Understanding the Implementation of System Architectures in the Context of Distributed Cognition

Paper 495

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Motivation for Study

- System Architectures attributed to System Architect(s)
- Problem Statement
  - System Architects don't understand entire architecture
  - Architecture diverges from vision of system architects
- Root Cause
  - Distributed Cognition
- Apply Systems Thinking
  - Manage Systems of Knowledge

Objective: Increase probability of success that architecture will meet needs in problem space

Distributed Cognition

- Psychological Theory
  - Thinking extends beyond the individual and is distributed among a collective group
  - Behavior of individual and group may diverge
  - Edwin Hutchins credited for work in mid-1980's
    - "Cognition in the Wild" 1995
    - Uncoordinated system of Navy ships at port

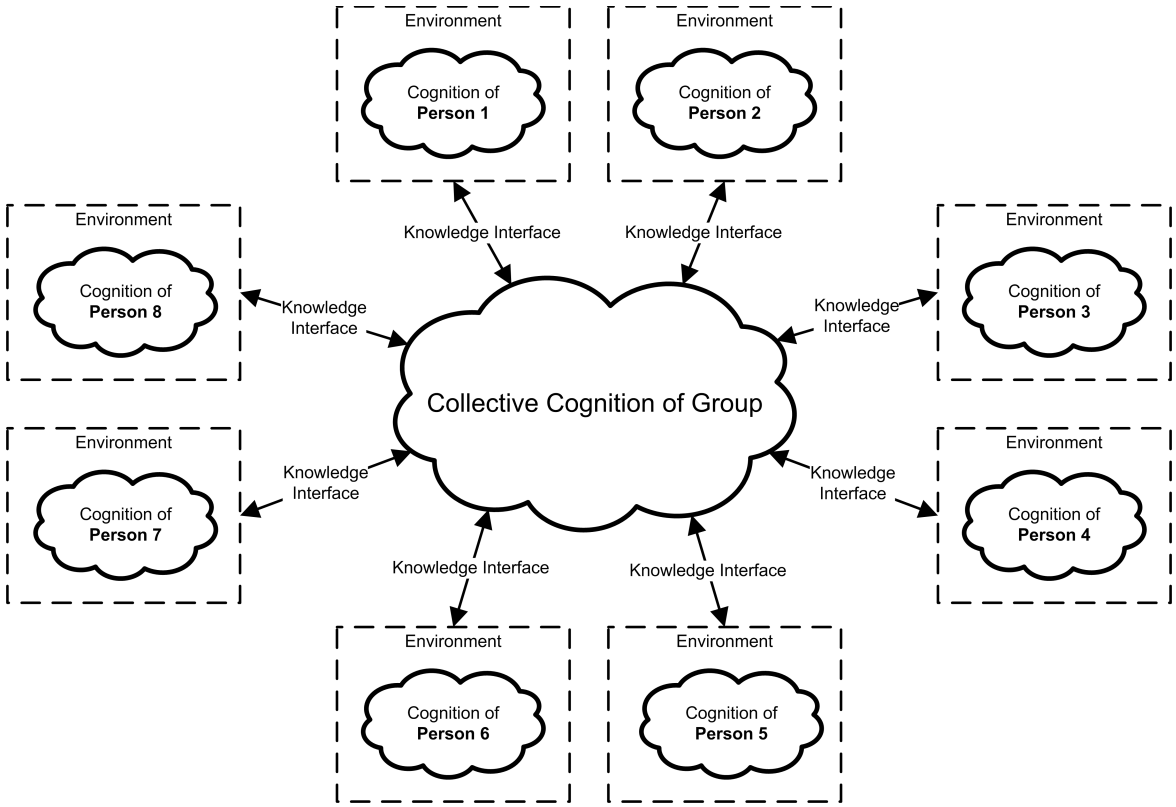
How does "Group Think" influence problem solving behaviors?

