Artificial Intelligence, Blockchain, e Criptovalute nello Sviluppo Software

Lezione 6: Distributed Cognition, Extended Mind, and Systemic Thinking

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Structure of the lecture

- Extended Mind
- Communication Patterns
- Systemic Thinking
- Distributed Cognition
- Systemic Thinking

Boundaries of the Mind

- Where is our mind?
  - Are the hands part of our mind?

Reference: Robert MacDougall, "The Significance of the Human Hand in the Evolution of Mind," The American Journal of Psychology, 16(2):232 – 242, Apr., 1905
Picture taken from
`https://www.yourtherapysource.com/blog1/2019/02/07/3-evidence-based-benefits-of-writing-by-hand/`.

Extended Mind (1/2)

- Let us consider a simple problem: we are given shapes and we have to see if they fit holes:

Source of the content: Andy Clark and David Chalmers, "The extended mind," Analysis 58 (1): 7–19 , 1998

Picture taken from `https://gurugamer.com/mobile-games/shapes-and-holes-a-new-mobile-puzzler-where-you-fit-things-into-other-things-1214`.

Extended Mind (2/2)

- Let us consider three cases:
  - this is a computer game (as in the picture) and the person has to rotate the pieces by mind and determines the fitting;
  - this is a paper game and the person has pieces that s/he rotates manually to determine the fit;
  - let us assume that the person has an implanted device, say, special smart glasses, that perform the rotation and then s/he just does the fitting
- What is the level of cognition present in these cases?
  - Clark and Chalmers claim that it is the same.
- Therefore, what is the boundary of our mind?

Source of the content: Andy Clark and David Chalmers, "The extended mind," Analysis 58 (1): 7–19 , 1998

Tools and Mind

- There are many tools even before computer that helped our cognitive tasks
  - abacus
  - paper and pen
  - sliding rule
  - ...
- Once we start using it, they become intrinsic part of our reasoning and computational process
- Think at how we do computations in column
  - papers and pen are essential components of our reasoning process
  - even when we do the computation in our mind we often simulate the presence of paper and pen
- Once more, **what are the boundaries of our mind**?

Source of the content: Andy Clark and David Chalmers, "The extended mind," Analysis 58 (1): 7–19 , 1998

Impact

- We care about this for at least three reasons:
  - we understand that the request of tools may be not a caprice of a spoiled kid but an actual desire to organize the (extended) mind in the most effective way
  - when developing tools we need to think at how such tools can most effectively "extend" the mind of the users, and not simply being tools
  - when creating a (development) environment for us and for our people we must determine the best configuration
- Once more, **what are the boundaries of our mind**?

Source of the content: Andy Clark and David Chalmers, "The extended mind," Analysis 58 (1): 7–19 , 1998

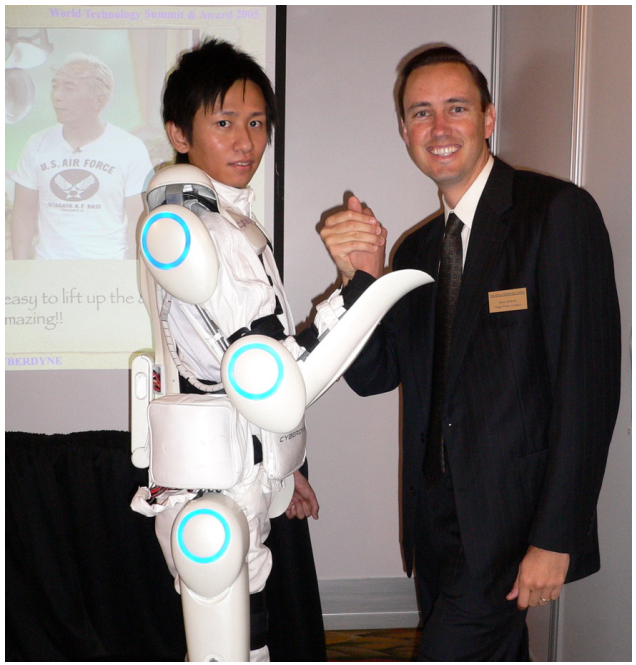
Active Externalism

- The claim of Clark and Chalmers is that the tool and the person couple together forming a unique mix
- The external tools are not just instruments for actions that are determined in an hypothesized internal mind
- Rather, they are a key active external component of our mind, hence we talk of:
  - Active Externalism
- Think at exoskeleton, for instance

Source of the content: Andy Clark and David Chalmers, "The extended mind," Analysis 58 (1): 7–19 , 1998

Example: Exoskeleton

- A Hybrid Assistive Limb:



- "The external features here are just as causally relevant as typical internal features of the brain" Clark and Chalmers.

