LOOKING INTO THE PAST - PREDICITING THE FUTURE

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Cyclic Universe versus Linear Time Concepts

Figure 1: Wheel of life expresses the *cyclic view of time* and life of Buddhism. “The thing that hath been, it is that which shall be; and that which is done is that which shall be done: and there is no new thing under the sun.” (Ecclesiastes 1:9)


Cosmology: *oscillatory Universe* (?)

Figure 2: Knowing the past and expecting the future.

- Linear time concepts: *arrow of time*.
- Macroscopic processes are irreversible: *thermodynamic arrow of time*. James C. Maxwell and Ludwig Boltzmann.
- Two big Victorian narratives (Charles Darwin (1809–1882) and Karl Marx (1818–1883) stated the *biological* and *historical arrow of time*.
- The *cosmological arrow of time* describes the direction of the expansion of the Universe, and the *psychological arrow of time* expresses that we feel ourselves as travelers from the past to the future.
Reasoning: Deductive versus Inductive

Deductive arguments
If the premises are true
The conclusions must be true

• can usually be phrased as "syllogisms," i.e.

• a brief, mathematical statements in which the premises lead to the conclusion

• are truth preserving

"... While studying to become a doctor, Doyle became greatly impressed by the ability of one of his professors, a surgeon, to use deductive reasoning to uncover information about patients. Doyle modeled Sherlock Holmes on this doctor, as well as on another professor who taught forensic medicine..."
Inductive arguments

Francis Bacon (1561-1626)
- English lawyer, statesman, essayist, historian, intellectual reformer, philosopher, and champion of modern science
- proposed an entirely new system based on empirical and inductive principles
- ultimate goal: the production of practical knowledge for the use and benefit of men and the relief of the human condition
The world of Tycho Brahe: DATA COLLECTION (induction starts here)
Kepler: **MATHEMATICAL** not locally but globally predictive: integral laws. Second law: The planets move such that the line between the Sun and the planet (i.e., the radius vector) sweeps out the equal areas in equal intervals of time in any place of the orbit. (combined induction and deduction)

Newton’s laws: **PREDICTIVE gravitation + differential laws.** When an external force acts on a body of constant mass then the acceleration produced is directly proportional to the force.
DYNAMICAL MODELS: a way to understand temporal changes

"ALL MODELS ARE WRONG, BUT SOME ARE USEFUL"

ASSUMPTIONS -> PREDICTIONS ->
COMPARISON to DATA (Direct problem: deductive)

DATA -> MODEL (Inverse problem: inductive (mostly))
Growth processes: Malthusian and super-Malthusian growth, limits to growth

Will democratization show a monotonous increase?

Growth processes: Malthusian and super-Malthusian growth, limits to growth

RATE of CHANGE of any STATE = some function of the STATE

\[ \dot{x}(t) = f(x(t)) \]

this is a differential equation.

By telling how the the actual state influences the change of \( x \), we get specific equations.

The equations can be solved and the solutions are the growth (and other) TEMPORAL PROCESSES

Let’s specific examples!
Growth processes: Malthusian and super-Malthusian growth, limits to growth

Figure 3: Unbounded growth processes: infinite and finite-time singularities. Feedback between the rate of change and the state controls the DYNAMICS (size, price, force, population density...)

- Linear growth
  \[ \dot{x} = c, \quad x(0) = x_0 \]
  - increase at CONSTANT (i.e., state independent) rate
  - no feed-back
  - zero acceleration

- Exponential growth
  \[ \dot{x} = cx, \quad x(0) = x_0 \]
  - increase PROPORTIONAL to the actual state
  - linear positive feed-back
  - constant acceleration

- Super-exponential growth
  \[ \dot{x} = cx^m, \quad x(0) = x_0 \]
  - increase with HIGHER-THAN-LINEAR positive feed-back
  - increasing acceleration

\[ \dot{x} = cx^m \]
The dynamic laws behind rises and falls, periodicity and irregular changes

- boundless growth
- equilibrium dynamics
- rise-and-fall (boom and bust)
- periodicity
- chaos
**Basic Dynamics**

- Linear growth: \( v = x = c \) with \( a > 0 \)
- Exponential growth: \( v = ax \) with \( a > 0 \)
- Super-exponential growth: \( v = ax^n \) with \( a > 0, n > 1 \)
- Boundless growth

