Performance Evaluation of Software Development Teams: a Practical Case Study

*Int. Workshop on Practical Applications of Stochastic Modelling (PASM’11)*

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Globally distributed projects

- dispersed multiple sites (borders and time zones)
- difficulties distributing resources (availability, expertise, and support)
- techniques to measure team’s performance indices

Why use analytical modeling in this context?

It allows to estimate project duration (or a given phase duration) considering heterogeneous participants and conditions/average costs for performing selected activities.
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- difficulties distributing resources (availability, expertise, and support)
- techniques to measure team’s performance indices

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Analytical Modeling in GSD projects

Target: geographically distributed projects
- practical case study for a project in a world wide IT company
- key factors in GSD: communication and coordination
- analytical modeling of participants activities and interactions

Tool: high-level modeling formalism
- Stochastic Automata Networks (SAN) [Plateau’85]
- modular representation (states, transitions, events)
- suitable for modeling independent entities with synchronizing activities
- numerical solution using GTAexpress software package [QEST’09]
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- key factors in GSD: **communication** and **coordination**
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Analytical Modeling in GSD projects

Case study: Project ALPHA

- Globally distributed project: USA, India, Brasil and Malaysia
- Participants coordinated by a central team (project and delivery managers)
- Different participants roles (developers, testers, QA managers, ...) compose each team (both junior and senior expertises)

Project ALPHA execution phase - quantitative data

Execution phase: when the application components are created and tested based on the development plans

- Phase duration: 11 months × 22 workdays = 242 days
- Estimated effort: 3,364.35 hours
- Actual hours: 3,317.22 hours
- Impediments hours: 332 hours
## Participants configuration

(2 partic. on central team plus 14 distributed participants)

<table>
<thead>
<tr>
<th>Qty.</th>
<th>Role</th>
<th>Expertise</th>
<th>Site</th>
<th>Allocation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Delivery Manager</td>
<td>Senior</td>
<td>USA</td>
<td>25%</td>
</tr>
<tr>
<td>1</td>
<td>Project Manager</td>
<td>Senior</td>
<td>Brazil</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Developer</td>
<td>Senior</td>
<td>Brazil</td>
<td>100%</td>
</tr>
<tr>
<td>3</td>
<td>Developer</td>
<td>Junior</td>
<td>Brazil</td>
<td>75%</td>
</tr>
<tr>
<td>1</td>
<td>Tester</td>
<td>Senior</td>
<td>Brazil</td>
<td>20%</td>
</tr>
<tr>
<td>2</td>
<td>Business Analyst</td>
<td>Senior</td>
<td>USA</td>
<td>10%</td>
</tr>
<tr>
<td>1</td>
<td>Data Warehouse Eng.</td>
<td>Junior</td>
<td>USA</td>
<td>3%</td>
</tr>
<tr>
<td>3</td>
<td>User</td>
<td>Senior</td>
<td>USA</td>
<td>3%</td>
</tr>
<tr>
<td>1</td>
<td>System Eng.</td>
<td>Junior</td>
<td>Malaysia</td>
<td>5%</td>
</tr>
<tr>
<td>1</td>
<td>Database Admin.</td>
<td>Senior</td>
<td>India</td>
<td>5%</td>
</tr>
<tr>
<td>1</td>
<td>Data Warehouse Eng.</td>
<td>Senior</td>
<td>India</td>
<td>3%</td>
</tr>
</tbody>
</table>
Central team modeling with two automata

Available (A), Unavailable (U), Management (M), Collaboration (C)
Participant modeling with one automaton

**Participant**

<table>
<thead>
<tr>
<th>Type</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>loc</td>
<td>$e_i$</td>
</tr>
<tr>
<td>loc</td>
<td>$r_i$</td>
</tr>
<tr>
<td>syn</td>
<td>$co_i$</td>
</tr>
<tr>
<td>syn</td>
<td>$s_i$</td>
</tr>
</tbody>
</table>

Working (W), Seeking solution (S), Collaborating (C)
### Central Team and Participant’s events (I)

<table>
<thead>
<tr>
<th>Event</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$a$</td>
<td><strong>Available</strong>: central team becomes available to manage and collaborate with partic. <em>(2 hours <em>per</em> workday)</em></td>
</tr>
<tr>
<td>$u$</td>
<td><strong>Unavailable</strong>: central team unavailable to collaborate. <em>(6 hours <em>per</em> workday)</em></td>
</tr>
<tr>
<td>$e_i$</td>
<td><strong>Impediment</strong>: $i$-th participant goes to seek a solution. <em>(junior spend on average 1 hour actually working - <em>per</em> workday - and seniors, 7 hours)</em></td>
</tr>
</tbody>
</table>

