The Evolution of Emerging Technologies in Market-Driven Software Product Development

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ABSTRACT
This paper investigates the lifecycle of emerging technologies from the perspective of market-driven software product development. Typically, the underlying concepts of the emerging technology are first elaborated at universities; after some time of intensive research effort, the first prototype is developed. The next stage brings to the scene companies aiming to develop software products using the technology. Then, the first commercial product is developed and introduced to the market. It gains market share, reaches maturity and finally decline. In this paper, we explore the different challenges, opportunities and actors involved in each stage of technology lifecycle. We believe that a better understanding on the dynamics of innovation in market-driven software product development is a key factor to advance the diffusion of research results into commercial software development.

Categories and Subject Descriptors
D.2 [Software Engineering]: Management--- *life cycle*; K.6.3 [Management of Computing and Information Systems]: Software Management---*software process*

General Terms
Management, Economics, Human Factors.

Keywords
Market-driven software development, emerging technologies.

1. INTRODUCTION
Emerging technologies have the prospect to reshape existing software industries and create new ones. They include disruptive technologies originated from radical innovations (e.g. genetic engineering) to evolutionary technologies derived as the result of a long trajectory from different research fields (e.g. wireless technologies and the Internet) [1].

The development of market-driven software products produces a major impact on established software engineering practices [2]. The reasons for that are twofold. Firstly, the awareness of consumer behavior is generally uncertain and limited during the initial stages of product lifecycle [3]. Potts [4] suggests that requirements for such software systems are invented rather than elicited from stakeholders. Secondly, pressure on time to market and demand for innovative solutions are high due to aggressive competition among companies providing alternative software products [5].

By focusing on the dynamics of emerging technologies and identifying the different stages in which a technology achieves dominance in the market, we are able to have a better understanding on the complex issues and decisions involved in the development of software products. Consumer adoption of technological innovations can be divided into five categories: innovators, early adopters, early majority, late majority, and laggards [6]. Each category of consumer will play important roles during the different stages of technology lifecycle. In the next section we describe the evolution path of technologies.

2. TECHNOLOGY EVOLUTION PATH
We propose that the trajectory of emerging technologies can be described in terms of an evolution path divided in three key sections. Each section is characterized by distinct dynamics including a number of challenges, opportunities and actors. Figure 1 describes the S-shape curve representing the evolution of emerging technologies in the context of market driven product software. In the following sections, we outline the stages of technology lifecycle.

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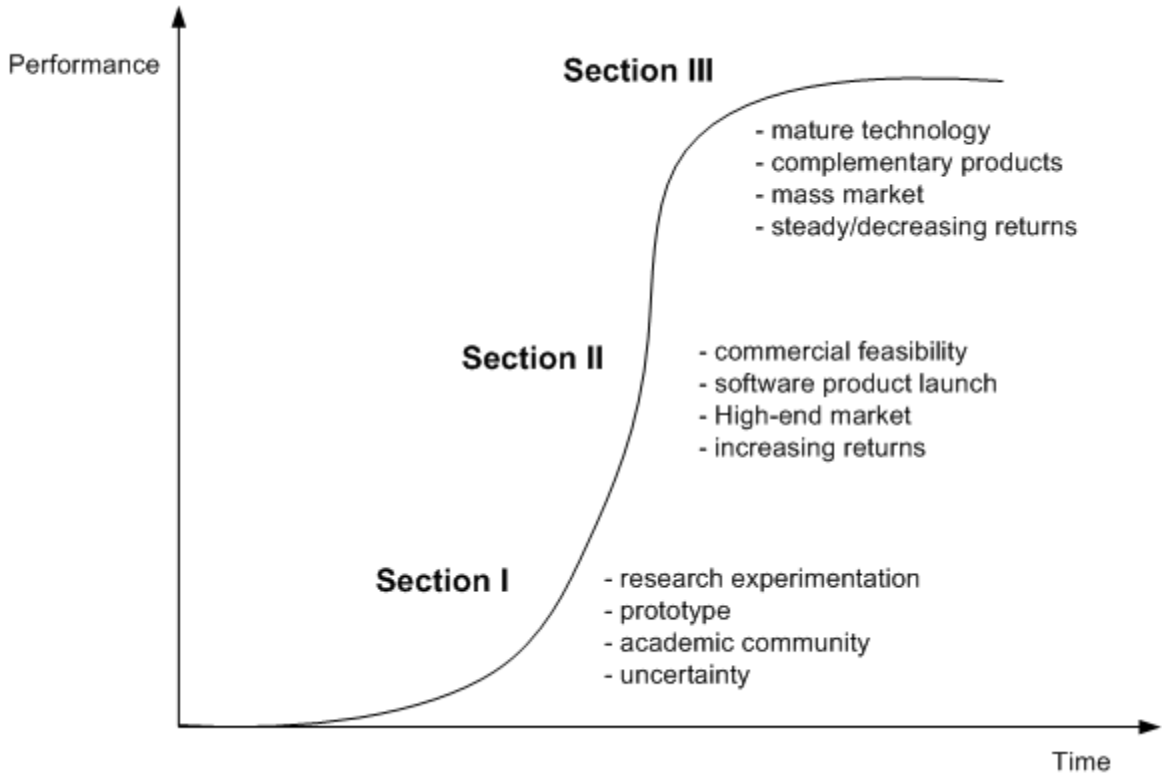

