Collaborative Creation of Engineering Artifacts by Geographically-Distributed Teams

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Background and Research Scope

- Engineering projects are frequently performed across geographically-distributed locations
- It is assumed that distributed collaboration tools/services for geographically distributed people are adequate for engineering projects
- Our research tested the validity of this hypothesis
- We focused on the development of software-intensive systems typically found in aerospace and energy industries.

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Bottom Line Up Front

- We discovered important limitations in electronic collaboration infrastructures for geographically-distributed collaborative development.
- We found that for large-scale complex systems development such infrastructures are
  - ***effective*** for geographically-distributed ***review*** of engineering artifacts
  - ***not effective*** for geographically-distributed ***creation*** of engineering artifacts

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Motivation

- Large-scale engineering projects often result in schedule- and cost-overruns, while also failing to meet system/product requirements
  - ***question:*** does geographic distribution of participants contribute to such failures
- Successful collaboration requires members of an engineering project to be ***aligned***
- The psychological literature clearly shows that most face-to-face communication tends to be ***non-verbal***
  - facial expressions, body language.
- Most non-verbal cues are lost when people communicate through an information-technology collaboration infrastructure.
- Are the IT infrastructure adequate to achieve alignment within distributed teams?

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Alignment

- Team members are motivated by the purposes of the project, are willing to take actions and make efforts that allow the project to succeed, and are occasionally willing to accept less than they desire in order to reach compromises with the other stakeholders
- Team members understand and agree with the ***goals*** for the project, and understand and concur with project ***constraints*** and ***limitations*** (e.g., schedule, cost, capabilities)
- Team members understand and agree with the *approach* (i.e., methods, tools, locations, facilities, key personnel, sequencing of steps, design)
- Team members are willing to work together to reach reasonable compromises on important issues
- Team members are committed to “keeping the project sold,” and see it through to a successful conclusion

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Experiments and Methods

- We conducted research on geographically-distributed engineering teams, using ***instrumented engineering sessions***
  - A real engineering team, assembled in a single location, worked on real engineering problems with working sessions instrumented, recorded, and monitored by trained observers.
  - Focus was on how engineering analysis was conducted, depth and merit of analyses, how consensus was reached, strength of consensus, how design decisions were made, and eventual merit of those design decisions.
  - The same team was then geographically distributed, assigned different engineering problems and same information was collected.
  - In both single-location and geographically-distributed locations, problems undertaken by the team included both the ***creation*** and ***review*** of engineering artifacts.
  - In both the single-location and geographically-distributed locations, actual company and government security / data-protection rules were applied.
- We also assessed the quality of engineering artifacts from actual, completed projects

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Findings

- Results of experiments clearly indicated that engineering ***creation*** and ***review*** tasks placed different burdens on coordination and communication
  - burdens imposed by the ***artifact creation*** tasks was far greater than that imposed by ***artifact review*** tasks.
- Other findings include:
  - Current methods of electronic coordination and communication (e.g., email, phone, speaker phone, video conference, sharable file repositories, etc.) were ***not*** adequate to achieve ***alignment*** among members of the engineering team.
  - For aligned teams, current methods of electronic coordination and communication appear to be ***adequate*** for geographically-distributed ***review*** of engineering artifacts.
  - Even with alignment of team members over a period of co-location, these same methods of electronic coordination and communications appear ***inadequate*** to support the geographically-distributed ***creation*** of those same engineering artifacts.
  - ***Designs resulting from the geographically-distributed creation activities were deemed to be critically weaker than those created by the single-site teams.***

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Analysis and Discussion

- Our experiments showed that today's electronic collaboration infrastructure products are capable of supporting geographically-distributed ***review*** of engineering artifacts
- They also showed that these products are inadequate and ineffective when supporting geographically-distributed ***creation*** of engineering artifacts.
- This finding appears to explain in part the poor track record of large-scale engineering development programs and projects.

