Towards ‘Human/System Synergistic Development’: How Emergent System Characteristics Change Software Development

Helena Holmström Olsson

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Background

• **Connected** systems allowing continuous data collection and experimentation (A/B testing).

• **Interconnected** systems that dynamically discover one another, and seamlessly interconnect during runtime.

• **Intelligent and autonomous** systems that adapt and improve over time and that proactively initiate actions.
Emergent System Characteristics

• **Self-learning systems:** Adaptive systems whose operation algorithm improves based on trial and error.

• **Self-actuation systems:** Systems that actively initiate actions based on input from the environment in which they operate

• **Decentralized control:** Systems in which each master in the network has all data. This supports local decision-making and allows for rapid actions to be taken in the network.
Research Objectives

• We explore some of the emergent system characteristics that we believe pose new challenges on software development.

• We outline the transition that many software development companies are currently experiencing in relation to R&D practices.

• We present a development approach where software development is no longer only a human effort, but instead a synergy between human development teams and autonomous systems.
Research Method

• Case study research in three domains:
  – Embedded systems
  – Online gaming
  – Internet of Things (IoT)

• We conducted interview studies, group interviews, workshops, observations and validation sessions.

• Roles representing software development, release, project and product management and sales and marketing.
## Case Companies

<table>
<thead>
<tr>
<th>Case company</th>
<th>Domain</th>
<th>System</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Company A</strong></td>
<td>Embedded systems</td>
<td>Developer of navigational information, operations management and optimization solutions for the world’s largest aerospace company.</td>
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<tr>
<td><strong>Company B</strong></td>
<td>Embedded systems</td>
<td>Producer of circular pumps for heating and air conditioning, as well as pumps for water supply.</td>
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<tr>
<td><strong>Company C</strong></td>
<td>Embedded systems</td>
<td>Developer of network cameras, video encoders and camera applications for professional IP video surveillance.</td>
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<tr>
<td><strong>Company D</strong></td>
<td>Embedded systems</td>
<td>Manufacturer and supplier of transport solutions for commercial use.</td>
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<tr>
<td><strong>Company E</strong></td>
<td>Embedded systems</td>
<td>A premium automobile manufacturer.</td>
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<tr>
<td><strong>Company F</strong></td>
<td>Embedded systems</td>
<td>Provider of telecommunication systems and equipment for mobile and fixed network operators.</td>
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<tr>
<td><strong>Company G</strong></td>
<td>Online gaming</td>
<td>Developer of mobile games.</td>
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<td><strong>Company H</strong></td>
<td>Online gaming</td>
<td>Developer of mobile games and online entertainment.</td>
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<tr>
<td><strong>Company I</strong></td>
<td>Online gaming</td>
<td>Developer of IT solutions for businesses, developers, individuals and children.</td>
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<tr>
<td><strong>Company J</strong></td>
<td>Internet of Things</td>
<td>Provider of services in the heating and ‘smart energy’ domain.</td>
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<tr>
<td><strong>Company K</strong></td>
<td>Internet of Things</td>
<td>Provider of waste monitoring and logistics solutions.</td>
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<tr>
<td><strong>Company L</strong></td>
<td>Internet of Things</td>
<td>Developer of mobile phones, tablets, smart wear and associated devices that enhance user experience for consumers and businesses</td>
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<tr>
<td><strong>Company M</strong></td>
<td>Internet of Things</td>
<td>Developer of mesh network technology that enables mobile devices to form instant networks.</td>
</tr>
<tr>
<td><strong>Company N</strong></td>
<td>Internet of Things</td>
<td>Developer of connected monitoring and alarm solutions and services for smart homes.</td>
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</tbody>
</table>
Current state: Online gaming

• The companies run continuous experiments and they collect data revealing system performance and operation.
• Specialized data analytics teams that serve the organizations by processing requests, creating reports, defining data dashboards and by automating analysis.
• Management and development teams have a set of key metrics that provide insights into how the organization is delivering value to its customers.
• Collect far more data than what they use, and they struggle with identifying what data that helps in driving overall business goals.
Current state: Embedded systems

• Data works as the basis for troubleshooting and support activities, and as input for understanding misbehaviors or deviations in the system.

• There is no systematic analysis and use of the data.

• Typically, ad hoc practices emerge in relation to individual or team needs or based on specific requests from a customer.

• Analysis is not automated.
Current state: IoT

• Companies experience an explosion in the amounts of data that is generated.
• Trying to understand how to make effective use of this data in relation to systems that interconnect in larger networks.
• The processing of the data needs to become quicker otherwise innovative value propositions and interesting business cases might be lost.
Challenges: R&D process (1/3)

• The transition from early specification of requirements, towards *continuous validation* of hypotheses.
• The transition from development of standardized systems, towards *dynamic systems* that continuously evolve.
• The transition from long-term planning and pre-defined milestones, towards *continuous experimentation*.
• The development of architectures that define *control and access* in decentralized systems consisting of interconnected objects and devices.
Challenges: Data Collection and Use (2/3)

• The collection, analysis and visualization of data from *multiple* sources.
• The collection of real-time data for *dynamic optimization* of user interfaces and data presented to the user.
• The collection of data in systems where user interaction over time *decreases* due to the intelligence of the system itself.
• The collection of data revealing user behaviors and preferences in relation to a *larger system* of which an individual device is only one part.
Challenges: Business and Organization (3/3)

• The *alignment* of R&D data collection practices and PdM decision-making processes.

• The *interplay* between R&D teams/human efforts, and smart systems/automated efforts.
Software Development Practices

• All systems will employ *continuous deploy*ment (at least once per agile sprint).

• R&D teams will employ A/B testing for all feature development and “MVP” approach for new products *(instead of requirements!)*.

• Systems will use streaming analytics in various forms and exhibit *data-driven* behaviors.

• Systems will *autonomously experiment* with their behavior to improve the delivered value.

• Families of similar systems will *learn and share* learnings with each other automatically.
Human/System Development:
Continuous Evolution of Systems

- Human hypothesis testing
- Automated experimentation
- Predefined adjustment
- Smart system

Deployment environments:
- Staged deployment
- Friendly customer deployment
- Company internal deployment
- Test bed
- Simulation
- Continuous integration
Conclusions

• New types of systems and emergent system characteristics pose new challenges – and opportunities – on current software development practices.
• These have an impact on (1) R&D processes, (2) data collection and use and (3) organization and business.
• With interconnected and increasingly intelligent and autonomous systems, software development becomes a joint effort between R&D teams and the systems themselves.
Thank you!

helena.holmstrom.olsson@mah.se