Picture taken from `https://en.wikipedia.org/wiki/Powered_exoskeleton`. Statement from Andy Clark and David Chalmers, "The extended mind," Analysis 58 (1): 7–19 , 1998.

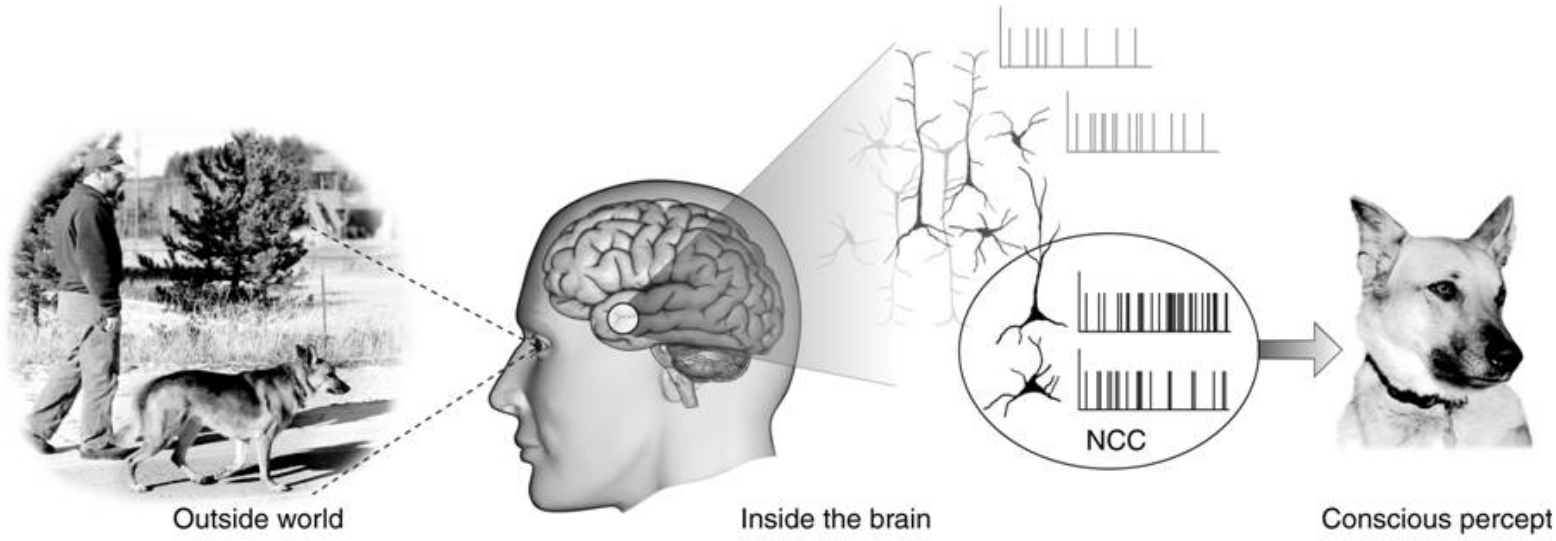
Beliefs

- The mind is also the center of our beliefs
- Typically we think at beliefs as something completely internal to our mind
- Is it really so?
- Or think at how many interaction with an environment of tools and devices we would need to think if we would assume that:
  - processes are only inside the body and
  - everything is is something that is manipulated and "used"

Source of the content: Andy Clark and David Chalmers, "The extended mind," Analysis 58 (1): 7–19 , 1998

Cognition and consciousness

- Cognition is not consciousness
- Remember of the emotional long term memory or even at the procedural long term memory
- And think at all the work, for instance of therapists of moving feelings at the consciousness level
- Discussing consciousness is beyond the purpose of this course



Picture taken from `https://en.wikipedia.org/wiki/Consciousness` where it is credited to Christof Koch (`https://en.wikipedia.org/wiki/Christof_Koch`).

