system design & management

How to Pick Breakthrough Technologies Using Network and Game Theory

MITsdm

Nissia Sabri | Director
Strategic Business Development at Novanta

nissia.sabri@sloan.mit.edu

Introduction

Education

- MS, Engineering and Management
  - MIT SDM
- MS, Nuclear and Radiological Engineering
  - University of Florida
- MS, Physics
  - Grenoble Institute of Technology (France)

Experience

- **Director of strategic business development at Novanta**
  - Novanta serves the industrial robotics and medical technology markets
- **Cofounder** at Bitsence, developing a space occupancy & analytics platform to improve cities, architecture, and real estate developments
- **Product Manager,** leading product portfolio management for large and medium size companies in the clean energy and radiation protection fields
- **Risk analyst**, creating data models to forecast complex energy systems' failures

About the Research

Technology Investments
SDM Master thesis 2016

Supervisors

Dr. Olivier de Weck

MIT School of Engineering

Professor of Aeronautics and Astronautics and Engineering Systems

Dr. Alessandro Bonatti

MIT Sloan School of Management

Associate Professor of Applied Economics

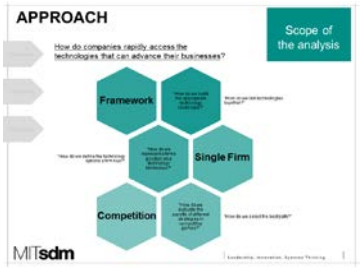
TODAY'S AGENDA

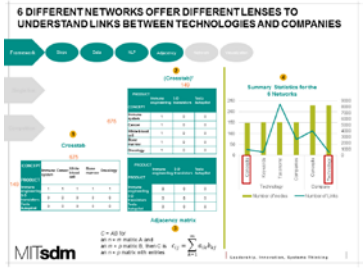
Part 1

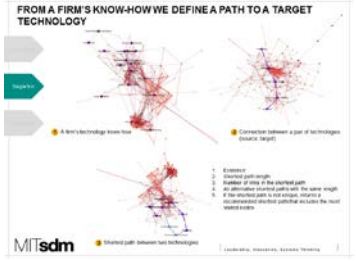
➔ **Context & challenges**

Part 2

➔ **A data driven approach**

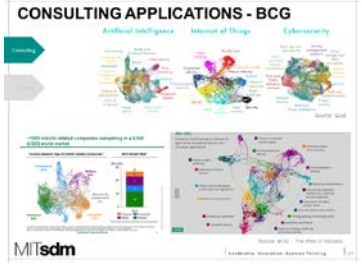






Part 3

➔ **Real world applications**



Context

Challenge

Part 1

CONTEXT & CHALLENGES

FAST RISE OF NUMBER OF DEALS INVOLVING A TECH TARGET

Context

Challenge

Today, one out of every five transactions has a clear link to some form of technology

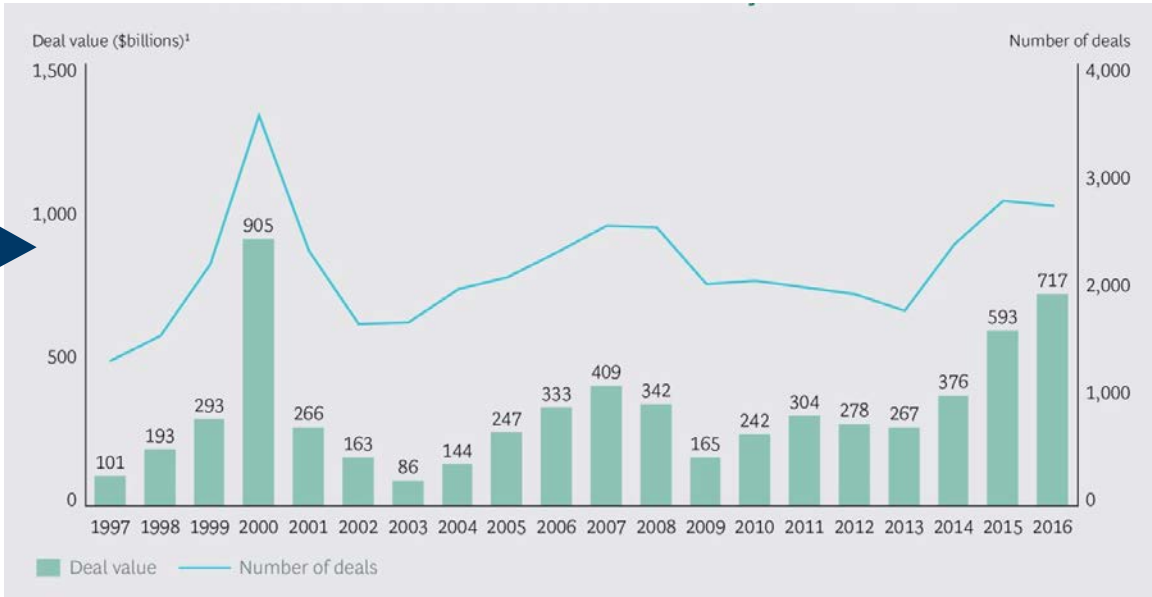
Source: BCG- The Resurgent High-Tech M&A Marketplace

TECH DEAL MARKET GROWTH IN VALUE SIGNIFICANTLY OUTPACING THE OVERALL M&A MARKET

Context

Challenge

High-tech deals represented almost 30% of the total $2.5 trillion of completed M&A transactions in 2016



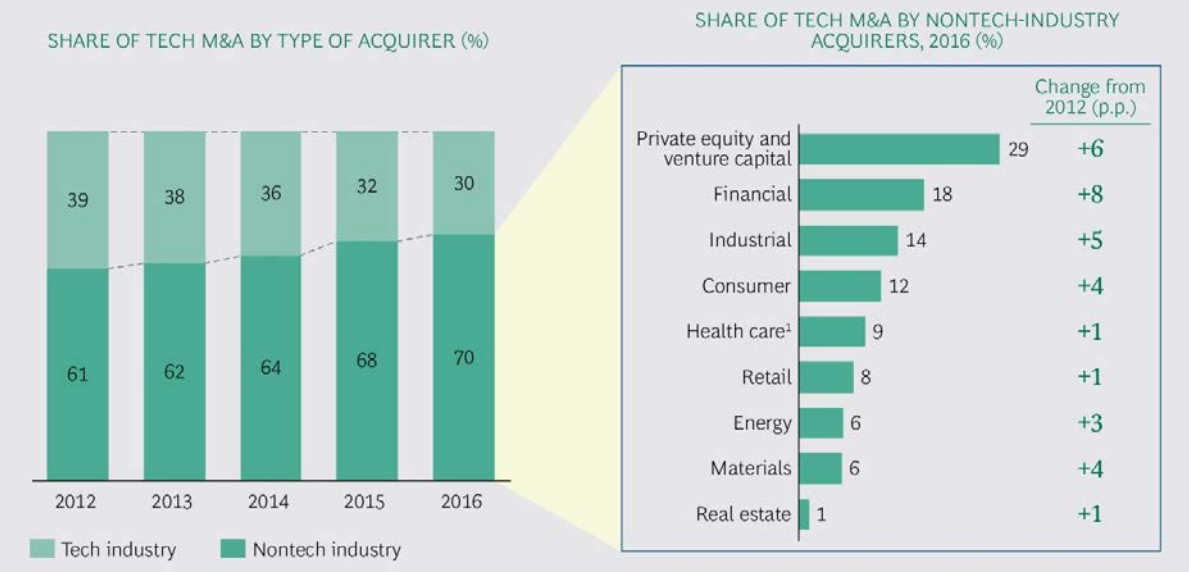
Source: BCG- The Resurgent High-Tech M&A Marketplace

THE SHARE OF NONTECH BUYERS IS RISING

Context

Challenge

Approximately 70% of all tech deals in involved buyers from outside the tech sector.



