Research Challenges in Forecasting Technical Emergence

Dewey Murdick, IARPA
25 September 2013
“Invests in high-risk/high-payoff research programs that have the potential to provide our nation with an overwhelming intelligence advantage over our future adversaries”

http://www.iarpa.gov/
A Few Interesting Research Problems

• Scan for technical emergence
  – Move beyond search
  – Reliably query for indicative “patterns of technical emergence” without starting with a known, named subject

• Analyze diverse and large data streams across disciplines, cultures, and languages
  – Support strategic investment
  – Facilitate discovery and innovation

• Forecast scientific, technical, application, and market events
  – Quantitatively event forecasts
  – Improve accuracy and early event detection
Foresight and Understanding from Scientific Exposition (FUSE) Program

Reduce “technical surprise” via reliable & validated, early detection of emerging scientific and technical capabilities across disciplines and languages found within the full-text content of scientific, technical, and patent literature

Special focus from the outset on multiple languages, Phase 2 focus on English and Chinese

Novelty → Discover patterns of emergence and connections between technical concepts at a speed, scale, and comprehensiveness that exceeds human capacity

Usage → Alert analyst of emerging technical areas with sufficient explanatory evidence to support further exploration
What is technical emergence?

*Hypotheses from Phase 1*

- A concept has emerged if it has been accepted by others within and beyond one’s community. ~Columbia

- A concept is emerging when its “actant network” is increasing in robustness. ~BAE

- A concept has emerged when evidence has appeared that the concept is new and unexpected, noticeable and growing. ~Raytheon BBN

- A concept is emerging when it is identifiable by its own practitioners, enables a capability that was not achievable previously, and persists. ~SRI
Red edges – connect data sources to data fields  
Blue edges – connect BAE high-level indicators to BAE low-level indicators  
Line thickness between features and indicators, measures significance for the challenge
Evaluation Attempt #1: Case Studies

• Drawn from diverse areas of scientific inquiry & application:
  – Biological Sciences / Biotechnology
  – Computer Science / Information Science; Engineering
  – Mathematics / Statistics
  – Physical Sciences; Earth Science
  – Medical / Clinical / Infectious Disease / Health Services;
  – Social Sciences; …

• Technical emergence measured from “real world” viewpoint, but connected to literature

• Multiple case studies to be produced; some are held back for evaluation
  – Case studies are representative but not comprehensive
  – Insufficient to train technical emergence classifiers
  – Limited examples of emergence & non-emergence (10s planned)
  – Reference baseline has limited temporal resolution (~5 year blocks)
Phase 2 Evaluation: Nomination Test

LEADING

Data Period

Reference Period

Forecast Period

FUSE Document Repository

Test Sample

e₁, e₅, e₃, e₂, e₄, e₅

Performer-defined indicators

Prominence Forecasts

FUSE Performer System

GTF*(E,D,R,F)

(E)ntity

(D)ata Period

(R)efERENCE Period

(F)orecast Period

T&E

Ground Truth Data

Compare

NQ Score

*GTF = Ground Truth Function
### Indicator Development and Testing Underway

Regular analysis and evaluation of each team’s features (e.g., scientific noun phrases, topic models) and their portfolio of indicators (i.e., quantitatively measured aspects / patterns of technical emergence)

#### Promising Midterm Indicator Types

- Citation, Author Networks (All)
- Topic Diversity (SRI)
- Citation Context and Sentiment (SRI)
- Technology and application concept type evolution (SRI)
- Patent classification dynamics (SRI, BAE)
- Emerging cluster / hot patent status (BAE)
- Patent originality (BAE)
- Corporate, Academic patent authorship (BAE)
- Topic modeling across time, thread dynamics (BBN)
- Research levels (BBN)
- Time series analysis, extensive portfolio (COL)
- Temporal pattern classification, time-series clustering (COL)

#### Fundamental Research

- Argumentative Zoning (SRI, COL)
- Time-dependent term co-occurrence (SRI)
- Author-topic modeling (SRI)
- Operations on annotated graphs, e.g., scientific concepts, terms (SRI)
- Chinese patent indicators (BAE, BBN)
- Fine-grained topic models (BBN)
- Causality modeling framework (BBN)
- Primary concept mentions (COL)
- Citation sentiment (COL)
Now Developing a Market for Scientific and Technical Forecasting

- **Goal:** Generate precise, testable forecasts for S&CT developments
- **Approach:** Build world’s largest prediction market for S&T events
  - Thousands of subject matter experts in dozens of countries will make nuanced conditional forecasts for around one thousand S&T events
  - Data-driven (i.e., scientific and patent literatures) indicators will be used to generate questions and adjust forecasts
- **Evaluation:** Forecasts will be scored against actual events, as they occur
- **Potential impact:** Dramatically improve S&T foresight with actionable information
- **Schedule:** June 2013–June 2015

By 31 December 2014, how much of the visible spectrum will a metamaterial be able to deflect?

- Probabilities assigned to event in each period
- Number of forecasters providing judgments in each period

Real-world timeline (months)
Teams will Generate Questions

• What is the probability of a 10cm carbon nanotube being fabricated before 31 Dec 2014?
• Will the number of accepted articles for the 2015 International Conference on Machine Learning (ICML) conference that contain the term ‘deep learning’ in the title/abstract exceed those that contain the term ‘support vector machine(s)’ in the title/abstract?
• How many unique assignees will have at least two USPTO patent applications published using the term ‘Type III Secretion System’ in its title/abstract/background/claims between 1 Oct 2013 and 30 Sep 2014?
• By 31 Dec 2017, how many FDA-approved products will be based on RNA interference?
• Will there be reported shortages of technetium-99m in the US in 2015?
Discussion & Questions

Dewey Murdick, Ph.D.
Program Manager, IARPA
dewey.murdick@iarpa.gov