* Average values from historical data, surveys and interviews conducted by a project manager.
<table>
<thead>
<tr>
<th>Event</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$r_i$</td>
<td><strong>Resume working</strong>: $i$-th participant resumes work after seeking the solution by him/herself. (junior, 7 hours seeking solutions; seniors, spend just 1 hour)</td>
</tr>
<tr>
<td>$c_{oi}$</td>
<td><strong>Collaborate</strong>: this event synchronizes $i$-th participant automaton with central team <em>Activities</em> automaton, starting the collaboration between them. (if the central team is available - functional rate)</td>
</tr>
<tr>
<td>$s_i$</td>
<td><strong>Provided support</strong>: synchronizes both $i$-th participant and central team <em>Activities</em> automata, indicating the participant resumes work after receiving support during the collaboration. (on average 2 hours per workday)</td>
</tr>
</tbody>
</table>

* Average values from historical data, surveys and interviews conducted by a project manager.
Instantiating the case study

**Brazil**
- Developer (senior)
  - W
  - C
  - S
  - Type: loc
  - Event: e_1
  - r_1

- Developer (junior)
  - W
  - C
  - S
  - Type: loc
  - Event: e_2
  - r_2

- Developer (junior)
  - W
  - C
  - S
  - Type: loc
  - Event: e_3
  - r_3

- Tester (senior)
  - W
  - C
  - S
  - Type: loc
  - Event: e_4
  - r_4

**Malaysia**
- System Engineer (junior)
  - W
  - C
  - S
  - Type: loc
  - Event: e_12
  - r_12

**Delivery & Project Managers**
- Availability
  - A
  - U

- Activities
  - M
  - W
  - C
  - S
  - Type: loc
  - Event: a
  - u

**India**
- Database Admin. (senior)
  - W
  - C
  - S
  - Type: loc
  - Event: r_13
  - e_13

- Data Warehouse Engineer (senior)
  - W
  - C
  - S
  - Type: loc
  - Event: r_14
  - e_14

**USA**
- Business Analyst (senior)
  - W
  - C
  - S
  - Type: loc
  - Event: e_6
  - r_6

- Business Analyst (senior)
  - W
  - C
  - S
  - Type: loc
  - Event: e_7
  - r_7

- Data Warehouse Engineer (junior)
  - W
  - C
  - S
  - Type: loc
  - Event: e_8
  - r_8

- User (senior)
  - W
  - C
  - S
  - Type: loc
  - Event: e_9
  - r_9
**Steady-State probabilities (entities)**

*model composed of 16 automata (i.e., more than 19 million states)*

<table>
<thead>
<tr>
<th>Entity</th>
<th>State</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Central Team</strong> (low availability)</td>
<td>$A$</td>
<td>25.00%</td>
</tr>
<tr>
<td></td>
<td>$U$</td>
<td>75.00%</td>
</tr>
<tr>
<td></td>
<td>$M$</td>
<td>56.27%</td>
</tr>
<tr>
<td></td>
<td>$C$</td>
<td>43.73%</td>
</tr>
<tr>
<td><strong>Seniors</strong> (low support needed)</td>
<td>$W$</td>
<td>87.09%</td>
</tr>
<tr>
<td></td>
<td>$S$</td>
<td>11.96%</td>
</tr>
<tr>
<td></td>
<td>$C$</td>
<td>0.95%</td>
</tr>
<tr>
<td><strong>Juniors</strong> (high support needed)</td>
<td>$W$</td>
<td>14.70%</td>
</tr>
<tr>
<td></td>
<td>$S$</td>
<td>78.26%</td>
</tr>
<tr>
<td></td>
<td>$C$</td>
<td>7.04%</td>
</tr>
</tbody>
</table>

* Only collaborations with CT are represented by (C)ollaboration state;  
* Collaborations among participants are implicit in (W)orking and (S)eeking states of a participant.
### Project working hours obtained from the model

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Expertise</th>
<th>Allocation (%)</th>
<th>State W (%)</th>
<th>Working hours per day</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Senior</td>
<td>100</td>
<td>87.09</td>
<td>6.97</td>
</tr>
<tr>
<td>3</td>
<td>Junior</td>
<td>75</td>
<td>14.70</td>
<td>2.65</td>
</tr>
<tr>
<td>1</td>
<td>Senior</td>
<td>20</td>
<td>87.09</td>
<td>1.39</td>
</tr>
<tr>
<td>2</td>
<td>Senior</td>
<td>10</td>
<td>87.09</td>
<td>1.39</td>
</tr>
<tr>
<td>1</td>
<td>Junior</td>
<td>3</td>
<td>14.70</td>
<td>0.04</td>
</tr>
<tr>
<td>3</td>
<td>Senior</td>
<td>3</td>
<td>87.09</td>
<td>0.63</td>
</tr>
<tr>
<td>1</td>
<td>Junior</td>
<td>5</td>
<td>14.70</td>
<td>0.06</td>
</tr>
<tr>
<td>1</td>
<td>Senior</td>
<td>5</td>
<td>87.09</td>
<td>0.35</td>
</tr>
<tr>
<td>1</td>
<td>Senior</td>
<td>3</td>
<td>87.09</td>
<td>0.21</td>
</tr>
</tbody>
</table>