Source: BCG - The Resurgent High-Tech M&A Marketplace

HOW CAN FIRMS GAIN A COMPETITIVE ADVANTAGE THROUGH TECHNOLOGY ACQUISITION?

Context

Challenge

Latent Need

As the pace of technology-driven change accelerates, a key question for senior executives has become: **how do we position ourselves in a highly disruptive ecosystem?** More often than not, acquisitions of tech-driven, and especially digital, business models have become the instrument of choice to **acquire needed technologies, capabilities, and products and to close innovation gaps.**

Key Question

The question is, **How do companies rapidly access the technologies that can advance their businesses** and integrate them successfully with their current operations?

Source BCG: The 2017 M&A Report: The Technology Takeover

Framework

Single firm

Competition

Part 2

A DATA DRIVEN APPROACH

APPROACH

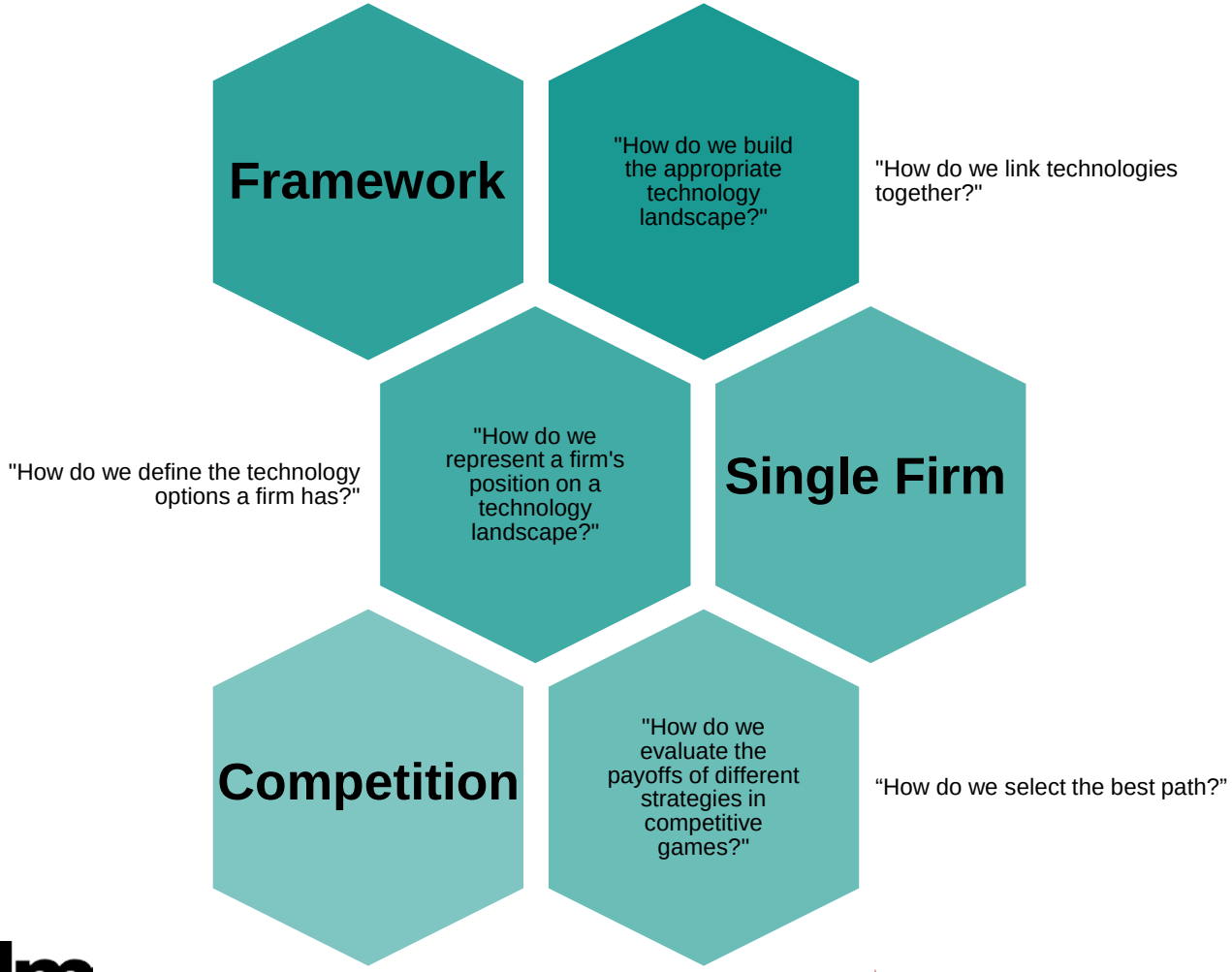
Framework

Single firm

Competition

How do companies rapidly access the technologies that can advance their businesses?

Scope of the analysis



Framework

Single firm

Competition

Part 2

A DATA DRIVEN APPROACH

APPROACH

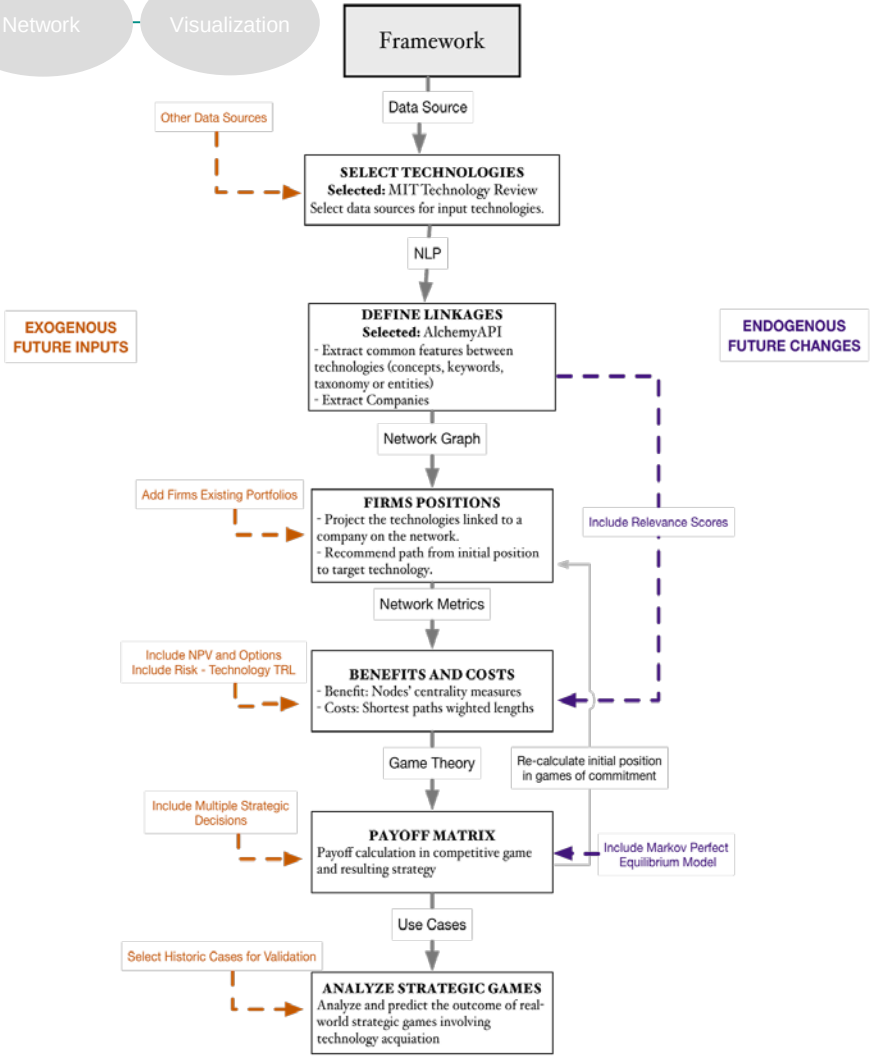
Framework | Steps | Data | NLP | Adjacency | Network | Visualization

Single firm

Competition

Steps

1. Technology landscape
2. Links between technologies
3. Map a firm's position
4. New technology options
5. Payoffs of different strategies



BEYOND PATENTS – USING DATA SOURCES THAT REPRESENT THE SOCIO-TECHNICAL ENVIRONEMTN OF A TECHNOLOGY

Framework | Steps | Data | NLP | Adjacency | Network | Visualization

Single firm

Competition

Input data

1. **Source:** MIT Technology Review (2001-2016)*

2. **Size:** 150 articles on the top 10 technologies of the year

3. **Content:** Companies, technology description, organization, key stakeholders

MIT Technology Review

Immune Engineering

Genetically engineered immune cells are saving the lives of cancer patients. That may be just the start.