Location of our beliefs (1/3)

- Let us consider these two cases (from the reference):
  - Inga wants to go to the MoMA and remembers that it is on 11 West 53 Street, Manhattan, and she goes there
    - She had a (previous) belief in her **mind** about the location and she uses it to direct her actions
  - Otto suffers from Alzheimer diseases, so he forgets what he learns and to overcome this he takes with him a tablet where marks down information
  - Also Otto wants to go to the MoMA, he looks it up in the tablet, finds that it is on 11 West 53 Street, Manhattan, and goes there
    - He had a (previous) belief about the location in his the **tablet** and he uses it to direct her actions
  - What is the difference?

Source of the content: Andy Clark and David Chalmers, "The extended mind," Analysis 58 (1): 7–19 , 1998

Location of our beliefs (2/3)

- We could explain the reasoning process of Otto in terms of external tools, but it would be quite convoluted
- For Otto the tablet plays the same role as the *mind* for Inga
- For beliefs what matter is not where they are located but the role that they play
- After all, in what the beliefs of Otto and of Inga differ?
  - Their only difference is in the physical location
- There could be additional counterclaims of the differences on beliefs:
- The tablet of Otto could not be always with him for instance when he takes a shower
  - Inga beliefs could also be our her if she is drunk or excited

Source of the content: Andy Clark and David Chalmers, "The extended mind," Analysis 58 (1): 7–19 , 1998

Location of our beliefs (3/3)

- Otto could be slower in gathering the information
  - What if Inga had a memory disorder that requires her a slow process to recall her beliefs?
- The process of Otto requires perception while the one of Inga only introspection
  - Are we sure that when we look up information on a table we are really exercising perception? If we consider the tablet as part of the mind, the process is still introspective
- There are no strong arguments against considering also the one of Otto as a belief, and thus that his minds extends to the tablet

Source of the content: Andy Clark and David Chalmers, "The extended mind," Analysis 58 (1): 7–19 , 1998

Additional speculation on Otto

- The tablet is an integral part of the life of Otto
- Otto can access directly and without any problem the information there
- Otto accepts as true the information stored in the notebook automatically
- Otto has once validated such information, and since then such information is valid
  - What if someone leaks inside the table and put there wrong information?
  - Well, if someone by some subliminal manipulation forces in the mind some wrong information?

Source of the content, also copied verbatim: Andy Clark and David Chalmers, "The extended mind," Analysis 58 (1): 7–19 , 1998

Can we extend this concept beyond?

- What about groups of people, where the knowledge is distributed?
- The key point is how much our belief is:
  - trust
  - reliance
  - availability
- indeed, the language pays a major role, but ...

Source of the content, also copied verbatim: Andy Clark and David Chalmers, "The extended mind," Analysis 58 (1): 7–19 , 1998

Communication means (1/3)

- Empirical studies with 38 IT professionals
- Analysis of the communication patterns

When the communication is considered positive

What is being used	by me	by others	by any
Vocalics	16%	16%	26%
Kinesics	21%	8%	24%
Chronemics	3%	5%	5%
Proxemics	0%	3%	3%
Oculesics	0%	0%	0%
Synchrony	3%	0%	3%

Source: Paolo Ciancarini, Mirko Farina, Sergey Masyagin, Giancarlo Succi, Sofiia Yermolaieva, and Nadezhda Zagvozkina. "Non verbal communication in software engineering - an empirical study." IEEE Access, 9:71942–71953, 2021

Communication means (2/3)

When the communication is considered negative

What is being used	by me	by others	by any
Vocalics	5%	8%	11%
Kinesics	11%	5%	11%
Chronemics	8%	8%	16%
Proxemics	0%	3%	3%
Oculesics	0%	3%	3%
Synchrony	5%	0%	5%

Source: Paolo Ciancarini, Mirko Farina, Sergey Masyagin, Giancarlo Succi, Sofiia Yermolaieva, and Nadezhda Zagvozkina. "Non verbal communication in software engineering - an empirical study." IEEE Access, 9:71942–71953, 2021