- Pull-back dynamic equilibrium
  - \( \dot{x} = c - dx \)
  - Gain term
  - Loss term
  - \( \dot{x} = ax - bx^2 \)

- Logistic growth
  - \( \dot{x} = axY - dx^2 \)
  - \( \dot{Y} = ax \) non-renewable

- Boom-bust cycle
  - \( \dot{x} = axY - dx^2 \)
  - \( \dot{Y} = ax + by \) renewable
The dynamic laws behind rises and falls, periodicity and irregular changes

From super-exponential growth to crash

- unbalanced (higher-than-linear) positive feedback $\rightarrow$ finite-time singularities
- infinite value during finite time: (chemical) explosion and "explosion"
- earthquakes, volcano, epilepsy stock prices ...
- super-exponential increase (due to the irrational expectations) cannot be continued for “ever” due to the unstable nature of this process
- followed by a compensatory process (i.e. stock market crash)

Figure 4: Stock market crashes
Sir Isaac Newton, scientist, master of the mint, and a certifiably rational man, fared less well. He sold his £7,000 shares of stock in April for a profit of 100 percent. But something induced him to reenter the market at the top, and he lost £20,000.

"I can calculate the movement of the stars, but NOT the madness of men.”
The dynamic laws behind rises and falls, periodicity and irregular changes

Oscillations: (predictable)

- harmonic oscillation
- Belousov - Zhabotinsky reaction: nonlinear chemical oscillator
- predator - prey systems
- neural oscillation
- circadian rhythms
- female hormonal cycle
- business cycle
The dynamic laws behind rises and falls, periodicity and irregular changes

Temporal complexity

Chaotic patterns: unpredictable

Lorenz: meteorology. "Butterfly effect".

Lorenz attractor
Unpredictability. Chaos: Sensitive Dependence on Initial Condition

For Want of a Nail
For want of a nail the shoe was lost.
For want of a shoe the horse was lost.
For want of a horse the rider was lost.
For want of a rider the message was lost.
For want of a message the battle was lost.
For want of a battle the kingdom was lost.
And all for the want of a horseshoe nail.

Should Pentagon concentrate on constructing perfect (well, the modern equivalents of) nails?
Scope and limits of predictability

- Surprising events: no rule?

- Self-organized criticality (P. Bak) $\rightarrow$ inherently unpredictable

- Intermittent criticality (D. Sornette) $\rightarrow$ there are precursors
Earthquakes, Epilepsy, Stock Market Crashes: Predicting and Managing Extreme Events

Earthquake eruption

Gutenberg-Richter law

\[
\log N(M) = -bM \tag{1}
\]

\(b \sim 1\)

\(N(M):\) number of earthquakes of magnitude greater than \(M\)
Earthquakes, Epilepsy, Stock Market Crashes: Predicting and Managing Extreme Events

Epilepsy

- epileptic seizures may begin hours earlier than their clinical onset
- definition of different measures
- relative self-excitation is a control parameter to induce/suppress epilepsy
- our own lab in Budapest: Zoltán Somogyvári
Earthquakes, Epilepsy, Stock Market Crashes: Predicting and Managing Extreme Events

Epilepsy

Somogyvári et al: Slow dynamics of epileptic seizure: analysis and model
Earthquakes, Epilepsy, Stock Market Crashes: Predicting and Managing Extreme Events

Market crash
Earthquakes, Epilepsy, Stock Market Crashes: Predicting and Managing Extreme Events

Figure 5: An excitatory-inhibitory networks supplemented with self-excitatory and self-inhibitory connections

- Uncompensated positive feedback: epilepsy and financial crisis
- Onset of two types of financial crisis
- Stock market crash and hyperinflation: generated by the positive feedback between the Actual and the Expected Growth Rate
- Large stock market crashes are social analogues of epileptogenesis
- Unsustainable velocity of price increase resembles to over-excitation of the epileptic brain
- Disinhibition: systems without having the ability to "cool down" are subject of explosion
- Seizure prediction?
Diagnosis and Prediction of Tipping Points

Outliers vs extreme value statistics

- What is the probability of having a big earthquake in California within a year?
- How large might a possible stock market crash be tomorrow?
  - lowest daily return (the minimum)
  - highest daily return (the maximum) over a given period
  - not normally distributed
• "small events which don't stop" are inherently unpredictable at individual level ("size of avalanches"