Cellectis began developing the treatment in 2011 after doctors in New York and Philadelphia reported that they'd found a way to gain control over T cells, the so-called killer cells of the immune system. They had shown that they could take T cells from a person's bloodstream and, using a virus, add new DNA instructions to aim them at the type of blood cell that goes awry in leukemia. The technique has now been tested in more than 300 patients, with spectacular results, often resulting in complete remission. A dozen drug firms and biotechnology companies are now working to bring such a treatment to market.

Immune Engineering

Breakthrough
Killer T cells programmed to wipe out cancer.

Why It Matters
Cancer, multiple sclerosis, and HIV could all be treated by engineering the immune system.

Key Players in Immune Therapies
- Cellectis
- Juno Therapeutics
- Novartis

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** Not all years were represented*

NATURAL LANGUAGE PROCESSING UNCOVERING CONNECTIONS BETWEEN TECHNOLOGIES

Framework | Steps | Data | NLP | Adjacency | Network | Visualization

Single firm

Competition

1 Concepts ~8

Concept	Relevance
Immune system	0.955482
Cancer	0.777922
White blood cell	0.582719
Bone marrow	0.558695
Oncology	0.514501
Chemotherapy	0.506064
Antibody	0.495587
Thymus	0.471906

2 Keywords ~30

Keyword	Relevance
cells	0.98233
white blood cells	0.837876
extensively engineered cells	0.831548
Immune cells	0.82056
so-called killer cells	0.805677
engineered T cells	0.790827
immune system cells	0.788983
engineering human cells	0.771505
cancer cells	0.762188
tumor cells	0.745861
futuristic T cells	0.732288
killer T cells	0.725298
single T cells	0.723793
Great Ormond	0.691386
drug companies	0.685833
immune engineering	0.680573
cancer treatment	0.663458
gene editing	0.653015
Integrative Cancer Research	0.64483
cancer immunotherapy	0.643333
Hospital Great Ormond Street	0.638253
new DNA instructions	0.63576
major cell types	0.632493
New York	0.631327
clinical trial	0.625835
dozen drug firms	0.625794
new research techniques	0.6248
largest drug companies	0.622664
bone marrow transplant	0.621293
immune therapy	0.621248

3 Entities (companies) ~30

Entity	Entity Relevance	Entity Type
Great Ormond	0.412777	City
Manhattan	0.379174	City
San Francisco	0.351447	City
Cellectis	0.686313	Company
TALENs	0.396606	Company
Google	0.385513	Company
Juno	0.326018	Company
Great Ormond	0.31739	Company
Pfizer	0.311992	Company
Cell Design Labs	0.298714	Company
Juno Therapeutics	0.294232	Company
Nobel Prize	0.305582	EntertainmentAward
immune system	0.952346	FieldTerminology
bone marrow	0.338757	FieldTerminology
biotechnology companies	0.312867	FieldTerminology
Mount Sinai	0.355874	GeographicFeature
leukemia	0.578772	HealthCondition
HIV	0.451964	HealthCondition
cancer	0.438812	HealthCondition
infectious disease	0.369968	HealthCondition
researcher	0.406895	JobTitle
U.S. Food and Drug Administration	0.339952	Organization
MIT's Koch Institute for Integrative Cancer Research	0.330135	Organization
UCSF	0.292967	Organization
Layla Richards	0.535751	Person
Wendell Lim	0.449181	Person

4 Taxonomy ~3

Label	Score
/health and fitness/disease/cancer	0.524787
/health and fitness/disease/aids and hiv	0.397025
/health and fitness/disease	0.28493

Example: Immune Engineering

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Leadership, Innovation, Systems Thinking

6 DIFFERENT NETWORKS OFFER DIFFERENT LENSES TO UNDERSTAND LINKS BETWEEN TECHNOLOGIES AND COMPANIES

Framework | Steps | Data | NLP | Adjacency | Network | Visualization

Single firm

Competition

1

Crosstab

675

149

CONCEPT / PRODUCT	Immune system	Cancer	White blood cell	Bone marrow	Oncology
Immune engineering	1	1	1	1	1
3-D transistors	0	0	0	0	0
Tesla Autopilot	0	0	0	0	0

675

2

$(\text{Crosstab})^T$

149

CONCEPT / PRODUCT	Immune engineering	3-D transistors	Tesla Autopilot
Immune system	1	0	0
Cancer	1	0	0
White blood cell	1	0	0
Bone marrow	1	0	0
Oncology	1	0	0

Adjacency matrix

PRODUCT / PRODUCT	Immune engineering	3-D transistors	Tesla Autopilot
Immune engineering	8	0	0
3-D transistors	0	8	0
Tesla Autopilot	0	0	8

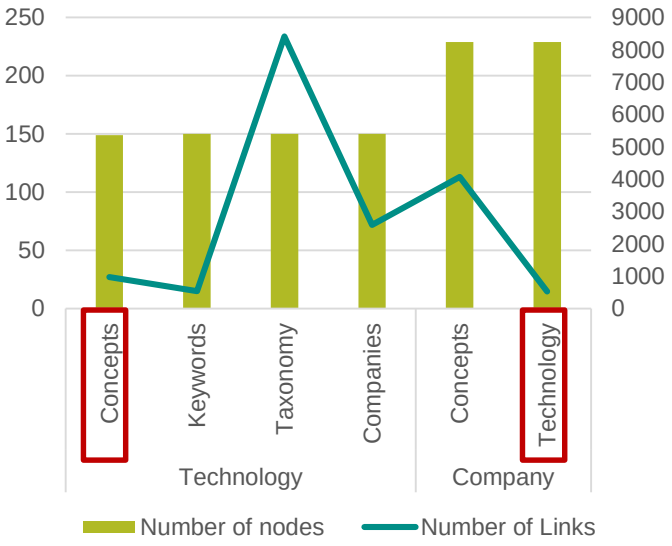
3

C = *AB* for an *n* × *m* matrix A and an *m* × *p* matrix B, then C is an *n* × *p* matrix with entries

$$c_{ij} = \sum_{k=1}^{m} a_{ik} b_{kj}$$

4

Summary Statistics for the 6 Networks



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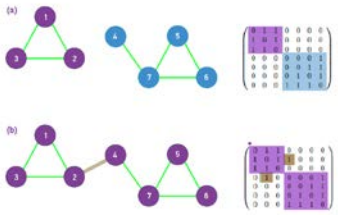
Leadership, Innovation, Systems Thinking