Communication means (3/3)

- When the communication is positive:
  - There is a larger incidence of vocalics and kinetics
  - When the communication is negative people think that time is wasted
- Chronemics play a major role in meetings:
  - When the communication is negative they are remarkably noted
  - When the communication is positive people feel them implicitly (coded in comments)

Source: Paolo Ciancarini, Mirko Farina, Sergey Masyagin, Giancarlo Succi, Sofiia Yermolaieva, and Nadezhda Zagvozkina. "Non verbal communication in software engineering - an empirical study." IEEE Access, 9:71942–71953, 2021

Systemic Thinking (1/2)

- Systemic thinking is an interdisciplinary field of research that
  - attempts to comprehend complex human (and non-human) structures
  - by explaining their mutual interconnections from a holistic standpoint
- It is an approach applied in many disciplines, including sociology, psychology, management, etc
- An idea inspired somehow by many Eastern philosophies
- There are elements also in Pythagorean theories, then going to Plato, Avicenna (Ibn Sina), ...

Source: Mirco Farina, Giancarlo Succi, Ananga Thapaliya. "A Systemic Perspective on Software Engineering." Under review

Systemic Thinking (2/2)

- Systemic thinking draws from different disciplines (engineering, computer science, cognitive science, management, philosophy, psychology, biology, ...)
  - it attempts to provide a discipline-agnostic approach for dealing with complex problems
  - to understand the structure and properties of a given system in terms of the relationships among its components
- It was introduced in software engineering in 1971 by Weinberg ("The psychology of computer programming") and then forgotten or declassed under the term *peopleware*
- The agile proponents of the division between tame and wicked problems were apparently unaware of systemic thinking.

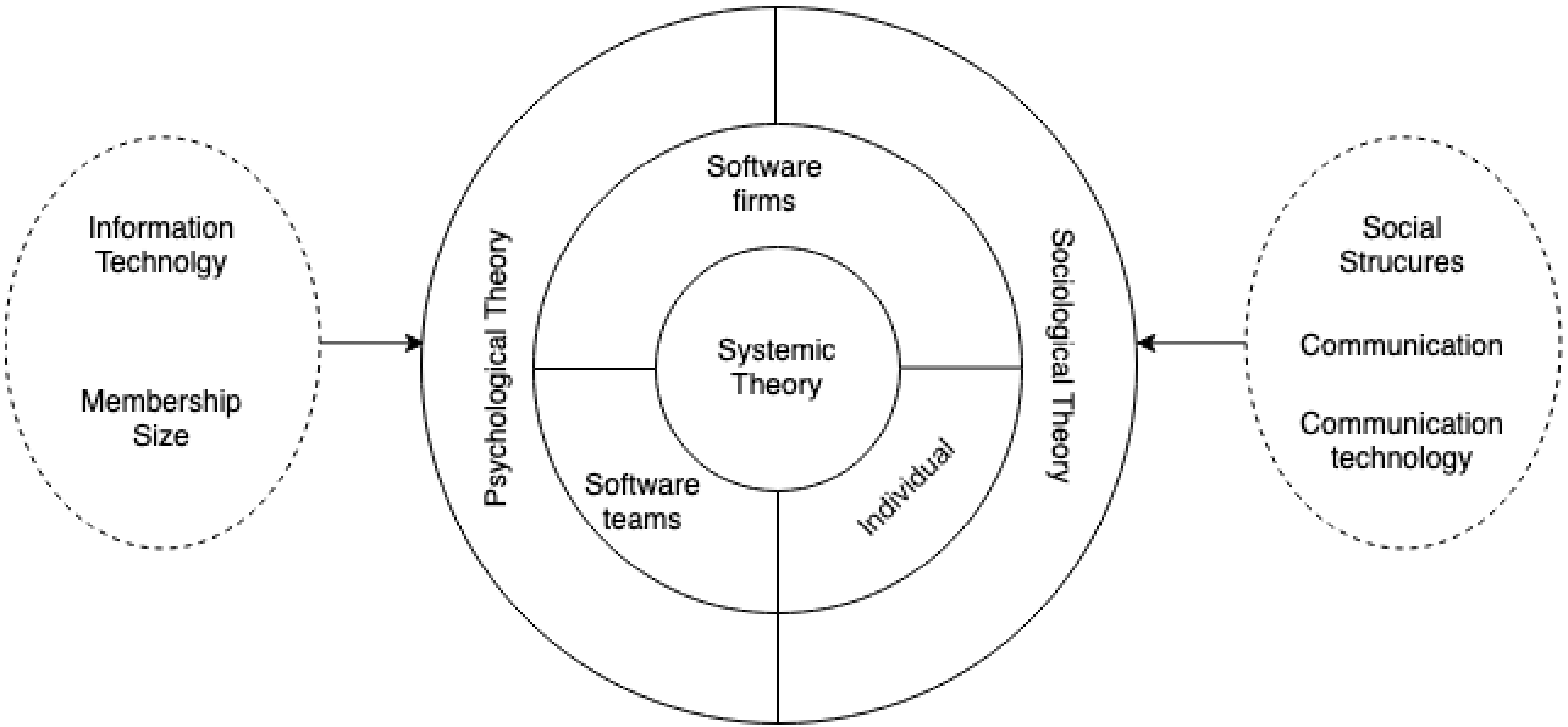
Source: Mirco Farina, Giancarlo Succi, Ananga Thapaliya. "A Systemic Perspective on Software Engineering." Under review