**Total** 13.69

*considered a 8-hour workday per participant
*calculated total hours in the (W)orking state
### Comparative results: actual x model

#### Project ALPHA execution phase - quantitative data
- Phase duration: 11 months $\times$ 22 workdays = 242 days
- Estimated effort: **3,364.35 hours** (2% error)
- Actual hours: **3,317.22 hours**

#### Project ALPHA execution phase - model results
- **Calculated working hours** of partic. in a workday: **13.69 hours**
- **Calculated effort**: **3,312.98 hours** (0.2% error)
  
  (13.69 hours $\times$ 242 days)
<table>
<thead>
<tr>
<th>Qty.</th>
<th>Expertise</th>
<th>Allocation (%)</th>
<th>State C (%)</th>
<th>Cooperating hours per day</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Senior</td>
<td>100</td>
<td>0.95</td>
<td>0.076</td>
</tr>
<tr>
<td>3</td>
<td>Junior</td>
<td>75</td>
<td>7.04</td>
<td>1.267</td>
</tr>
<tr>
<td>1</td>
<td>Senior</td>
<td>20</td>
<td>0.95</td>
<td>0.015</td>
</tr>
<tr>
<td>2</td>
<td>Senior</td>
<td>10</td>
<td>0.95</td>
<td>0.015</td>
</tr>
<tr>
<td>1</td>
<td>Junior</td>
<td>3</td>
<td>7.04</td>
<td>0.017</td>
</tr>
<tr>
<td>3</td>
<td>Senior</td>
<td>3</td>
<td>0.95</td>
<td>0.007</td>
</tr>
<tr>
<td>1</td>
<td>Junior</td>
<td>5</td>
<td>7.04</td>
<td>0.028</td>
</tr>
<tr>
<td>1</td>
<td>Senior</td>
<td>5</td>
<td>0.95</td>
<td>0.004</td>
</tr>
<tr>
<td>1</td>
<td>Senior</td>
<td>3</td>
<td>0.95</td>
<td>0.002</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td></td>
<td><strong>1.43</strong></td>
<td></td>
</tr>
</tbody>
</table>

*considered a 8-hour workday per participant
*calculated total hours on (C)ollaboration state to solve issues with CT
Comparative results: actual x model

Project ALPHA execution phase - quantitative data

- Phase duration: 11 months × 22 workdays = 242 days
- Estimated effort: 3,364.35 hours
- Actual hours: 3,317.22 hours
- Impediments hours: **332 hours**

Project ALPHA execution phase - model results

- **Calculated collaboration hours** per workday: **1.43 hours**
- **Calculated impediment hours:** 346.06 hours (4% error)
  
  (1.43 hours × 242 days)

*relative error is probably related to the abstraction level used.*
Different scenarios configurations

Other performance analysis

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Level of availability (event $a$)</th>
<th>Level of quality of support (event $s$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>High</td>
<td>Higher</td>
</tr>
<tr>
<td>2</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>3</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>4</td>
<td>High</td>
<td>Lower</td>
</tr>
<tr>
<td>5</td>
<td>Low</td>
<td>Higher</td>
</tr>
<tr>
<td>6</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>7</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>8</td>
<td>Low</td>
<td>Lower</td>
</tr>
</tbody>
</table>

*varying parameters to predict other behaviors*
### Estimated time for executing the project

<table>
<thead>
<tr>
<th>Actual proj. exec. time</th>
<th>Scenario</th>
<th>Estim. working h per day</th>
<th>Estimated proj. exec. time</th>
</tr>
</thead>
<tbody>
<tr>
<td>3,317.22 h performed during 11 months</td>
<td>1</td>
<td>17.87 h</td>
<td>8.44 months</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>15.40 h</td>
<td>9.79 months</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>14.09 h</td>
<td>10.70 months</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>13.41 h</td>
<td>11.24 months</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>14.25 h</td>
<td>10.58 months</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>13.85 h</td>
<td>10.89 months</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>13.58 h</td>
<td>11.10 months</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>13.37 h</td>
<td>11.28 months</td>
</tr>
</tbody>
</table>

*varying parameters to predict other behaviors*
Conclusion

- theoretical modeling effort to describe a complex environment
- analytical modeling is useful to predict behaviors before implementing a project or process
- once validated models can provide new quantitative measures only changing model parameters
- can help team building process

Future works

- to capture other important dimensions such as different time-zones, geographic distance, communication patterns, teams coordination
- focus on software development processes such as flow of requirements engineering, development and testing, project schedule evolution, agile practices, etc.
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