Building a Theory of Coordination: Why and How

Jim Herbsleb
Agenda

• Bell Labs Collaboratory
  • Management reactions
• The need for science
• What kind of science do we need?
  • Human science of software engineering
• The way forward
  • Barriers
  • Next steps
Executive VP:

Don’t study the problem! Just solve it!
Problems Uncovered

• Issue resolution paralysis, delay
• Very difficult to stay “in the loop”
  • constantly surprised
• Misalignment
  • undiscovered, conflicting assumptions
• Nonexistent or impaired social networks
  • loss of critical problem-solving mechanism
• Ineffective collaborative sessions
  • “What was decided?”
Problems Uncovered

• Issue resolution paralysis delayed

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• Ineffective collaborative sessions
  • “What was decided?”

Result: Delay
Work split across sites took *much* longer
Communication and Coordination

Coordination Capacity

Gap

Within site

Across sites

Frequent and unplanned contact
Knowing who to contact about what
Easy to initiate contact
Effective communication
Trust

Research VP:

This is a waste of time! Don’t work on this – this project counts for nothing on your performance review.
MR Interval
Distance Requires More People?

• MR is assigned to “owner” who recruits others
• Finding the right expert
  • Search time
  • If mistaken, reassignment and delay
• Trust and familiarity: Can MR owner get “right person” to do the work?
  • Slow to respond
  • Refuses or gives very low priority
Bridging the Gap

Coordination Capacity

De-Couple the work

Within site

Needed

Across sites

Across sites
Organizational Models

Bridging the Gap

Coordination Capacity

Within site

De-Couple the work

Needed across sites

Increase communication opportunities and effectiveness

Actual across sites

Across sites

ConnectIcon

- Antidote for phone tag
- Send presence and contact ability to anyone
ConnectIcon from Ann Kelly:

We need to talk about the review next Thursday!

- specification document for review
- Ann Kelly’s calendar
- call Kelly now
- send Ann Kelly an instant message

Right now, here’s what Ann is doing:

- Device: Currently in use
  - 23 hours ago
- Device: Most recent use
  - 10 minutes ago
  - 26 hours ago
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**Busy**
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Bell Labs Executive Team:

• This is a breakthrough project! You have the attention of the President of Bell Labs.

• We are assigning development teams to productize these technologies.

• Tell us what resources you need!
DotCom Bubble . . .

New Products

Research Team

Global Development Solutions

Empirical Studies

Models of Development
How to distribute work across global sites.

Tools
- TeamPortal
- Rear View Mirror
- CalendarBot
- Experience Browser

Best Practices
- Planning Travel
- Establishing Liaisons
- Building Trust
- Communication Etiquette
- Preventing Delay
- Using Commercial Tools

Research Team

New Products

Global Development Solutions

Empirical Studies

Nuremberg
Naperville
Swindon
Malmesbury
Chippenham

Brussels
Paris
Columbus
Bangalore
Hilversum
Huizen
DotCom Bubble . . .

• Stock price: $80/share → $0.50/share

• Employees: 150,000 → 35,000

• Oops!
What does this have to do with engineering?

- Identified specific problems
- Crafted tools and practices to address them
- All very ad hoc, not like other, more mature forms of engineering
What Is Engineering?

- Creating cost-effective solutions
  - Engineering is not just about solving problems; it is about solving problems with economical use of all resources.
- to practical problems
  - Engineering deals with practical problems whose solutions matter to people outside the engineering domain—the customers.
- by applying scientific knowledge
  - Engineering solves problems in a particular way: by applying science, mathematics, and design analysis.
- to building things
  - Engineering emphasizes the solutions, which are usually tangible artifacts.
- in the service of mankind.
  - Engineering not only serves the immediate customer, but it also develops technology and expertise that will support the society.

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We Need a Science

• But what science do we need?
Many Engineering Challenges Are about Physical Components

- Strength of structural members
- Power consumption and output of a motor
- Power storage
- Sensitivity of sensors
- Etc., etc.