Systemic Thinking and Software Engineering

- Systemic thinking in software engineering views the software development process as a complex and dynamic system composed of multiple interconnected parts.
  - it emphasizes the interdependences of individuals, teams, and organizations, and
  - how each interdepencency influences and are influenced by one another
  - also identifying coherences and incoherences in representations and
  - (self-)contradicting thought
  - schismogenesis
- Can be divided into psychological and sociological systemic thinking

Source: Mirco Farina, Giancarlo Succi, Ananga Thapaliya. "A Systemic Perspective on Software Engineering." Under review

Sociological and Psychological Views



Picture from an earlier version of the paper: Mirco Farina, Giancarlo Succi, Ananga Thapaliya. "A Systemic Perspective on Software Engineering." Under review

Example of Systemic Analysis (1/2)

Written Process	Interviewee 1	Interviewee 2
The Senior Architect defines a list of requirements through a direct interaction with the customer and writes them in natural language		
The Senior Architect presents the information to the Lead Analysts and some implementation scenarios; together they write the specifications of each task to perform in natural language.	The Lead Analyst analyzes the written documentation from the Senior Architect and produces the specifications of each task to perform in free text.	The Senior Architect writes the specifications of each task to perform and discusses them with the customer
The Lead Analysts transfer specification back to the Senior Architect for the effort estimation.		This activity has not been mentioned
The Senior Architect and the Lead Analysis analyze the current situation and determine in which release it is possible to include the task	Senior Architect, based on the current workload the urgency of the task and its expected duration determine in which release to put it.	The Senior Architect determine in which release to put each task to perform.
This activity has not been mentioned	This activity has not been mentioned	The assignment of the task to a specific release is confirmed by the customer
The Lead Analysts with the Senior Architect assigns the task to a Developer	The Senior Architect assigns the task to a Developer	
The Developer writes the code		
This activity has not been mentioned	The Developer tests the code whether it is done correctly	
The Senior Architect verifies the code done by the Developer		
This activity has not been mentioned	The Senior Architect devotes approximately 25% of his time to the architectural changes	This activity has not been mentioned

Picture from: Vladimir Ivanov, Manuel Mazzara, Witold Pedrycz, Alberto Sillitti, and Giancarlo Succi. "Assessing the Process of an Eastern European Software SME Using Systemic Analysis, GQM, and Reliability Growth Models: A Case Study." In Proceedings of the 38th International Conference on Software Engineering Companion (ICSE 2016), pages 251–259, Austin, Texas, May 2016. ACM

Example of Systemic Analysis (2/2)