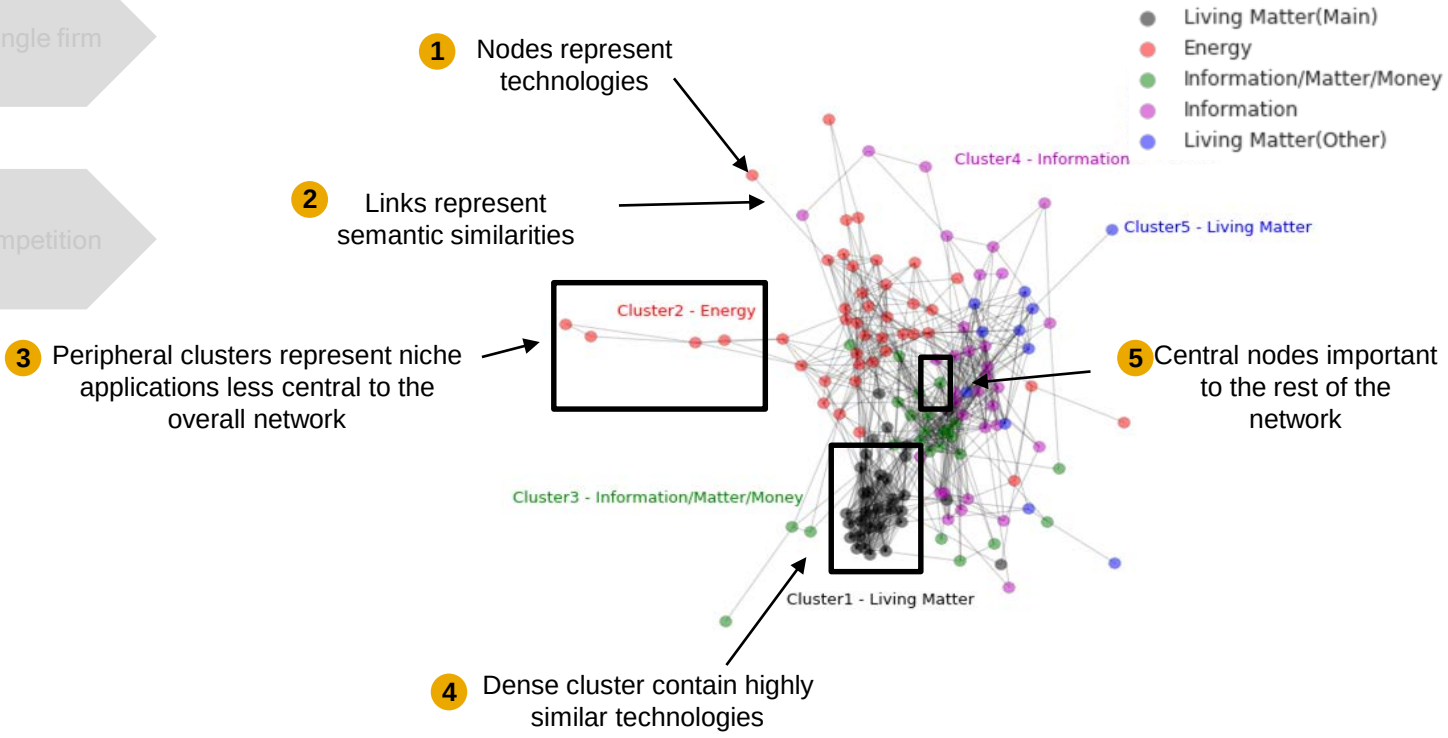
NETWORKS' NODES AND LINKS OFFER INSIGHTS ON CORE AND NICHE TECHNOLOGY APPLICATIONS



Framework | Steps | Data | NLP | Adjacency | Network | Visualization

Single firm

Competition



6 Nodes and network level measures

Each node has:
- Degree
- Closeness
- Betweeness

The higher degree, the higher benefit

Each link has:
- Weight

The higher similarity, lesser cost

[ON AVERAGE] A TECHNOLOGY IS CONNECTED TO 13 OTHER TECHNOLOGIES WHILE A COMPANY IS CONNECTED TO 4 OTHER COMPANIES

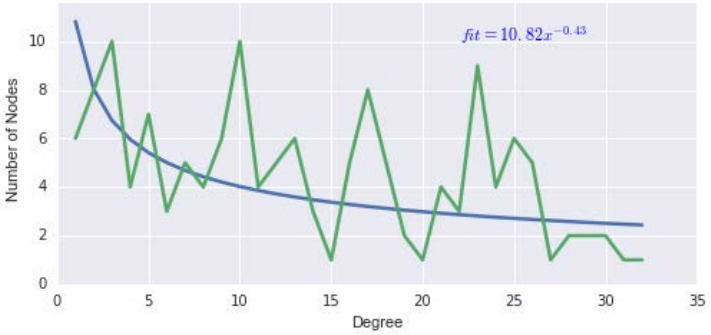
Framework | Steps | Data | NLP | Adjacency | Network | Visualization

Single firm

Competition

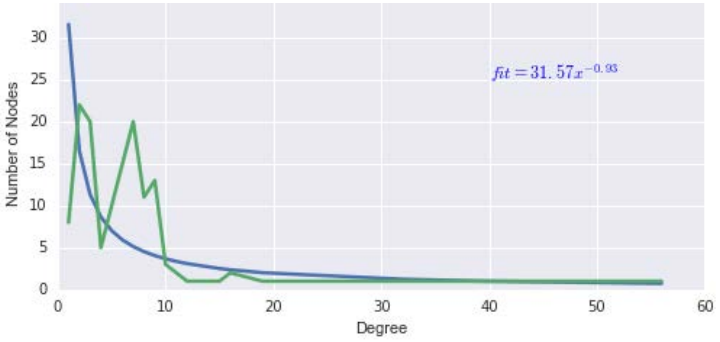
1 Technologies through concepts

Measure	Value
Number of nodes	149
Number of edges	971
Average degree	13.03
Number of connected components	7
Size of largest connected component	143
The average shortest path length	2.79



2 Companies through technologies

Measure	Value
Number of nodes	229
Number of edges	525
Average degree	4.58
Number of connected components	49
Size of largest connected component	138
The average shortest path length	2.91



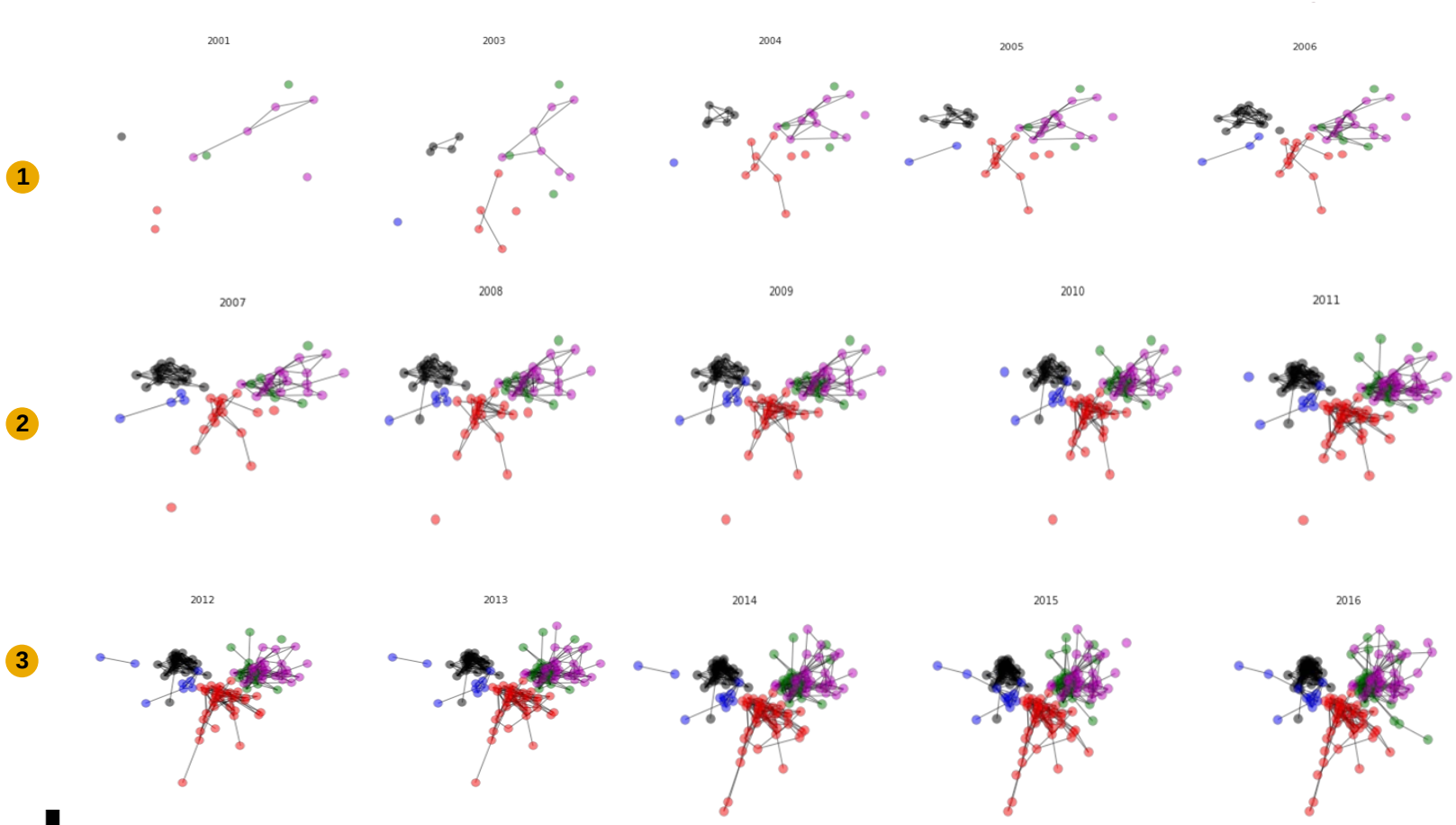
OVER TIME TECHNOLOGY CLUSTERS BECOME DENSER BEFORE CREATING LINKS TO OTHER CLUSTERS

