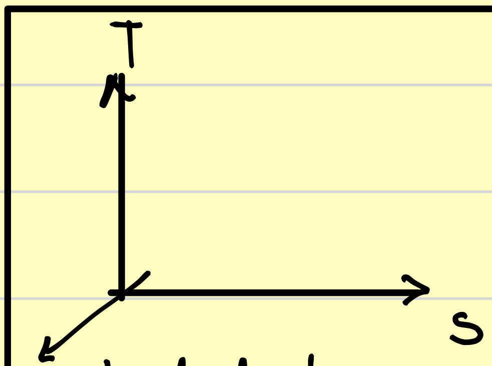
20211018_Project_Management_VH7

Mathematical formalization of Complex Network Dynamics

- Description of spreading Phenomena within complex networks: spreading of viruses, spreading of opinion, ...
- Projects & Processes ≡ Networks. We are going to investigate the spreading of (CPD)nA & (DCP)nA within organizations.



Standardization

YOKOTENKAI

„横展開"

2 Assumptions:

1. Individual (nodes) can be in two different states
   - (S). susceptible (not yet infected)
   - (I). infected
2. Each individual can infect anyone else (HOMOGENEOUS MIXING HYPOTHESIS) HMH

I First approximation of yokotenkai can be considered analogous to the „SUSCEPTIBLE - INFECTIOUS - SUSCEPTIBLE" SIS - Model, in which we consider a behavioural pattern like a "disease" that spreads in a population (network) and allow for individuals to „forget" the behavioural pattern and abandon it.

Parameters:

- $i(t)$ represents the fraction of individuals who have been „infected" by the pattern.
- β rate of infection
- $\langle k \rangle$ average network degree
- $\mu \cdot i(t)$ forgetfulness rate at which the population unlearn the pattern.

$$(1)\quad \frac{di(t)}{dt} = \underbrace{\beta \cdot \langle k\rangle \cdot i(t) \cdot (1 - i(t))}_{\text{INFECTION (learning)}} - \underbrace{\mu i(t)}_{\text{(forgetting)}}$$

SPEED OF INFECTION

...

SOLUTION (2)

$$\boxed{i(t) = \left[1 - \frac{\mu}{\beta\langle k\rangle}\right] \cdot C \cdot \frac{e^{(\beta\langle k\rangle - \mu)t}}{1 + C e^{(\beta\langle k\rangle - \mu)t}} \qquad C = \frac{i(t=0)}{1 - i(t=0)\frac{\mu}{\beta\langle k\rangle}}}$$

we're interested in the behaviour when $t \to \infty$:

$$i(t=\infty) = \lim_{t\to\infty} i(t) = 1 - \frac{1}{R_0}$$

$$\boxed{R_0 \equiv \text{reproductive Number} \equiv \frac{\beta\langle k\rangle}{\mu}}$$

INFECTION RATE β
$\langle k\rangle$ CONNECTIVITY
FORGETFULNESS

$R_0 > 1$, $\beta\langle k\rangle > \mu \rightarrow$ we get infected faster than we forget $\rightarrow$ The behavioural pattern spreads in the organization

$R_0 < 1$. $\beta\langle k\rangle < \mu \rightarrow$ we get infected slower than we forget $\rightarrow$ The behavioural pattern dies out.

explanations:

$R_0 \uparrow\uparrow \equiv \beta \uparrow\uparrow$. Infection rate is high.
$R_0 \uparrow\uparrow \equiv \langle k \rangle \uparrow\uparrow$. People are a lot in contact to each other.
$R_0 \uparrow\uparrow \equiv \mu \downarrow\downarrow$. People recover slowly from the disease.

II Second approximation is when individuals can only transmit the behavioural pattern to those they are in contact with.

(*) statistics

$\langle k \rangle$ = average degree

$\langle k^2 \rangle \equiv$ heterogeneity (std deviation^2). scale free $\langle k^2 \rangle \to \infty$

Parameters:

i_k. Fraction of the nodes with degree "k" that are infected among all other nodes with degree "k".

θ_k. fraction of infected neighbours of a susceptible node with degree "k".

$$\frac{di_k}{dt} = \beta\, i_k (1 - i_k) \cdot \theta_k(t) - \mu \cdot i_k$$

$\downarrow$

...

$\downarrow$

The condition for global spread of the behavioural trait is given when the "characteristic time" to achieve $\frac{1}{e}$ fraction of the population infected $[\tau] > 0$.

$$(2) \quad \boxed{\tau = \frac{\langle k \rangle}{\beta \langle k^2 \rangle - \mu \langle k \rangle}}$$

$\tau > 0 \rightarrow \beta \langle k^2 \rangle - \mu \langle k \rangle > 0 \rightarrow$ The condition to predict if a behavioural pattern spreads on a certain organizational design:

$$\lambda = \frac{\beta}{\mu} > \frac{\langle k \rangle}{\langle k^2 \rangle} = \lambda_c$$

$\frac{\text{rate of infection}}{\text{rate of forgetfulness}}$

depends only on the organizational design

Interpretation:

- high λ means $\beta \uparrow$ (high infection rate)
  $\mu \downarrow$ (low forgetfulness rate)

These are the conditions that the organizational culture transmits rapidly.

Special case: Scale Free Network $\langle k^2 \rangle \rightarrow \infty \rightarrow$ the behavioural pattern will always propagate successfully in the culture:

$$\lambda = \frac{\beta}{\mu} > \frac{\langle k \rangle}{\infty} = 0$$

In SFN there is no oposition to spreading.

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