Declared values and principles	Actual behavior	Type of inconsistency
The company has a flat structure. There are no team leaders who distribute tasks, and no managers who control the order of the team's work	The company has hierarchical and functional-oriented structure	Misalignment
There are several separate and motivated self-organizing teams focused on primary business goals	Working environment do not support the formation of cross-functional teams; employees are selected into teams by the HR department based on necessity, not their preferences	Misalignment
The decision-making facing business problems is completely run by teams	Teams do not have any authority to make decisions on a product development strategy; lack of control over their work negatively affects teams' morale	Schismogenesis. The more tasks assigned to the teams from above the less commitment to the product and sprint goals which results in continuous divergence with agile culture
At least once every two weeks, each team together with the business decides what needs to be worked on next	There is no mutual desire for collaborative work within agile philosophy, middle-level management tends to the functionally oriented model	Schismogenesis. Managers of the bank act from the position of traditional project management. The more directive discussion, the more latent dissent exhibit developers
The teams use three types of metrics that are displayed on special information panels. They pay attention to product metrics, system health metrics, and process metrics (production metrics)	Business metrics are not detailed enough: product metrics are based on high-level increments and Time-to-market, team performance assessed by velocity. Teams do not have control over a number of assigned KPI	Schismogenesis. The measurement system is not aligned with the teams, their goals and responsibilities, which leads to frustration. The more metrics are introduced, the less accurate they are collected and the less transparent the development process becomes
In addition to INVEST, a number of criteria were developed for the Definition of Ready of User Story	Most of them unaware of INVEST criteria at all. A task can be assigned at any moment throughout the sprint obviously violating Definition of Ready	Misalignment
Definition of Done defines a checklist of what needs to be done in order for a task to be considered complete and ready for release	Improper usage of Definition of Done and omitting of this practice by some teams	Misalignment

Picture from: Merab Gogichaty, Vladimir Ivanov, Artem Kruglov, Witold Pedrycz, Aliya Samatova, Giancarlo Succi, Raphael Valeev, "A Systemic Approach to Evaluating the Organizational Agility in Large-Scale Companies," in IEEE Access, vol. 11, pp. 3307-3323, 2023

Empirical Study (1/2)

- Core question: How can the application of systemic thinking help us understand how software teams work and operate in their daily practice?
- Phase 1: Online questionnaire on to 50 software developers working in Russia, Nepal, and Luxembourg based on closed questions
  - Overall result: systemic thinking is deeply ingrained in the daily activities of software engineers

Source: Mirco Farina, Giancarlo Succi, Ananga Thapaliya. "A Systemic Perspective on Software Engineering." Under review

Empirical Study (2/2)

- Phase 2: Refinement of Phase 1 with physical interviews with 11 expert Russian programmers and managers based on open questions
  - Overall result: psychological and sociological systemic approaches should be considered in all software engineering practices and
  - an improved understanding of these systemic approaches would benefit all the roles in any team
- overall, the most commonly stated terms have to do with communication, teamwork, and social leadership.
  - i.e, software engineering is a social phenomenon that is heavily impacted by group dynamics and individual personalities — more on distributed cognition

Source: Mirco Farina, Giancarlo Succi, Ananga Thapaliya. "A Systemic Perspective on Software Engineering." Under review

Systemic Thinking and Agility (1/2)

- Another empirical study
- Questions:
  - Do software engineers have a high level of systemic thinking in general?
  - What is the level of systemic thinking in the different processes (traditional, agile, mix agile-traditional, ad-hoc)?
- Online questionnaire with 101 respondents worldwide
- Using the Systemic Thinking Scale to measure the level of systemic thinking (from 0 to 80)

Source: Paolo Ciancarini, Mirco Farina, Giancarlo Succi, Ananga Thapaliya. "Systemic thinking and software development processes." Under review

Systemic Thinking and Agility (2/2)

Process	Average	Stdev	Score
Agile	2.78	0.17	55.66
Mixed	2.75	0.29	54.95
Traditional	2.74	0.32	54.75
Ad hoc	2.49	0.29	49.89

- In terms of significance:
  - agile and mixed have a probability of mean STS not different from ad-hoc of 1.1%,
  - traditional not different from ad-hoc of 7.1%
  - traditional and mixed are almost indistinguishable one another in terms of STS

Source: Paolo Ciancarini, Mirco Farina, Giancarlo Succi, Ananga Thapaliya. "Systemic thinking and software development processes." Under review