Framework | Steps | Data | NLP | Adjacency | Network | Visualization

Single firm

Competition

Visualizing Technology Clusters Evolution over Time



Part 2

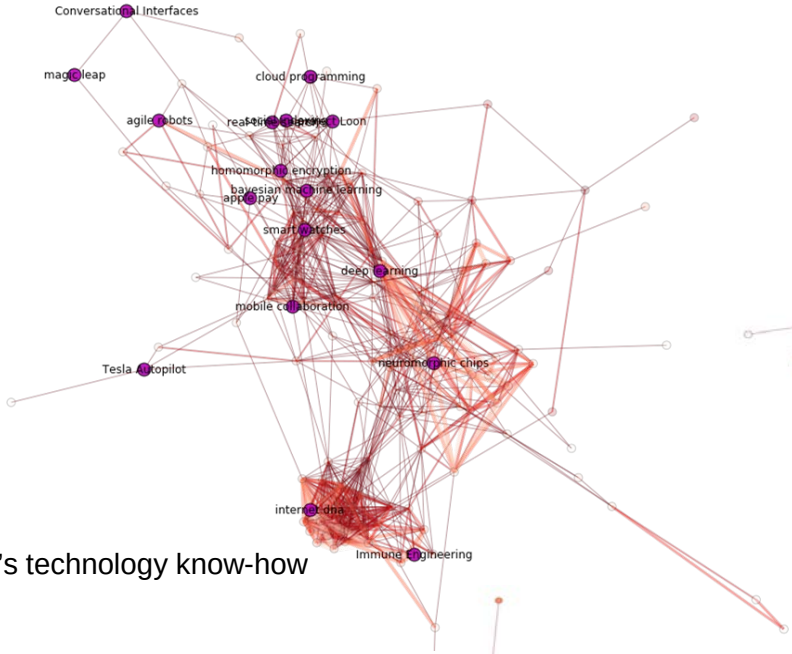
A DATA DRIVEN APPROACH

FROM A FIRM'S KNOW-HOW WE DEFINE A PATH TO A TARGET TECHNOLOGY

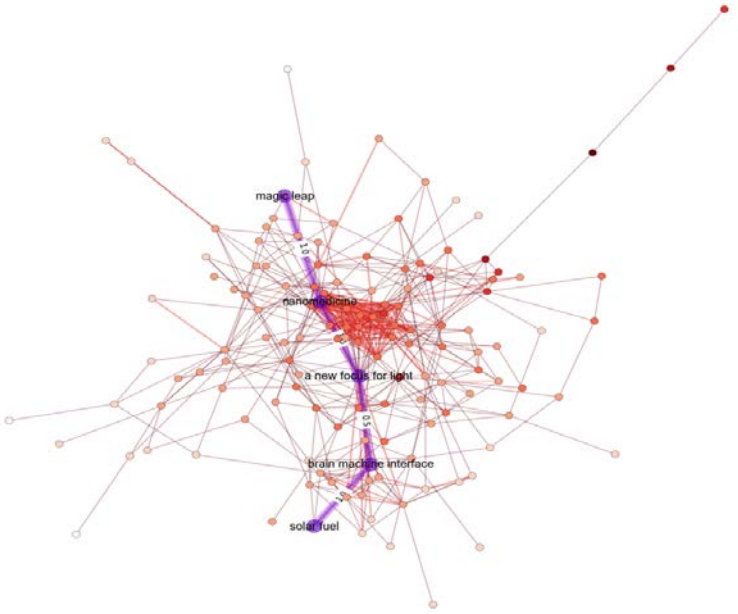
Framework

Single firm

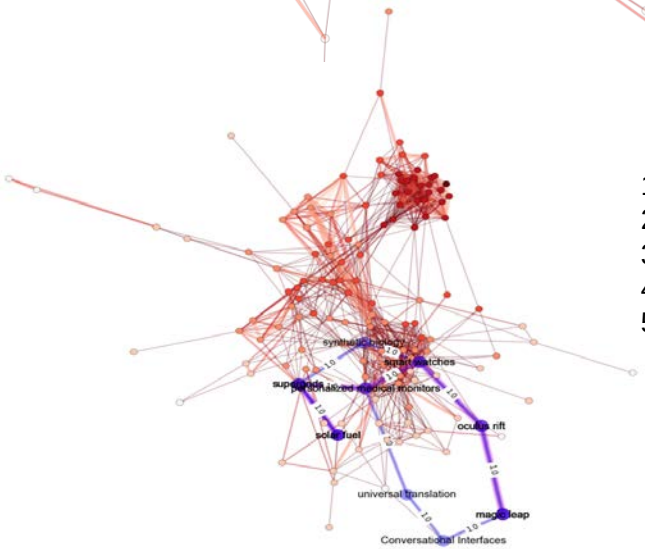
Competition



1 A firm's technology know-how



2 Connection between a pair of technologies (source, target)



3 Shortest path between two technologies

1. Existence
2. Shortest path length
3. Number of links in the shortest path
4. All alternative shortest paths with the same length
5. If the shortest path is not unique, returns a recommended shortest path that includes the most visited nodes

EACH TARGET TECHNOLOGY HAS A BENEFIT AND A COST ASSOCIATED TO IT

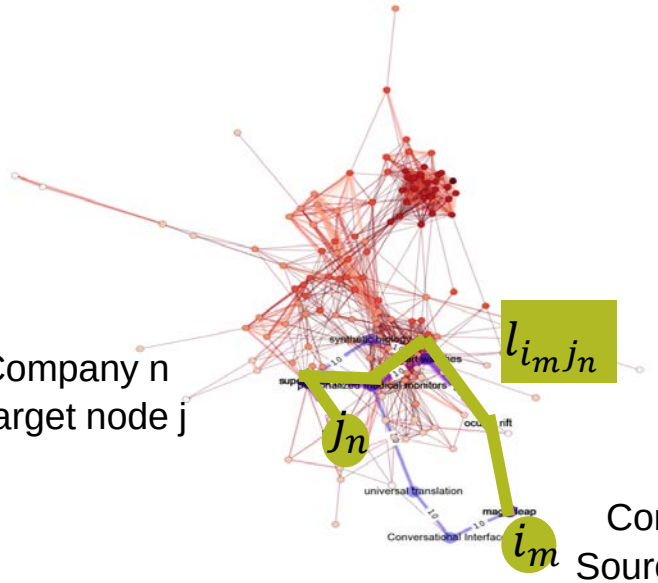
Framework

Single firm

Competition

Benefit	Cost	Payoff
$Benefit_i = Degree_i + Closeness_i + Betweenes_i$	$l_{ij} = \sum_{k=i}^{j} \omega_{k,k+1}\ with\ \omega_{ij} = \frac{1}{A_{ij}}$	$Payoff_m(s_{mk}, c) = \frac{Benefit_{jn}}{c} - l_{i_m j_n}$

- The initial position can be any one of the nodes in the firm's portfolio and is called the source node;
- The new position can only be one that is not part of the firm's portfolio and is called target node.
- Each pair of source-target nodes, and the specific path taken to move between the two, is a distinct strategy S
- The payoff of a strategy s for company m is the difference between the benefit of the target node j and cost incurred to reach it (represented by the length l of the recommended path between the source node i and target node j).



