

Towards a Method for Agile Development in Mechatronics

A Lead User-based Analysis on How to Cope
with the Constraints of Physicality

Tobias Sebastian Schmidt



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Constraints of Physicality

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Towards a Method for Agile Development in Mechatronics: A Lead User-based Analysis on How to Cope with the Constraints of Physicality

Abstract

More and more product development projects face Volatile, Uncertain, Complex and Ambiguous (VUCA) conditions that challenge the company's competitiveness. This is why an appropriate product development method is crucial to support the project team to successfully achieve an innovative and marketable product, that can stand out and yield the intended return on development investment. Traditional plan-driven approaches such as the V-model (product development approach) or the Stage-Gate model (project management approach) have turned out to be heavy-weight and inflexible. Agile development, which in particular has been shaped and became prominent in the software industry, adapts to changes quickly and strives to utilize them in one's own favor. However, agile methods are designed for virtual (*software*) products. Using them for physical (*hardware*) products in mechatronics, which involves materialization, is not trivial due to the so called Constraints of Physicality (CoP). Those constraints group all challenges that affect agile hardware development, but are not - or not to that extent - present in agile software development (e.g., quick and cheap prototyping). If agile development was applicable in mechatronics, it would be easier for companies to remain or to increase their competitiveness under VUCA conditions.

With this motivation in mind, the investigation at hand answers the question on how to cope with the CoP in order to organize mechatronic product development projects in an agile manner. New solution approaches in form of a framework are derived. While many existing agile methods suffer from the guru problem (i.e., founding fathers postulate their methods, but lack a thorough explanation on why they work), the framework needs to be well-grounded in theory. To achieve that, on the one hand, the lead user method was carried out to identify and learn from cutting-edge users of agile methods in mechatronic product development. On the other hand, a review of the scientific literature was conducted to enrich the solution space. Based on the results of both streams, the framework was developed in an iterative manner by asking for lead user feedback frequently and applying parts of the framework in practice.

As a result, the framework contains ten agile principles and three agile practices. The former explain the fundamental working mechanisms on a generalized level. The latter translate and specify the mechanisms to become applicable in daily business. Appropriate prototyping (as a reframed concept of prototyping), situation-specific evaluator selection and value-based product modularization are key takeaways of the framework for practitioners. They provide solution impulses to increase agility in mechatronic product development and support the company to maintain or increase competitiveness under VUCA conditions, yet they require context-specific adaptations as every method. Although the framework is not a self-contained agile method (as it lacks, e.g., role and process models), it suggests important stepping stones towards an agile method specifically for mechatronic products. By grounding the solution approaches in existing theory the investigation contributes to a theory for agile development. Moreover, it provides a case study for the lead user method applied as research method which has never been used as such.

Hin zu einer Methode für die agile Mechatronikentwicklung: Eine Lead User-basierte Analyse über den Umgang mit den Einschränkungen der Körperlichkeit

Abstract (German)

Immer mehr Produktentwicklungsprojekte unterliegen volatilen, unsicheren, komplexen und ambigen (VUCA) Bedingungen, die die Wettbewerbsfähigkeit des Unternehmens in Frage stellen. Deshalb ist eine geeignete Produktentwicklungsmethode entscheidend, um das Projektteam dabei zu unterstützen, ein innovatives und vermarktbare Produkt zu entwickeln, das sich von anderen abhebt und den angestrebten Return on Investment erzielt. Traditionelle, plangetriebene Ansätze wie das V-Modell (Produktentwicklungsansatz) oder das Stage Gate-Modell (Projektmanagementansatz) haben sich als schwerfällig und unflexibel erwiesen. Agile Entwicklung dagegen, die insbesondere in der Softwareindustrie geprägt und bekannt geworden ist, passt sich Veränderungen schnell an und ist bestrebt, sie zum eigenen Vorteil zu nutzen. Agile Methoden sind jedoch für virtuelle (*Software*) Produkte konzipiert. Ihre Verwendung für physische (*Hardware*) Produkte in der Mechatronik, was eine Materialisierung beinhaltet, ist aufgrund der sogenannten Einschränkungen der Körperlichkeit (CoP) nicht trivial. Diese Einschränkungen umfassen alle Herausforderungen, die die agile Hardwareentwicklung betreffen, aber in der agilen Softwareentwicklung nicht oder nicht in dem Maße vorhanden sind (z.B. schnelles und kostengünstiges Prototyping). Wenn agile Entwicklung in der Mechatronik anwendbar wäre, ist es für Unternehmen einfacher, unter VUCA Bedingungen ihre Wettbewerbsfähigkeit beizubehalten oder gar zu erhöhen.