**The science they need:** properties of physical and electronic components and compositions
We Need a Science

• But what science do we need?
• A science of humans as designers and builders
Mental/Social Equipment: Evolution

- Adapted to hunter/gatherer way of life
  - Mental and physical capabilities
  - Evolution is a slow process
  - We did not change much in last 12,000 years (since the agricultural revolution*)
- We need to use mental equipment suited to simple hunter/gatherer life to design and build software

Example Cognitive Modules

• Acquiring natural language
  • Chomsky: our brain has a built-in language acquisition device (LAD)

• Visually interpreting 3D space
  • The best terrain modeling and autopilot programs are not there yet

• “Theory of mind”
  • Cognitive module that interprets and predicts behavior of others based on inferred beliefs and desires*

What Is the Problem?

- Our most severe problems and limitations do not arise from physical components
- We need computer science, obviously, but:
- Most limitations come from our own limited capacities
  - What can we understand?
  - What languages, abstractions, algorithms, and data structures can we dream up?
  - What are our cognitive and communication limitations and how can we compensate for them?
  - How can we act together in a coordinated way?
Three Examples

- Transactive memory systems
- Gatekeepers and social networks
- Socio-technical theory of coordination
Transactive Memory Systems (TMS)

- Group level phenomenon
- Arises naturally
- Specialization + index
  - People take responsibility for group knowledge and memory in some area
  - Everyone shares an index of “who knows what”
  - Origins in people watching each other work
- Very powerful impacts on how well groups function
TMS: Benefits and Conditions

- Specialization gives better performance
- Better coordination, agree on responsibilities
- Facilitates adaptation to new situations or tasks
- Facilitates creativity
- Develops under right conditions
  - Observe each other working
  - Communication

Gatekeepers and Social Networks

- Small number of trusted people become information hubs
- Connected to information sources inside and outside organization
- People go to them with questions
- They form their own network, know each other’s expertise

Core-Periphery Topology

Core Membership and Productivity

Performance Level:
- Highest
- High
- Average
- Low
- Lowest
The Point . . .

- When people organize, under the right conditions they spontaneously form
  - Transactive memory systems
  - Gatekeeper networks
- Why this matters
  - Working with them provides powerful capability
  - Working against them will be difficult
Example: GitHub

• Why so successful?
• Provides means for humans to form and use social capabilities
  • TMS: activity traces, profiles, consistent across repositories
  • Gatekeeper networks: Watching, starring, following, curating, “asynchronous mentoring”
Socio-Technical Coordination

Technical coordination is a Constraint satisfaction problem (CSP) over decisions

Decisions distributed over people (DCSP)

Social algorithm to solve DCSP


Social Algorithms

- Can take advantage or fail to take advantage of powerful capabilities
- Can be derailed by people using capabilities mismatched to task
- We need a much sharper picture of these capabilities and how software tasks map onto them
The Science We Need

- Psychology, sociology, etc. are a starting point
- Only moderately useful by themselves
  - Stretched by complexity of environment and task
  - Stretched by rapid change
  - Stretched by capabilities of digital tools and materials: social reach, free copying, absence of geographic boundaries
- We need a socio-technical perspective to create our own behavioral science!
- *Theory-driven studies of people using technology to collaborate on technical tasks*
Barriers to Human Science

- The universal principle of interdisciplinary contempt
  - Intellectual worth is evaluated on a single dimension from math to BS
- DPHB* principle: everything I don’t understand is simple
  - Behavioral science is fuzzy and just common sense
- Culture does not always appreciate behavioral theory
  - Theory seen as mere decoration and distraction on top of statistical model
  - Statistics used to test relations between theoretical constructs
  - Not just associations among variables
- Border defense, antibodies
  - Is that really computer science?
- Necessity to argue for practical application of each result

*Dilbert’s pointy-haired boss
The demand for immediate relevance rather than overall contribution... a hypothetical rejection letter:

Drs. Watson and Crick:

I regret to inform you that we are unable to accept your paper.

I personally find it very interesting that the DNA molecule has the shape of a double helix held together by paired bases. But the reviewers felt that you have not demonstrated any practical application for this discovery, so it was decided that the contribution was insufficient.
Next Steps Toward a Behavioral Science of Software Engineering

• Work toward a community
• Workshops
• Collect readings
• Develop course/curriculum
• Special issue
A few readings I have found useful