Application of Systems Thinking

- Systems of Knowledge
  - Individual's Knowledge interfaces to other knowledge in a group
  - Knowledge system interfaces defined by mental and physical artifacts

Main elements:
Individual Knowledge
Interface
Environment

2 Knowledge Systems:
Problem Space
Solution Space



Recent Study about Group Thinking (Gureckis and Goldstone 2006)

- Authors draw conclusions about conditions under which the behavior of individual agents self-organize into adaptive problem-solving group structures
- Case Studies
  - Group path formation
  - Guess a number between 0 and 100
  - “Pacman” with invisible food
- Lessons learned (aka Heuristics)
  - People are a large part of people’s environments
  - Divide and conquer: Exploration and exploitation in groups
  - More information isn’t always better
  - Influencing groups by bottom-up pressures rather than top-down rules

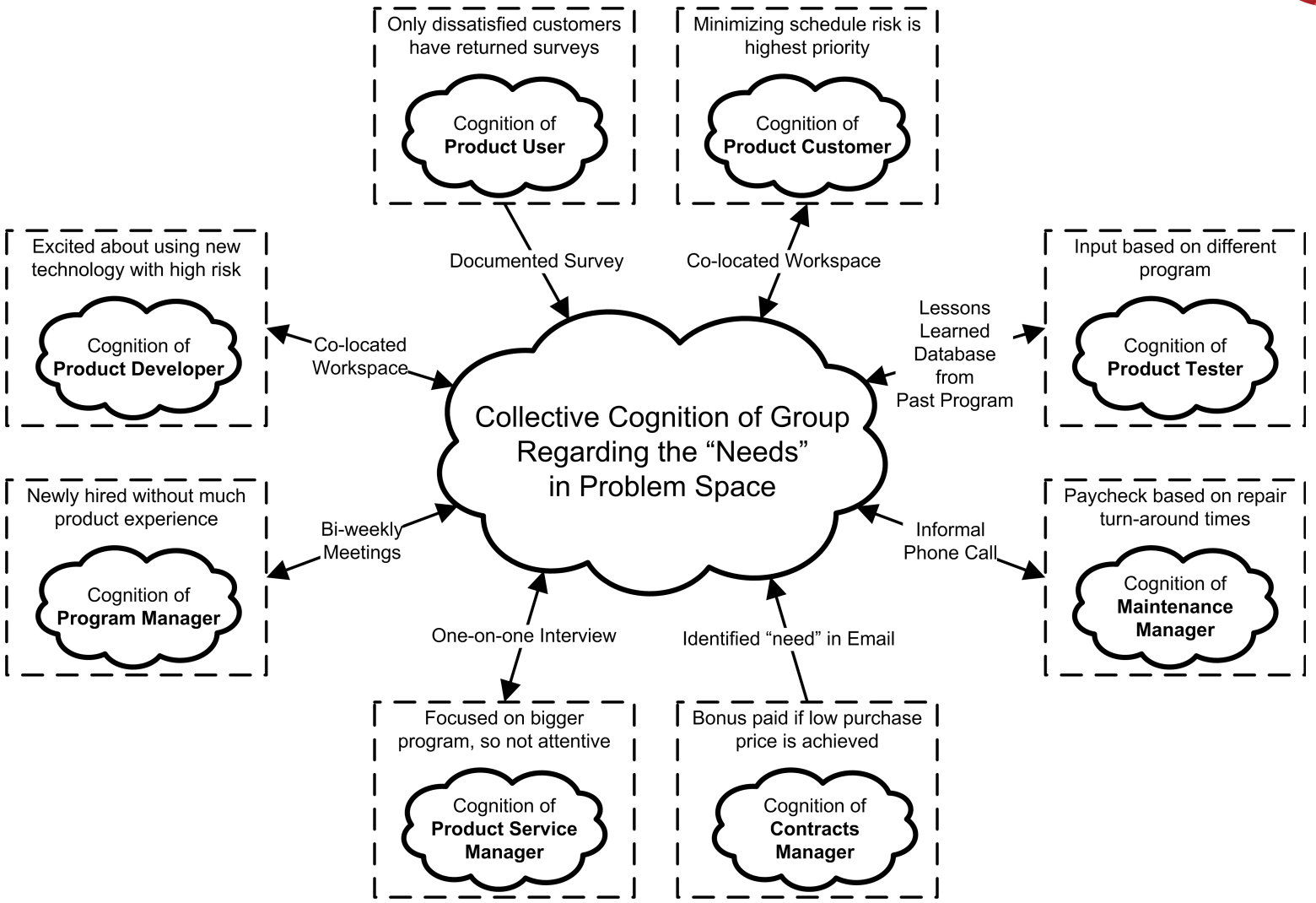
Application within Systems Engineering

- Implemented architecture is result of collective understanding of everyone that can affect architecture
- Who can affect a system architecture?
  - System Architects
  - System Designers
  - System Implementers
- Is distributed cognition beneficial or destructive?
  - Depends on how it is managed
  - Knowledge systems can be unintentional (wild) or intentional
- Requirements decomposition is not a sufficient knowledge system
- Recognizing the cost of a knowledge system
  - System costs increase proportionally to the increase in system complexity