Company n
Target node j

Company m
Source node i

No competitor

$$Payoff_m(s_m^*, 1) = \frac{Benefit_{jn}}{1} - l_{i_m j_n}$$

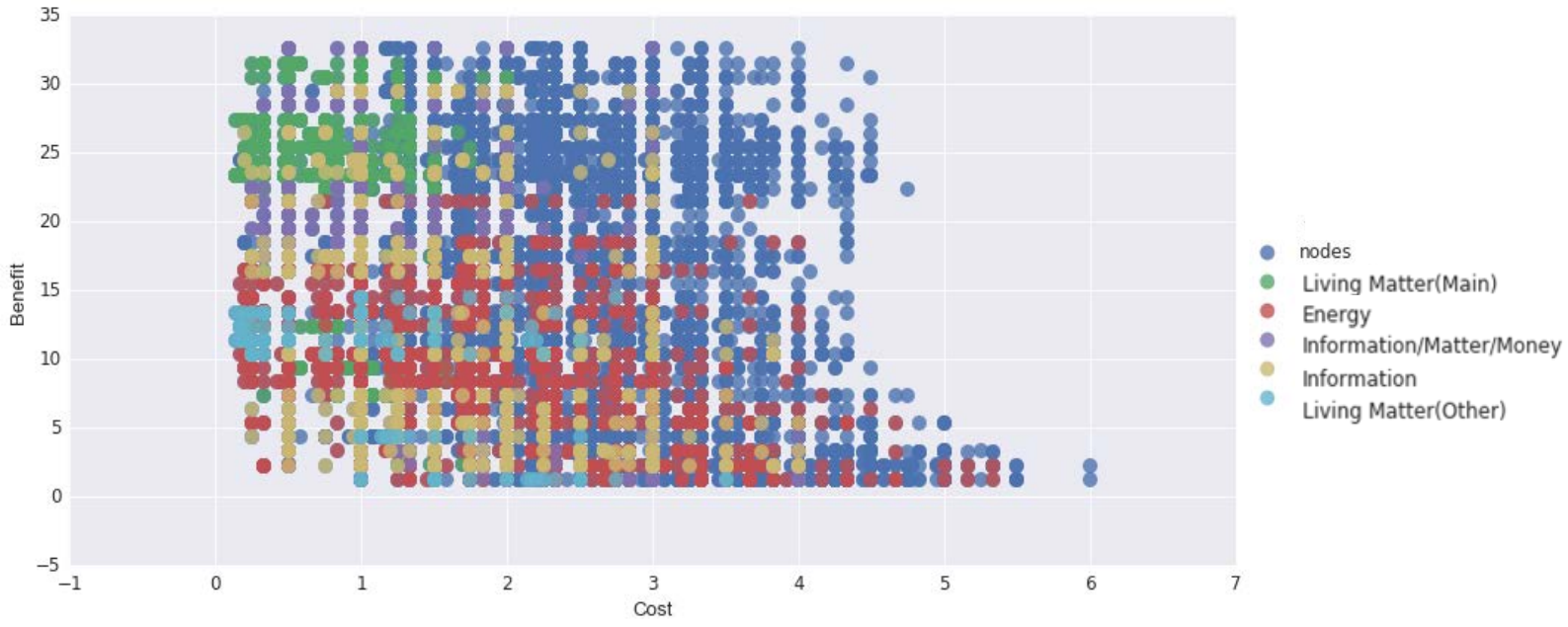
Company m has k strategies Smk
Sm* is the best strategy

DEPENDING ON A FIRM'S CORE VERTICAL MARKET SOME TECHNOLOGY TARGETS ARE MORE ATTRACTIVE THAN OTHERS

Framework

Single firm

Competition



- The different colors represent the pairs (source, target) that belong to the same cluster.
- For instance the green represents all the possible combinations of nodes in Cluster 1 (Living Matter), whereas red represents the pairs in Cluster 2 (Energy).
- If nodes in a pair belong to different clusters the pair would appear in blue.
- We note that pairs of nodes within the (Living Matter) cluster have higher benefit and lower cost than those in energy for example.

Framework

Single firm

Competition

Part 2

A DATA DRIVEN APPROACH

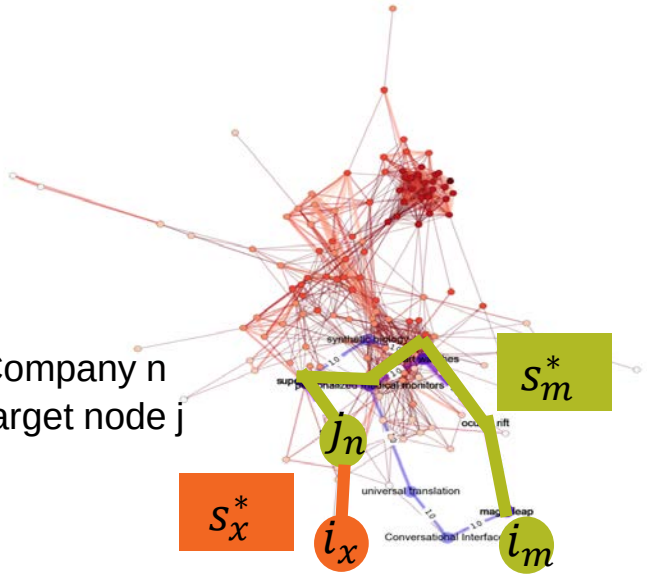
IN COMPETITIVE GAMES THE PAYOFFS CHANGE DEPENDING ON THE ACTIONS OF THE COMPETITOR

Framework

Single firm

Competition

Benefit	Cost	Payoff
$Benefit_i = Degree_i + Closeness_i + Betweenes_i$	$l_{ij} = \sum_{k=i}^{j} \omega_{k,k+1}\ with\ \omega_{ij} = \frac{1}{A_{ij}}$	$Payoff_m(s_{mk}, c) = \frac{Benefit_{jn}}{c} - l_{imjn}$



Company m/ Competitor x	x Invests in new technology j_n	x Does not Invest in new technology j_n
m Invest in new technology j_n	$Payoff_m(s_m^*, c)), (Payoff_x(s_x^*, c)$	$Payoff_m(s_m^*, 1)), (0)$
m Does not Invest in new technology j_n	0 , $Payoff_x(s_x^*, 1)$	0 , 0

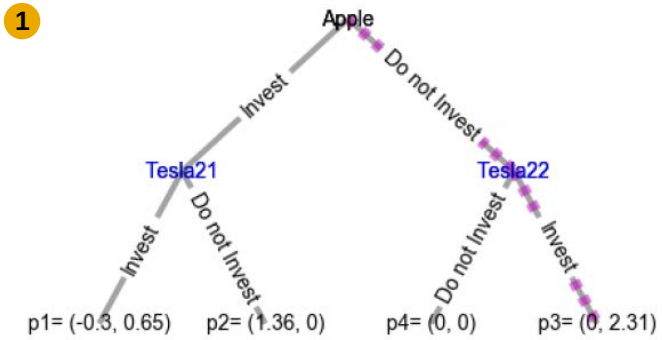
IF NO DOMINANT STRATEGY – CAN YOU ESTIMATE YOUR COMPETITOR'S LIKELY ACTIONS?