Toward Distributed Cognition

- We have seen that:
  - cognitive processes may extend to tools we are interacting with
- However
  - cognitive processes may also span through multiple individuals
  - cognitive processes may also cross time boundaries

Source: James Hollan, Edwin Hutchins, and David Kirsh. 2000. "Distributed cognition: toward a new foundation for human-computer interaction research." ACM Trans. Comput.-Hum. Interact. 7, 2 (June 2000), 174–196

Cognitive Architectures

- We have seen that:
  - cognitive processes define paths for the information to flow
  - during these path the information is transmitted and/or transformed
  - this network defines the cognitive architecture
- Now:
  - social organizations structure how the information flow in a group of people and devices
  - therefore **social organizations can be considered cognitive architectures themselves**

Source: James Hollan, Edwin Hutchins, and David Kirsh. 2000. "Distributed cognition: toward a new foundation for human-computer interaction research." ACM Trans. Comput.-Hum. Interact. 7, 2 (June 2000), 174–196

Distributed Cognition

- Given that social organizations can be considered cognitive architectures
  - we can use the dynamics of social groups to explain what passes to the minds (of people?)
  - and here we are understanding what phenomenologically we appreciated with systemic analysis
- we can conclude that also the cognitive process of an individual is distributed

Source: James Hollan, Edwin Hutchins, and David Kirsh. 2000. "Distributed cognition: toward a new foundation for human-computer interaction research." ACM Trans. Comput.-Hum. Interact. 7, 2 (June 2000), 174–196

Three fundamental questions

1. How groups of people implement cognitive processes that we usually consider belonging to an individual mind?
2. What are the differences of the cognitive process of a group as a whole from the cognitive process of the people in the group?
3. How is an individual cognitive processed affected by participating in a group cognitive process?

Source: James Hollan, Edwin Hutchins, and David Kirsh. 2000. "Distributed cognition: toward a new foundation for human-computer interaction research." ACM Trans. Comput.-Hum. Interact. 7, 2 (June 2000), 174–196

The role of culture

- How groups of people implement cognitive processes that we usually consider belonging to an individual mind?
- What are the differences of the cognitive process of a group as a whole from the cognitive process of the people in the group?
- How is an individual cognitive processed affected by participating in a group cognitive process?

Source: James Hollan, Edwin Hutchins, and David Kirsh. 2000. "Distributed cognition: toward a new foundation for human-computer interaction research." ACM Trans. Comput.-Hum. Interact. 7, 2 (June 2000), 174–196

Cognitive Ethnography

- If the structure of the society defines the cognitive architecture
  - then understanding the underlying culture has a pivotal role in determining the cognitive process
- the culture defines the cognitive process of the societies and the people living in it
- and inside the culture there are the specific environments with typical learning processes, problem solving approaches, reasoning mechanisms
- Therefore cognition crosses the boundaries of time
  - to understand cognition we need **cognitive ethnography**

Source: James Hollan, Edwin Hutchins, and David Kirsh. 2000. "Distributed cognition: toward a new foundation for human-computer interaction research." ACM Trans. Comput.-Hum. Interact. 7, 2 (June 2000), 174–196