• there are slowly accumulating subterrestrial events might have precursors

• new approach to statistics: significant deviation from the "Bell curve" (power law distributions)
Prediction of Emerging Field of Technologies based on the Analysis of Patent Citation

1. to provide a general predictive analytic methodology, which is able to identify structural changes in the patent cluster system and reveal precursors of emerging new technological fields

2. to test and validate the predictive force of the new methodology based on historical examples of new class formation

3. to identify specific mechanisms of the recombination process and formation of new classes

4. to scan the database to identify "hot spots" that may reflect incipient development of new technological clusters
INSIGHT: Data mining

Mining the next big thing

Patent citations could help predict where technology is headed

HORIZON scanning. Strategic prediction. Futurism. Whatever you call it, companies need to anticipate the next hot technologies ahead of time or they will be beaten to the punch by more agile competitors. But what’s the best way to do it?

Usually the answer is to pore over societal, environmental, technological, and economic trends. In this next big thing scenario, the aim is to identify the catalysts that will give rise to new trends and technologies, and to leverage the data to understand the likely trajectory of these developments.

However, this can be a daunting task, as such data is often fragmented and difficult to access. This is where patent data can come into play, offering a valuable resource for companies looking to gain insights into emerging technologies.

Patent data mining can help companies understand the current landscape of technology and the potential for new innovations. By analyzing patent citations and claims, companies can gain insights into the state of the art and the directions in which technology is heading.

The method involves using natural language processing (NLP) and machine learning algorithms to extract meaningful information from the patent text. This process can reveal patterns and trends that are not immediately obvious from the raw data.

Patent citation data also helps companies understand the potential impact of new technologies. By analyzing the number of citations a patent receives, companies can gauge its influence and the likelihood of its success in the market.

The influx of patents was short-lived, reflecting the fact that companies were figuring out how to do business online - with ideas too similar to prior offline methods, or just plain obvious.

“Our methodology provides just one way to extract information from this patent data mine,” says Érdi. “We hope to convince companies to use our insights in their business planning.”

Yesterday’s technology is today’s legacy. The future of innovation is shaped by the data we collect and the insights we gain from it.
punch by more agile competitors. But what’s the best way to do it?

Usually the answer is to pore over societal, environmental, technological and economic trends and come up with a forecast of which technologies will be in high demand. Now futurists may be getting a new tool that automatically helps them predict emerging technologies, thanks to an innovative data-mining technique.

Developed by Péter Érdi at the Hungarian Academy of Sciences in Budapest and colleagues, it works by analysing the frequency with which patents are cited by other patents. Each new filing is required to cite previous inventions, or prior art, that the new idea builds upon.

Plotting how the frequency of these citations changes over time shows that patents can be grouped into related clusters. These clusters often map to valuable ideas.

“Patent citation data seems to be a gold mine of new insights into the development of technologies, since it represents the innovation process,” says Érdi. They tested their algorithm on old data from the US Patent and Trademark Office’s “agriculture, textiles and food” category of inventions and found that it predicted the emergence of a field recently created to cover nonwoven textiles—fabrics whose fibres are squeezed or forced together, often using solvents as bonding agents.

Using old data to predict the new has its risks, though. Had the team’s method existed during the internet boom of the 1990s, for example, it might not have predicted the development of the mobile internet as an emerging field.
Prediction of Emerging Field of Technologies based on the Analysis of Patent Citation

Figure 7: An example of the splitting process in the citation space, underlying the formation of a new class. In the 2D projection of the 36 dimensional citation space, position of the circles denote the position of the patents in subcategory 11 in the citation space in three different stages of the separation process (Jan. 1, 1994, Jan. 1, 1997, Dec. 31, 1999). Red circles show those patents which were reclassified into the newly formed class 442, during the year 1997. The rest of the patents which reserved their classification after 1997 are denoted by blue circles. Precursors of the separation appear well before the official establishment of the new class.
Grand conclusions

- Newton’s dynamical model: predictions led to the discovery of Neptune and Pluto

- What to do with this dynamical approach to social sciences?

- Social sciences: the overwhelming majority of data has been evaluated and interpreted in static or equilibrium perspective

- Something should be done with social data deluge

- The a priori knowledge of the rules, which basically govern the dynamic evolution of the systems, is difficult;

- By combining inductive and deductive strategies we hope to predict our social Neptunes and Plutos