Coordination in Global Development

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Conway’s Law

- “Any organization that designs a system will inevitably produce a design whose structure is a copy of the organization's communication structure.”

Conway’s Law

Components

Teams

Software

Isomorphism

Organization

[Diagram showing relationships between components, teams, software, and organization with arrows indicating isomorphism.]
Conway’s Law

Components

Teams

Software

Organization

Homomorphism
What about the Connectors?

Components

Software

Teams

Organization
Architectural Decisions + Task Assignment → Required Coordination

What kind of coordination is required?
Research Program

Empirical Studies
• Behavior of coordination requirements
• Effects of congruence
• Closely-coupled work

Theory Development
• Constraint networks
• Network properties
• Game theory

Applications
• Tools – Tesseract, eMoose
• Tactics -- Distributability
Measuring Coordination Requirements ($C_R$)

**Concept**

<table>
<thead>
<tr>
<th>Task Assignments ($A$)</th>
<th>Task Dependencies ($D$)</th>
<th>Coordination Requirements ($C_R$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\begin{bmatrix} a_{11} &amp; \cdots &amp; a_{1k} \ a_{n1} &amp; \cdots &amp; a_{nk} \end{bmatrix}$</td>
<td>$\begin{bmatrix} d_{11} &amp; \cdots &amp; d_{1k} \ d_{k1} &amp; \cdots &amp; d_{kk} \end{bmatrix}$</td>
<td>$\begin{bmatrix} a_{11} &amp; \cdots &amp; a_{1n} \ a_{k1} &amp; \cdots &amp; a_{kn} \end{bmatrix}$</td>
</tr>
<tr>
<td>Developer modified files</td>
<td>Files changed together</td>
<td>Transpose of developer modified files</td>
</tr>
</tbody>
</table>

**Data**

Who needs to coordinate with whom

---

Socio-Technical Congruence and Productivity

Files changed together

Developer modified files

Transpose of developer modified files

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Volatility in Coordination Requirements

Proportion

Change in coordination group
Members of other teams

Week
Measuring Congruence

\[ \text{Coordination Requirements (C}_R\text{)} \]

\[
\begin{bmatrix}
cr_{11} & \ldots \\
cr_{1n} \\
cr_{n1} & \ldots \\
cr_{nn}
\end{bmatrix}
\]

\[ \text{Actual Coordination (C}_A\text{)} \]

\[
\begin{bmatrix}
cia_{11} & \ldots \\
cia_{1n} \\
cia_{n1} & \ldots \\
cia_{nn}
\end{bmatrix}
\]

- Team structure
- Geographic location
- Use of chat
- On-line discussion

\[ \text{Diff (C}_R\text{, C}_A\text{)} = \text{card } \{ \text{diff}_ij | cr_{ij} > 0 \& ca_{ij} > 0 \} \]

\[ \text{Congruence (C}_R\text{, C}_A\text{)} = \text{Diff (C}_R\text{, C}_A\text{)} / |C}_R| \]
## Results

Table 2: Results from OLS Regression of Effects on Task Performance (\( \dagger p < 0.10, * p < 0.05, ** p < 0.01 \)).