Figure 1. S-Shape Curve of Emerging Technology Lifecycle

2.1 S-Shape Curve

The technology management literature suggests that the lifecycle of a new technology follows a S-shape relationship between cumulative performance and time [1]. In the strategy field, business performance refers to different variables such as financial growth or number of adopters [14]. By doing so, we are able to analyze the trajectory of technologies from different perspectives. It is important to appreciate that such time path is not fixed. Rather, it is an expression of what may emerge in terms of technology performance over time. The S-shape curve can express varying performance rates (i.e. varying slopes of the curve). The new technological field begins when a research group does pioneer research, elaborating the underlying concepts and developing the first working prototype to demonstrate the initial feasibility of the technology. A second stage is marked by the launch of the commercial products using the technology. It is the first time that products are available to real customers.

At this stage, there is a prospect of rapid market growth and high returns. The next stage of the technology evolution marks a more stable consumer market. The core software products are consolidated and companies focus on developing complimentary products and product families. Finally, after a period of time, financial returns start to decrease; the current technology is substituted by another discontinuous technology and a new cycle start again.

It generally requires a some time before an innovative software product achieves initial market results, then it is followed by rapid progress leading to possible market dominance until reaching a limit. After that, market growth is stabilized and can last for a long time until a new technology comes out of research labs. Next, we explore the three stages described by the S-shape curve of technology. In each stage, we describe the main activities, challenges and opportunities as well as the role played by researchers and developing companies in the evolution of disruptive technologies.

Section I – Introduction of technological field

The beginning of the technological field can be characterized by the moment when a research lab or university undertakes research aimed at transferring academic results into industrial practice. Pioneer research efforts are soon followed by other researchers who set up similar research programs. The emerging field is progressively expanded into a community of researchers collaborating to improve the state-of-the-art in the technological field.

Rombach [7] suggests that experimentation is a major research and technology transfer engine. According to him, the availability of repeatable experiments on the emerging technology helps to demonstrate its applicability to potential investors and developing companies. In addition to that, continual experimentation helps to refine and mature technologies in order verify if technologies can scale up to commercially viable software products [8]. The inherent uncertainty and risk associated with disruptive technologies, together with high investment to develop and commercialize

products and slow financial returns [1] may inhibit the prompt immersion of technologies into industrial settings.

Sponsoring R&D projects is an effective way to manage uncertainty in situations where the path from early technology conception to commercial product development is long and not clearly visible. As noted by Pinheiro [9], successful technology transfer needs to be part of the company's strategic direction. Sponsors of the emerging technology need to identify critical transition points when emerging technologies realize their commercial importance. At this point, sponsors need to undertake appropriate actions to strategically position themselves in the battle for technological dominance. Entry timing is a fundamental aspect determining the success of new software products. Suarez [12] discusses that early market entry helps researchers and developing companies to experiment and improve different technological alternatives. Besides that, there is a combination of different selection criteria and availability of substantial resources to support innovative efforts that results in dramatic consequences for subsequent technological development [10]. For instance, the early joint venture between several leading manufacturers of wireless, handheld communications and computing devices was a decisive factor to strategically position Symbian in the market of operating systems for mobile phones. After years of intense research and technology evolution, Symbian is nowadays the global market-leading mobile operating system for advanced mobile phones.