The role of the cognitive architecture

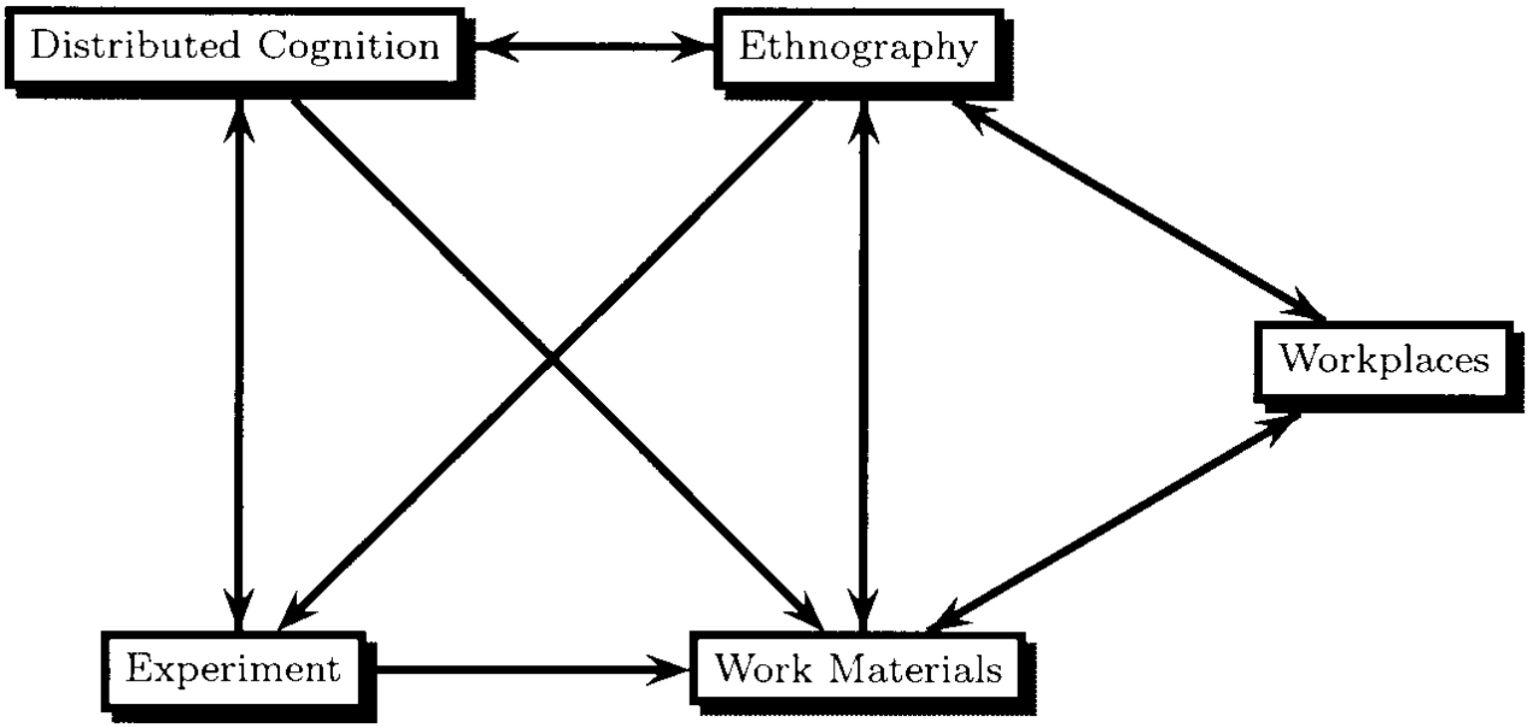
- The cognitive architecture is the root of the mind of the organization:
  - it is composed by people and tools
  - it is what differentiate different development processes
- failing to implement a development process often means failing to shape the cognitive architecture in the desired way and, consequently
  - understanding the cognitive architecture is the most effective way to enact effective development processes
- when agile methods refer to emerging structure of an organization the refer (often unknowingly) to making evident underlying cognitive architecture

Ethnography means . . .

- Experimentation is not just formal experiments
- Ethnography: understanding being inside; it depends on
  - the ability of the scientist to immerge into the reality and feel the experience but still provide a
  - reliable account of it understanding the own subjectivity

The drawing is "The Sirens and Ulysses" by William Etty (1837) taken from
https://en.wikipedia.org/wiki/File:The_Sirens_and_Ulysses_by_William_Etty,_1837.jpg

Understanding the cognitive architecture



Picture taken from James Hollan, Edwin Hutchins, and David Kirsh. 2000. "Distributed cognition: toward a new foundation for human-computer interaction research." ACM Trans. Comput.-Hum. Interact. 7, 2 (June 2000), pag. 181

Evidences of Distributed Cognition

- And of cognitive architectures:
  - The crew in a ship creating together a unique "computational" entity
  - The pilots in a plane working together and with tools
  - A group of fishermen also on different ships
- There are also multiple communication mechanisms
- This has also a strong impact on how to design HCI in computers

Source: James Hollan, Edwin Hutchins, and David Kirsh. 2000. "Distributed cognition: toward a new foundation for human-computer interaction research." ACM Trans. Comput.-Hum. Interact. 7, 2 (June 2000), 174–196

Questions?

End of lecture six.