<table>
<thead>
<tr>
<th></th>
<th>Model I</th>
<th>Model II</th>
<th>Model III</th>
<th>Model IV</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>(Intercept)</strong></td>
<td>2.987***</td>
<td>3.631***</td>
<td>1.572*</td>
<td>1.751*</td>
</tr>
<tr>
<td><strong>Dependency</strong></td>
<td>0.897*</td>
<td>0.653*</td>
<td>0.784*</td>
<td>0.712*</td>
</tr>
<tr>
<td><strong>Priority</strong></td>
<td>-0.741*</td>
<td>-0.681*</td>
<td>-0.702*</td>
<td>-0.712*</td>
</tr>
<tr>
<td><strong>Re-assignment</strong></td>
<td>0.423*</td>
<td>0.487*</td>
<td>0.304*</td>
<td>0.324*</td>
</tr>
<tr>
<td><strong>Customer MR</strong></td>
<td>-0.730</td>
<td>-0.821</td>
<td>-0.932</td>
<td>-0.903</td>
</tr>
<tr>
<td><strong>Release</strong></td>
<td>-0.154*</td>
<td>-0.137*</td>
<td>-0.109*</td>
<td>-0.098*</td>
</tr>
<tr>
<td><strong>Change Size (log)</strong></td>
<td>1.542*</td>
<td>1.591*</td>
<td>1.428*</td>
<td>1.692*</td>
</tr>
<tr>
<td><strong>Team Load</strong></td>
<td>0.307*</td>
<td>0.317*</td>
<td>0.356*</td>
<td>0.374*</td>
</tr>
<tr>
<td><strong>Programming Experience</strong></td>
<td>-0.062*</td>
<td>-0.162*</td>
<td>-0.117*</td>
<td>-0.103*</td>
</tr>
<tr>
<td><strong>Tenure</strong></td>
<td>-0.269*</td>
<td>-0.265*</td>
<td>-0.239*</td>
<td>-0.248*</td>
</tr>
<tr>
<td><strong>Component Experience (log)</strong></td>
<td>-0.143*</td>
<td>-0.143*</td>
<td>-0.195*</td>
<td>-0.213*</td>
</tr>
<tr>
<td><strong>Structural Congruence</strong></td>
<td>\textit{-0.526*}</td>
<td>\textit{-0.483*}</td>
<td>\textit{-0.317*}</td>
<td>\textit{-0.312*}</td>
</tr>
<tr>
<td><strong>Geographical Congruence</strong></td>
<td>\textit{-0.189*}</td>
<td>\textit{-0.196*}</td>
<td>\textit{-0.129*}</td>
<td>--</td>
</tr>
<tr>
<td><strong>MR Congruence</strong></td>
<td>\textit{-0.189*}</td>
<td>\textit{-0.196*}</td>
<td>\textit{-0.129*}</td>
<td>--</td>
</tr>
<tr>
<td><strong>IRC Congruence</strong></td>
<td>\textit{-0.013}</td>
<td>\textit{-0.017}</td>
<td>\textit{-0.011*}</td>
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</tr>
<tr>
<td><strong>Interaction: ReleaseX Structural Congruence</strong></td>
<td>\textit{0.007}</td>
<td>\textit{0.009}</td>
<td>809</td>
<td>809</td>
</tr>
<tr>
<td><strong>Interaction: ReleaseX Geographical Congruence</strong></td>
<td>\textit{-0.009*}</td>
<td>\textit{-0.017}</td>
<td>1983</td>
<td>1983</td>
</tr>
<tr>
<td><strong>Interaction: Release X MR Congruence</strong></td>
<td>\textit{-0.017*}</td>
<td>\textit{-0.017}</td>
<td>\textit{0.787}</td>
<td>\textit{0.756}</td>
</tr>
<tr>
<td><strong>Interaction: Release X IRC Congruence</strong></td>
<td>--</td>
<td>--</td>
<td>\textit{0.854}</td>
<td>\textit{0.872}</td>
</tr>
</tbody>
</table>

N 809 809 1983 1983
Adjusted R\(^2\) 0.787 0.872 0.756 0.854
Effects of Congruence

- Time to complete a work item is reduced by *each* of the types of congruence
  - Team structure congruence
  - Geographic location congruence
  - Chat congruence
  - On-line discussion congruence
Average Level of Congruence for Top 18 Contributors

![Graph showing the average level of congruence for top 18 contributors across different releases. The graph includes lines for IRC, MR, Structure, and Geography, with data points indicating trends over time.](image-url)
Average Level of Congruence for the Other 94 Developers

- IRC
- MR
- Structure
- Geography

Legend:
- IRC
- MR
- Structure
- Geography

Graph:
- X-axis: Releases (1 to 4)
- Y-axis: Congruence (avg.)