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First Insight

Humans have evolved to see both context and detail at the same time; we can use the entire 15,000,000- to 20,000,000- pixel frame human vision to do this, and rapidly (in periods measured in fractions of a second) move our focus of attention from one location to another. No existing electronic collaboration infrastructure supports this vital capability across distributed locations. Directional hearing also appears also to be a vital portion of this human capability, yet is seldom supported at all (much less supported effectively) by electronic collaboration infrastructures.

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Second Insight

Electronic collaboration infrastructures generally omit all of the non-verbal communications modes, even though (as cited above) these comprise the majority of human-to-human information exchange. Who is paying attention? Who seems to disagree? These appear to be vital aspects of creation and the forming of consensus.

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Third Insight

During creation, we found that people are very susceptible to losing their train of thought due to distractions. We found that the need to operate computer programs, even simple typing, frequently caused such a loss of the train of thought. The electronic tools cannot operate as fast, or with as little disruption to thought, as drawing on a white board or on a piece of paper. We need – but do not have – electronic tools that can "operate at the speed of thought".

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Second Study:
Survey Instrument

- Collaboration with USC Business School on distributed engineering teams
- A formal survey instrument was used in this study
- Approximately 1,000 responses were received.
- The survey provided key insight into organizational practices
  - Commercially available tools in use include speaker phones, shared data repositories, and group-document editing (e.g., Google docs)
  - They supplement remote collaboration with physical travel, but generally fail to distinguish between those willing to travel, and those ideally suited to travel.
  - They acknowledge that today's tools slow down project progress and increase project costs, relative to performing project at a single geographic location.
  - They still undertake geographically-distributed projects for business reasons
  - They use available distributed collaboration tools in lieu of co-location or travel because customers and management expect them to
  - They have firm ideas about exactly where existing collaboration infrastructure/tools and methods fall short

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Deficiencies in Collaboration Infrastructure and Tools

- Participants had clear ideas on where existing collaboration infrastructure tools and methods fell short:
  - They believed they were *slowed down* by the tools
  - They felt they were unable to deal with *complicated concepts* using these tools
  - They could not tell *who was paying attention* to the discussion, and who was not
  - *They could not confirm consensus* ("couldn't see the head-nods")

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Main Conclusions and Findings

- Geographically-distributed engineering teams were quite prevalent in the sampled industries and companies.
- Geographically-distributed engineering projects were considered more difficult, slower, more expensive, and with a lower success rate than co-located engineering projects.
- There was little variation across companies and industries in the types of tools and methods that were used to implement distributed collaboration infrastructures
  - they all used electronic mail, audio and video teleconferencing, group on-line editing, sharable file repositories
- Key finding
  - Distributed collaboration infrastructure was effective for artifact **review**, but not for artifact **creation**

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Potential Enhancements

- See context and details at the same time
- Enable rapid and effortless shift in focus of attention from one location to another
- Support all human senses, including directional sound
- Support non-verbal modes of human-to-human communications: head-nods, body language, indicators of paying attention (or not!) - even the most sophisticated video teleconferencing systems available to-date have proven grossly inadequate.
- Record and annotate work-in-progress "almost at the speed of thought"

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Promising Research Directions

- Context-aware Collaboration
- Process-Driven Collaboration
- Dynamic Context Management.
- Complexity Reduction
- Multi-perspective Visualization
- Interactive Model-Driven Storytelling

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Summary

- Large-scale, complex engineering projects in the aerospace, defense, and energy industries tend to be performed by geographically distributed teams
- It has been assumed that today's distributed collaboration infrastructure is adequate and, therefore, work can be accomplished with little or no physical travel between geographically-distributed work sites
- Our research suggests that this is not necessarily the case
  - Artifact review – distributed collaboration infrastructure is adequate
  - Artifact creation – distributed collaboration infrastructure is lacking
- We identified specific deficiencies that need to be overcome before distributed collaboration infrastructures become adequate for distributed artifact creation.
- We offered several promising research directions to ameliorate this problem

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