Mit dieser Motivation beantwortet die vorliegende Untersuchung die Frage, wie Unternehmen mit den CoP umgehen sollten, um mechatronische Produktentwicklungsprojekte agil zu organisieren. Neue Lösungsansätze in Form eines Frameworks werden abgeleitet. Während viele bestehende agile Methoden unter dem Guru-Problem leiden (d.h., die Gründerväter postulieren ihre Methoden, geben aber keine gründliche Erklärung dafür, warum sie funktionieren), muss das Framework theoretisch fundiert sein. Um dies zu erreichen, wurde zum einen die Lead User-Methode angewendet, um trendanführende Nutzer von agilen Methoden in der Mechatronikentwicklung zu identifizieren und von ihren Bedarfen und Erfahrungen zu lernen. Zum anderen wurde eine Literaturrecherche durchgeführt, um den Lösungsraum zu erweitern. Basierend auf den Ergebnissen beider Streams wurde das Framework iterativ entwickelt, indem regelmäßig Lead User-Feedback eingeholt und Teile des Frameworks in der Praxis angewendet wurden.

Im Ergebnis enthält das Framework zehn agile Prinzipien und drei agile Praktiken. Erstere erklären die grundlegenden Wirkmechanismen auf verallgemeinerter Ebene. Letztere übersetzen und spezifizieren sie, um sie im Tagesgeschäft anwendbar zu machen. Geeignetes Partyping (als erweitertes Konzept des Prototypings), situationsspezifische Evaluatorauswahl und wertorientierte Produktmodularisierung sind wichtige Takeaways für Praktiker. Sie liefern Lösungsimpulse zur Steigerung der Agilität in der mechatronischen Produktentwicklung und unterstützen das Unternehmen dabei, die Wettbewerbsfähigkeit unter VUCA Bedingungen zu erhalten oder zu erhöhen, erfordern aber wie jede Methode kontextspezifische Anpassungen. Obwohl das Framework keine in sich geschlossene agile Methode ist (da es ihr an Rollen- und Prozessmodellen fehlt), schlägt es wichtige Schritte hin zu einer agilen Methode speziell für mechatronische Produkte vor. Indem sie die Lösungsansätze in bestehender Theorie verankert, trägt die Untersuchung zu einer

Theorie für die agile Entwicklung bei. Darüber hinaus präsentiert sie eine Fallstudie für die als Forschungsmethode angewandte Lead User-Methode, die noch nie als solche verwendet wurde.

This work is dedicated to my parents (who made it conceivable)
and to my wife (who made it achievable).

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List of Abbreviations

A-MRT	Adapted Media Richness Theory
AM	Agile Modeling
CAD	Computer-Aided Design
CK-Theory	Concept-Knowledge Theory
CoP	Constraints of Physicality
DSDM	Dynamic Systems Development Method
DT	Design Thinking
FDD	Feature-Driven Development
FEM	Finite Element Method
MVP	Minimum Viable Product
MxP	Minimum X (Something) Product
OODA	Observe-Orient-Decide-Act
PDCA	Plan-Do-Check-Act
PMBok	Project Management Book of Knowledge
SWOT	Strength Weaknesses Opportunities and Threats
TAF	The Agile Framework
TMS	Think.Make.Start.
VUCA	Volatile, Uncertain, Complex and Ambiguous
XP	eXtreme Programming