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Research Program

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• Effects of congruence
• Closely-coupled work

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Theoretical Views of Coordination

- Coordination theory (Malone & Crowston)
  - Match coordination problems to mechanisms
  - E.g., resource conflict and scheduling

- Distributed Cognition (Hutchins, Hollan)
  - Computational process distributed over artifacts and people

- Distributed AI (Durfee, Lesser)
  - Partial global planning
  - Communication regimens

- Organizational behavior
  - Stylized dependency types, e.g., sequential, pooled
  - Coordination regimens that address each type
Three Propositions

- P1: Artifact design is a process of making decisions, and these decisions are linked by constraints in a potentially large and complex network (which we call the “constraint network”).
- P2: The need for coordination among individuals and teams arises from the constraints on the decisions they are making.
- P3: What we call task coupling between individuals and between teams is simply the result of the properties of the constraint network and the assignment of decisions to people.
Google Lunar X Prize
Observed Constraint Networks

- Lander leg design
  - Crushable
  - Foldable
  - Collapsing
  - Pin release

- Rover clearance
  - value between 2 and 8 inches

Key:
- Design decision
- Constraint
- Constrained by

Power
Mass
Shock
Egress height
Properties of Constraint Networks

- **Constraint Diffusion**
  - Touches many components
  - Influences many decisions

- **Constraint Violation Detection**
  - When considering a choice, determining if it will violate a constraint

- **Decision Constraint Diversity**
  - Decision is influenced by many different types of constraints
Example:
**Total Mass**

- High diffusion
- Easy violation detection

![Diagram showing Total Mass connected to Components 1 to n]
Example:

**Sidearm Design**

- Low constraint diffusion
- Difficult violation detection
Example:

**Antenna Cable**

- High decision constraint diversity
Constraint Network Analysis

- **Goal**
  - Understand how constraint network properties generate detailed coordination requirements
  - Lead to novel ways to support distributed work

- **Current activities**
  - Aggregate constraint networks
  - Observe evolution over time
  - See how network properties influence speed and errors
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### Project

- gnome/rhythmbox

**DoubleClick node to drill down upon all selected.**

### Files

<table>
<thead>
<tr>
<th>File name</th>
</tr>
</thead>
<tbody>
<tr>
<td>data/node-views/rb-node-view-radio.</td>
</tr>
<tr>
<td>data/node-views/rb-node-view-song.</td>
</tr>
<tr>
<td>data/node-views/rb-node-view-art.</td>
</tr>
<tr>
<td>po/ml.po</td>
</tr>
<tr>
<td>data/glade/buffering-dialog.glade</td>
</tr>
<tr>
<td>data/ui/Makefile.am</td>
</tr>
<tr>
<td>data/node-views/rb-node-view-auth.</td>
</tr>
</tbody>
</table>

### Developers

<table>
<thead>
<tr>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jose Osteen</td>
</tr>
<tr>
<td>Vivian Johns</td>
</tr>
<tr>
<td>Earl Haber</td>
</tr>
<tr>
<td>Katrina Bolt</td>
</tr>
<tr>
<td>Joshua Boughton</td>
</tr>
<tr>
<td>Veilma Morehead</td>
</tr>
<tr>
<td>Marvin Montelongo</td>
</tr>
<tr>
<td>Sandra Wakefield</td>
</tr>
</tbody>
</table>

### Issues

<table>
<thead>
<tr>
<th>Bug</th>
<th>Start</th>
<th>End</th>
<th>Severity</th>
<th>Priority</th>
<th>Status</th>
<th>Resolution</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>7641</td>
<td>2003-08-25</td>
<td>2004-12-21</td>
<td>trivial</td>
<td>Normal</td>
<td>RESOLVED</td>
<td>FIXED</td>
<td>Minor language fixes</td>
</tr>
<tr>
<td>7793</td>
<td>2003-09-17</td>
<td>2004-12-21</td>
<td>normal</td>
<td>Normal</td>
<td>RESOLVED</td>
<td>FIXED</td>
<td>Error on track end</td>
</tr>
<tr>
<td>7794</td>
<td>2003-09-17</td>
<td>2004-12-21</td>
<td>critical</td>
<td>Normal</td>
<td>CLOSED</td>
<td>INCOMPLETE</td>
<td>Rhythmbox crashes with</td>
</tr>
</tbody>
</table>
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