technology domination

Selected for further analysis
Identification of structural holes

**1991-2000**

- Moving to the next period = 85
- Share of total = 3.3%

**2001-2010**

- Moving to the next period = 118
- Share of total = 7.1%

**2011-2015**

- Potentially moving = 358
- Share of total = 15.1%

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<th>Period</th>
<th>Mean betweenness of authors who move</th>
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<td>31822.6</td>
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Identifying key technology driven areas from papers with higher betweenness centrality

1991-2000

- Global technology markets and emergence of new form of firms – multinational;
- Foreign investments and their spillover effects;
- Measuring productive efficiency;
- Innovation development;
- Technological change

2001-2010

- All previous + Biotechnology, Nanotechnology, Oncology, Semiconductors,
- Mathematical modeling, Astronomy (Advanced Technology Solar Telescope),
- Microelectronics, Environment, Medicine

2011-2015 (topics likely to emerge in the further decade)

- Environment; Energy; Fuels; CMOS Transistors; Electrical Engineering;
- Genetics; Geochemistry; Material Sciences; Meteorology; Oncology; Technology and Society
Discussion and conclusions

• There is observable penetration of the concept on ‘Advanced Technology’ from social sciences discourse to natural and engineering disciplines identified both through the analysis of co-citation networks and keywords mapping:


• Co-citation networks eliminated a common background for the papers in the observable periods and therefore can be considered as a ‘knowledge base’ of the professional discussions, however, different traditions in citations might lead to systemic bias towards certain disciplines

• Application of centrality metrics allowed identification of key works of the period and empirically verify the adoption of the ‘politically sounding’ term by specific studies in technology

• No stable communication core was identified – there is still continuous diversification of the topics associated with the concept of advanced technology

• Further work can be aimed at deeper analysis of the disciplinary structures in communication networks and identification of specific technologies considered as advanced in certain time periods
Thank you!

ksfursov@hse.ru
akadyrova@hse.ru