The Bounds of “Bounded Rationality”

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Agenda

- Decision Making and Rationality
- Bounded Rationality *(Herbert A. Simon)*
- Heuristics approach to Decision Making
- Ecological Rationality *(Gerd Gigerenzer)*
- Rationality and Interconnectedness
- Internet of Things, Industry 4.0 and Semantic Web
- Concluding Remarks
"We are our choices."
What is a Choice?

Passing from several Potentialities to the single Actualization
An Example of “Rational Decision”

Customer A offers you: CHF10

Customer B offers you: CHF20

In Economics, this is called as “the Rational Agent Assumption”
Decision-Making and Rationality

What is Decision-Making?
Decision-Making is a Cognitive Process resulting in a Choice, according to certain Criteria in the frame of a Model.

What is a Rational Agent?
A Decision-Maker who:
- is always Aware of the available Potentialities (Sample Space) and Probabilities (Probability Distribution over the Sample Space)
- has well-defined Preferences (Utility Function over the Sample Space)
- always selects the Optimal Decision (Maximization of the Expected Utility)
Agents of Bounded Rationality

In practice, agents make their decisions under Bounded Rationality due to limited available resources.

Limitations of available:
- Cognitive Capabilities / Computational Intelligence
- Data, Information, Knowledge
- Time/Budget

form the Bounds of:
- Computability
- Accuracy
- Predictability

Bounds of “Decidability”
Decisions of Bounded Optimality

As agents are not able to implement the Optimal Decision, they act as Satisficers (Satisficing: Satisfy and Suffice)

Epsilon-Optimization:

\[ U(s) \geq \max_{\omega \in \Omega} \{U(\omega)\} - \varepsilon \]

- \( \Omega \) is the set of all Possible Outcomes
- \( U(\omega) \) is the Expected Utility of Outcome \( \omega \in \Omega \)
- \( \varepsilon \geq 0 \) is the epsilon bound
- \( s \in S(\varepsilon) \) is an «epsilon-optimizing» Outcome
- \( S(\varepsilon) \subset \Omega \) is the set of all «epsilon-optimizing» Outcomes

Herbert A. Simon
Nobel Prize in Economics (1978)
WHAT is the Problem?

How to minimize the epsilon bound $\varepsilon$ \textit{effectively}?
If everything seems under control, you're just not going fast enough

Mario Gabriele Andretti
Heuristics

Heuristic Technique: A fast and «frugal» Decision-Making method which is based on a Simple Rule sufficient for Fast Decision Making under Limited Resources or Uncertainty.

Heuristic is a Mental Shortcut or «Bypass» using ad-hoc selected simplifying assumptions.

Examples:
- Greedy Algorithm (consider only immediate benefit and wait for the next step)
- Trial & Error
An Example of Heuristics: Greedy Algorithm

**Goal:** Reach the **Largest-Sum**

Starting at A, a Greedy Algorithm will find the **Local Maximum** at "m", oblivious of the **Global Maximum** at "M"
Who does this calculation to catch a ball?!!

\[ y(x) = x \cdot \tan(\alpha) - \frac{g \cdot x^2}{2 \cdot v_c^2 \cdot \cos^2(\alpha)} \]  
\( (g = 9.81 \text{m/s}^2) \)
Gaze Heuristic

Adjust your motion to achieve a goal, using one variable only.
Gaze Heuristic

Fix your gaze on the ball, start running, and adjust your running speed so that the angle of gaze remains constant.
Fix your gaze on the ball, start running, and **adjust** your running speed so that the **angle of gaze remains constant**.
Gaze Heuristic

Fix your gaze on the ball, start running, and **adjust** your running speed so that the **angle of gaze remains constant.**
Fix your gaze on the ball, start running, and **adjust** your running speed so that the **angle of gaze remains constant**.
Adaptive Toolbox and Ecological Rationality

- **Adaptive Toolbox**
  Heuristics are **evolving**.
  They are **continuously** shaped by **Evolution** and **Learning** (**Feedback Loop**), resulting into their **Adaptation** within a **specific** Context/Environment.

- **Ecological Rationality**
  A Heuristic is **Ecologically Rational**
  «to the degree that it is adapted to an Environment».
  Heuristics **co-evolve** with their Environment.
Is Rationality related to Interconnectedness?
Information Diffusion in Networks and Decision Making

Higher interconnectedness expands the bounds of rationality of the Agents.
Access to Web = Better **real time** Decision Making
Network Effect and Metcalfe's law

The more «users» joining the Network, the more Value they give and eventually gain from the Network.

- The Value that you gain from being in the Network depends critically on the number of interconnected users: Value of the Network $\propto N^2$ (Metcalfe's law).
- Network Effect becomes significant after a certain threshold, called «Critical Point».
Internet of Things: Living beings (People) and non-living entities (Things) interact and decide in real time, forming a Complex Adaptive System, allowing their «Harmonious Symbiosis»

Examples: SMART Ecosystem, SMART Industry/Value Chain, SMART Health System
Cyber-Physical Systems: **Interconnected «Mechatronics»** (Mechanical and Electronic devices) augmented with **communication capabilities** based on computer algorithms
More Users Generate More Data
Semantic Processing and Significance

- How **data** can help me to take **rational Decisions effectively**?
- What is the **Meaning** of data (**Semantic Information**) and what is their **Significance** (**Pragmatic Information**)? ⇒ **Complexity reduction**

- **Semantic Networks**: A Network of Semantic Relations between Concepts
- **Ontology**: A Semantic Network together with the relevant **Inference Rule** (**Semantic Web**)
- **Linked Data**: **Structured** data by **interlinking** them in order to become more useful when questioning (making a Query) and take Decisions.
Concluding Remarks

- A higher level of **Interconnectedness** will allow better Decision-Making
  4\(^{\text{th}}\) Industrial Revolution – Internet of Things

- Considering Software aspects, **Semantic Information processing** is needed, in order to **deal with Big Data effectively in real time**.
  Semantic Web

- When more and more people and/or devices become interconnected, the damage of a potential **Information/Knowledge Warfare** increases
  Cyber-Security
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