Framework

Single firm

Competition

1

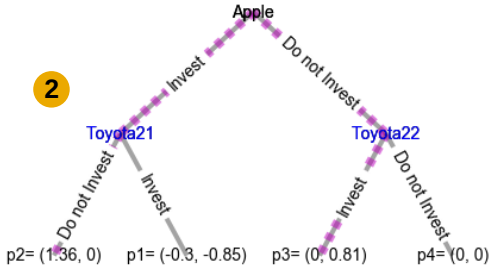


Tesla has a dominant strategy

Apple / Tesla	Invest	Do not invest
Invest	(-0.3, 0.65)	(1.36, 0)
Do not invest	(0, 2.31)	(0, 0)

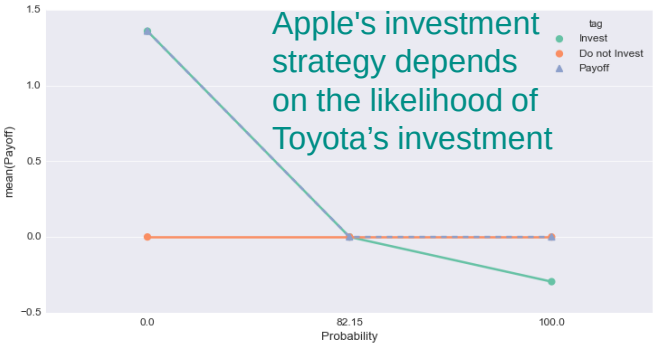
Therefore Apple should not invest

2



No dominant strategy

Apple / Toyota	Invest	Do not invest
Invest	(-0.3, -0.85)	(1.36, 0)
Do not invest	(0, 0.81)	(0, 0)



Probability of opponent's investment

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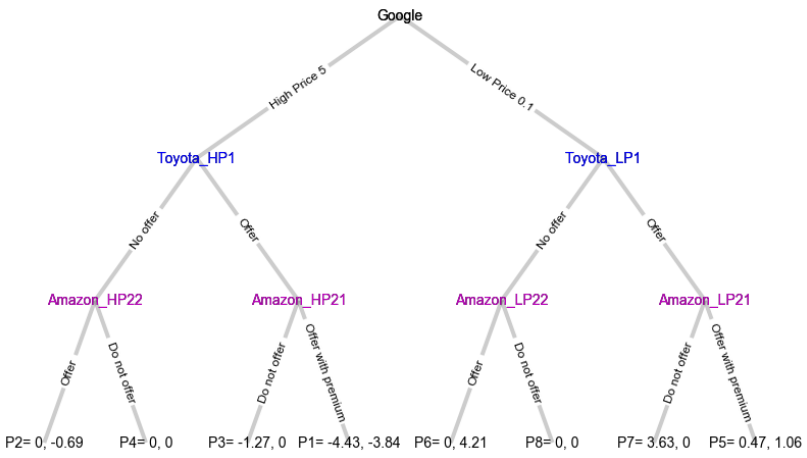
Leadership, Innovation, Systems Thinking

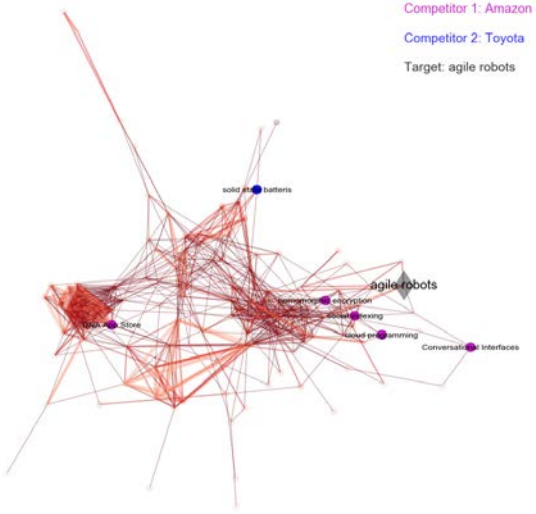
HOW TECHNOLOGY PRICE CAN AFFECT THE PAYOFFS AND ACTIONS

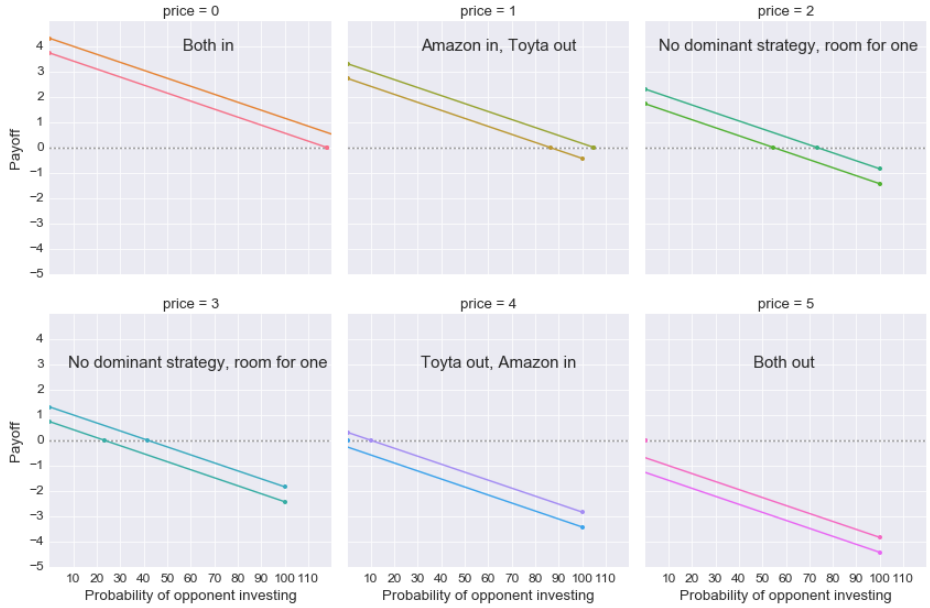
Framework

Single firm

Competition







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Leadership, Innovation, Systems Thinking

Consulting

Industry

Part 3

REAL WORLD APPLICATIONS

Consulting

Industry

Part 3

REAL WORLD APPLICATIONS

CONSULTING APPLICATIONS - MCKINSEY

Consulting

Industry

Startup and Investment Landscape Analytics

Features

- Inform strategic and investment choices for organic and inorganic growth.
- Supported 60+ clients in over 100 projects cutting across industries and geographies.
- Provides market map, identify disruptive trends driven by new business models and investments in technologies, potential partners and competitors.
- Combines diverse data sets with advanced analytic techniques, visualization and sector.