Distributed Cognition in Problem Space

- (Saunders 2007) Biggest value in systems engineering is to sufficiently characterize the problem space
  - SCARIT process model
- (Trainor and Parnell 2007) Initial problem statement is rarely the full statement of the problem
- Distributed Cognition:
  Problem not fully understood by any single person
  - System of Knowledge

System of Knowledge: Problem Space



Example

- Proposal submitted to geographically separated, cross-cultural customer
  - RFP issued (no RFI)
  - RFP assumed to fully document problem space
  - Virtually no communication about RFP
  - Proposal Rejected
- Proposal submitted to co-located customer
  - Recognized that neither supplier, nor customer were fully cognizant of entire need in problem space
  - Co-wrote RFI
  - Responded to RFP
  - Proposal successfully met needs of customer

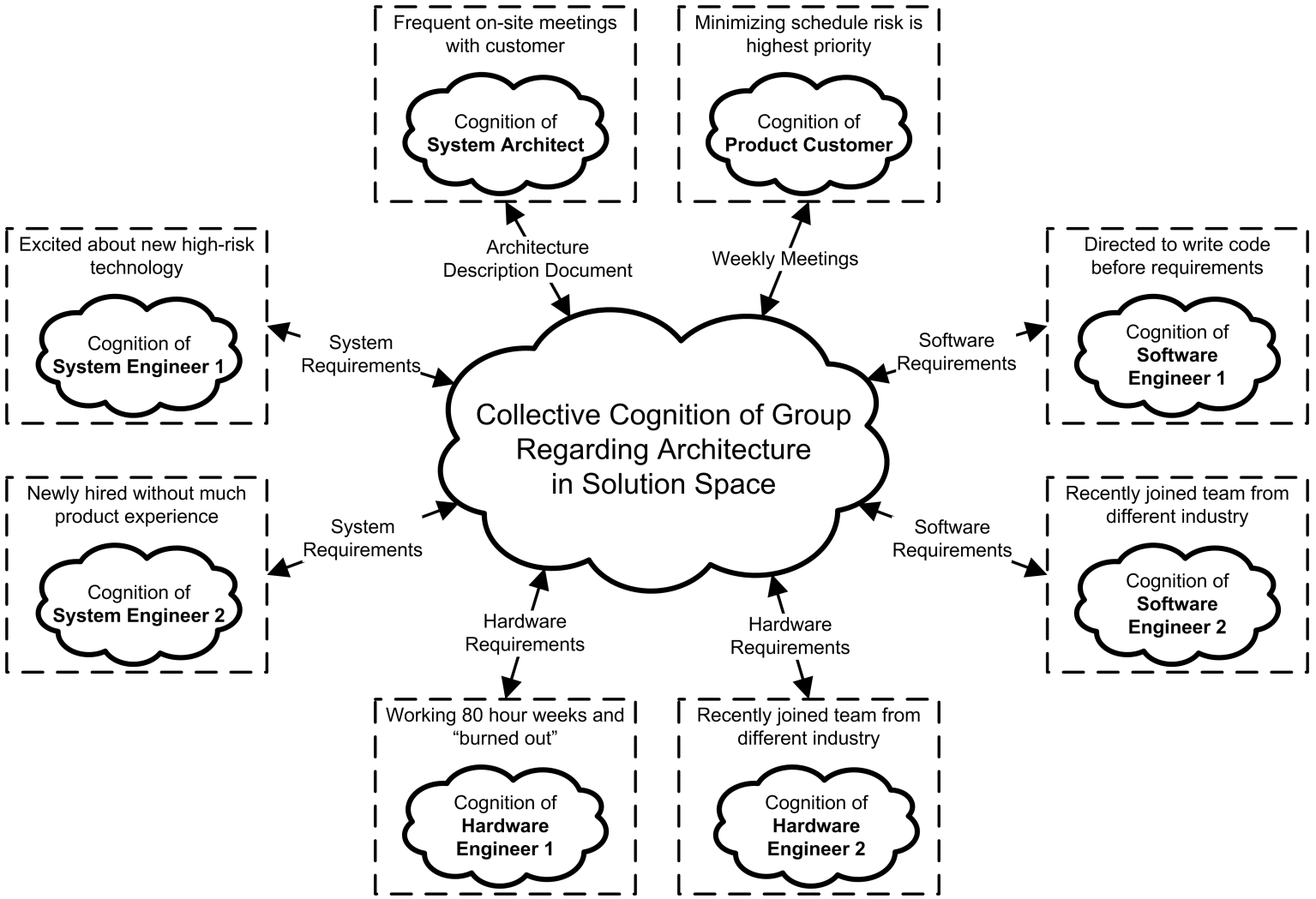
Architecting Systems in the Problem Space