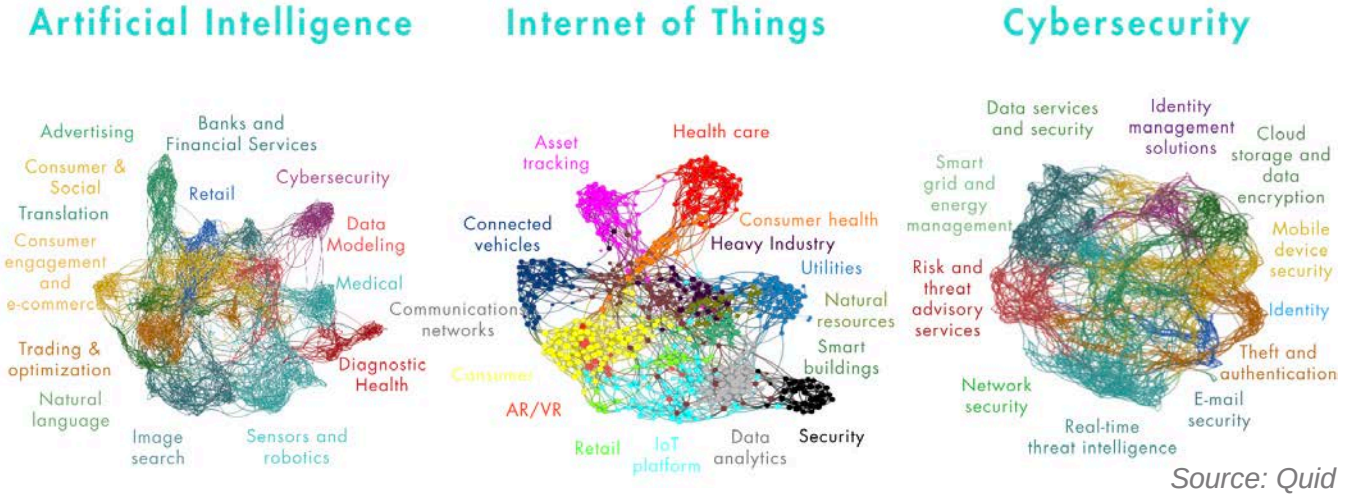
Benefits

- From weeks to Days
- White spaces
- Less experts interviews

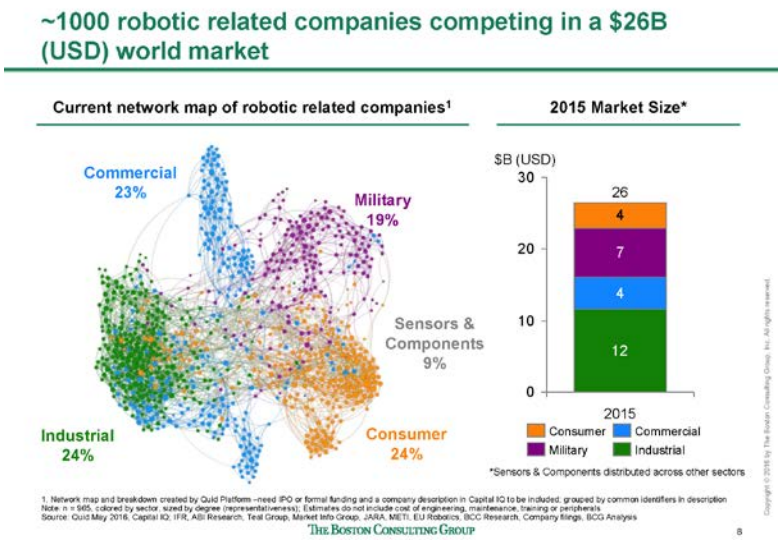
CONSULTING APPLICATIONS - BCG

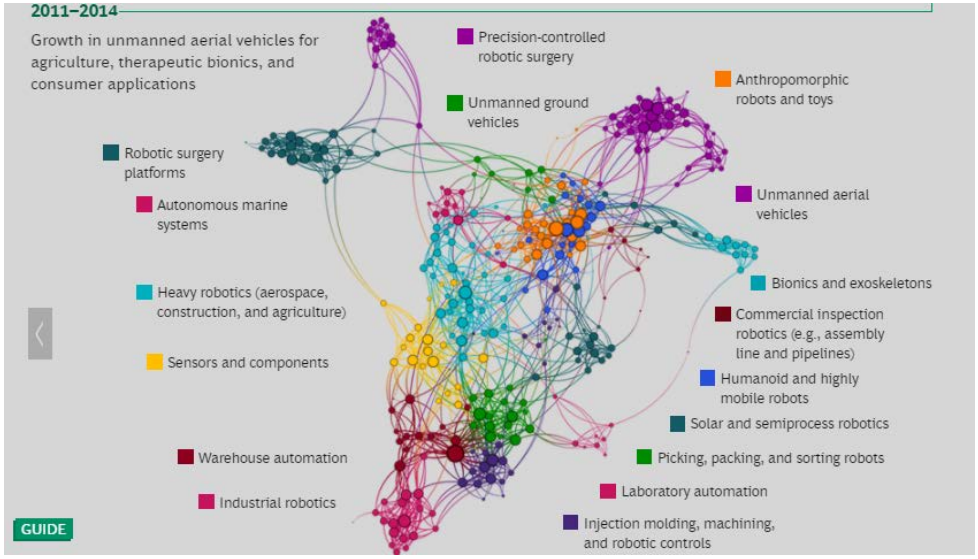
Consulting

Industry



Source: Quid





Source: BCG - *The Rise of robotics*

Consulting

Industry

Part 3

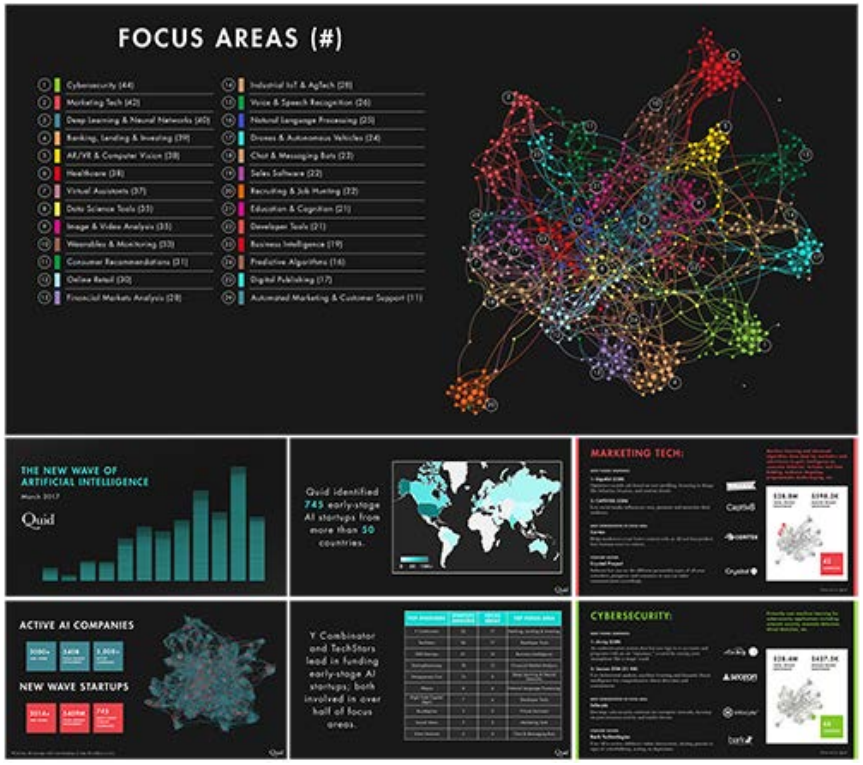
REAL WORLD APPLICATIONS

QUID

Consulting

Industry

In side by side comparisons, the Quid Intelligence Platform delivers insight 4X faster, 10X broader, and 5X deeper than traditional tools



QUID

Consulting

Industry

Technology

Consulting

Healthcare

Marketing/PR

Financial Services

Summary

Context and Challenge

- Fast rise of **number** of deals involving a tech target
- Tech deal market growth in **value** significantly outpacing the overall M&A market
- The share of **non-tech buyers** is rising
- There is a **need for a data driven approach companies could use to rapidly access the technologies** that can advance their businesses

Approach

- **Beyond patents**, other data sources that represent the socio-technical environment of a technology are proving useful (Capital IQ, Crunch base, News and Journals)
- **Natural language processing** is helping us uncover underlying connections between technologies
- **Networks'** nodes and links **offer insights on core and niche technology applications**
- From a firm's **know-how** we are able to define a path to a target technology
- Each target **technology has a benefit and a cost** associated to acquiring it
- Depending on a firm's **core vertical market some technology targets are more attractive than others**
- In competitive games the **payoffs** change **depending on the actions of the competitor**

Applications

- Data driven approaches are increasingly **used in consulting and industry** but need to be paired with the right strategic analysis
- **You can do it too** – commercial services or home grown but you need the right skills