- Heuristic #1: People are a large part of people's environment
  - Shared environment for stakeholders fosters better understanding
- Heuristic #2: People divide and conquer. As a group they explore the unknown while exploiting the known.
  - Shared environment for stakeholders fosters additional contributions
- Heuristic #3: More information isn't always better
  - Drowning stakeholders in information will give false sense that problem space is already fully explored and can lead to less contributions
- Heuristic #4: Groups are best influenced by bottom-up pressures rather than top-down rules
  - Personal benefit of solving problem should be clearly defined for each stakeholder up-front so that they are motivated to contribute
- Heuristic #5: System cost increases proportionally to the increase in system complexity
  - Interface with minimum number of people from each stakeholder group as necessary to capture stakeholder needs

Distributed Cognition in Solution Space

- Important to manage knowledge system in the solution space
- (Dagli, Miller and Abbott 2007) Practical techniques for managing knowledge interfaces in a geographically separated development environment
  - Two-way video over internet
  - Shared information databases
  - Affect positive group behaviors through joint venture business model

Distributed Cognition in Solution Space



Example

- Toyota's "Big Room" concept
  - Leverages communication interfaces
  - Closed offices and cubicles replaced with large open spaces
  - Team leaders located in center of the room
  - Outer wall hosts visuals that support development process

Toyota's development process is **4x shorter** than typical North American Company (Cleveland 2006)

Architecting Systems in the Solution Space

- Heuristic #1: People are a large part of people's environment
  - Share working environment with development team
- Heuristic #2: People divide and conquer. As a group they explore the unknown while exploiting the known.
  - Don't separate teams in the same sub-solution space
  - Avoid work duplication by communicating what people are working on between teams of sub-solution spaces
- Heuristic #3: More information isn't always better
  - Architects should not stifle creativity by micro-managing implementation team
  - Recognize that implementation team can positively affect architecture
- Heuristic #4: Groups are best influenced by bottom-up pressures rather than top-down rules
  - Evaluate individual/team performance based on how their dependent's are able to use their work product
- Heuristic #5: System cost increases proportionally to the increase in system complexity
  - Minimize complexity of the knowledge system by minimizing the number of people required to implement the architecture

Conclusions:
Don't Neglect Your Knowledge Systems

- Document knowledge systems along with architecture
  - Problem Space Knowledge System validates that problem space was thoroughly searched
  - Solution Space Knowledge System used to manage and explain architecture development in solution space
    - Example: 80-hour work weeks
- Document changes to knowledge systems throughout project lifecycle
  - Helps explains why changes are made to systems during development
  - Identify (and agree) if change was positive or negative
  - Identify (and agree) if change should be repeated in future projects based on same architecture

Knowledge Systems: How to Get Started

- Heuristic #6: It is better to design how a system will fail as opposed to invent how it will perform or operate. (David Stanislaw, FAA DER)
  - Identify failure conditions before designing a knowledge system
  - Knowledge System design should address how it will work in midst of failure
    - We don't live in a utopia
    - Be prepared for high risk failures

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Don’t Neglect Your

Knowledge Systems