For an innovative product to be appealing to potential customers, it needs to bring benefits over existing technology, either as a new functionality, better quality or reduction of cost. The primary goal of market-driven software development is to create solutions that will satisfy the needs and expectations of users within very different contexts of use [3]. When software products bring radically innovative features, users may not be able to perceive the benefits brought by the product. In fact, consumer market for such innovative product is highly uncertain. Effective market awareness has to be developed and users convinced of the importance of the new technology in their lives.

Emerging technologies are generally developed without a precise characterization of target consumer markets. Frequently, researchers envisage the results of their research efforts to solve the problems of a particular application domain. However, quite frequently technological innovations are used in very different domains from the ones they were initially conceived. For instance, wireless technology has evolved over hundred years, its evolution can be traced back to technological advances in different domains such as electromagnetic waves, wireless telegraphy and broadcast radio.

The ability to creatively explore different application domains in which technologies can be adapted and successfully "re-created" is seen as a strategic area to focus on. In [11], Maiden shows the use of explorative, combinatorial and transformational reasoning to stimulate creative thinking during the requirements process of software systems development. We believe that these strategies can be used to explore original ways to transfer technologies from research labs to the marketplace. Adner [10] supports this position by suggesting that emerging technologies are not necessarily the result of a sudden revolutionary innovation. Instead, the real revolution may be in the radical shift of application domain.

Section II – Market creation and growth

The first commercial software product is a sign that the chosen technological trajectory is feasible [12]. At the beginning of section II of the S-shape curve, consumer market is generally fragile and fragmented. Considerable effort is made to define the market in which the product will fit in. Day [1] proposes a tentative and error approach to assess the commercial viability of technologies with the following steps: introducing the product into a small set of market, refining concepts, modifying the product for next releases, refocusing marketing strategy, and starting the process again until the product is aligned with a particular segment of the market.

When the software product is launched, the size of consumer market is still embryonic. Given the high cost to develop the new product, consumer market mainly consists of innovators who detain substantial financial resources and technological knowledge. They are lead users who will give important feedback on the quality and usefulness of features provided by the product. Acceptance by the high-end market acts as a thermometer to estimate the feasibility of the innovation to mainstream consumer market. Conversely, effective dominance of a technology can only be determined after a certain critical mass of users has been achieved.

In market-driven software development, users are very different with very different requirements in mind and therefore, they perceive technology very differently. As a result, customers make use of different criteria when evaluating the suitability of products. According to Moore [13], the high-end market looks for technological novelty and gee-whiz functionality. While the mass market has more conservative behavior and are less impressed by innovation; they expect products with increased quality (e.g. reliability, usability) and better value for money. Suppliers have to reach equilibrium between adding new features and improving the quality of products.

In rapid market growth, financial returns are promising, and consequently the rivalry among companies developing competing products increases. This situation is marked by battles for dominance among rival suppliers. Market share is instable with new players entering and leaving the arena quickly. To gain competitive advantage, suppliers try to constantly add new and differentiating functionalities to make their products more appealing to consumers. A good example of this case is the broadcast mobile TV feature introduced in third generation mobile devices as a way to offer customers the widest range of services possible. Over the last years, a key challenge faced by mobile industry has been to improve transmission technology to support the high bandwidth demand to deliver TV content over mobile phones. Thus, an effective transfer between research advances and prompt commercial development is key factor to determine technical superiority of a particular product.

Section III – Market maturity and decline

Finally, section III of the S-shape curve marks the maturity and decline of the technology. Software products using the technology have evolved over several releases, and they have achieved a stable set of functionalities. Competing suppliers have accumulated substantial installed base of consumers.

At this stage, there is an increasing demand for complementary products and services, such as: specialized training, installation services, ongoing technical and user support, compatibility with other software products, etc. Strategic partnership with suppliers of complementary products is a key factor to attract late adopters and retain installed base of consumers. Joining forces with competing product suppliers will increase the chances of new revenue sources and opportunities [14]. A compelling example of this kind of strategy is the development of powerful partnership between Enterprise Resource Planning suppliers. Compatibility among complementary products is a key factor to foster the chances of building integrated software product solutions. Besides that, the strength of partnership between suppliers of complimentary products increases customer awareness for the benefits of integrated solutions. As a result, the switching costs customers will incur to change supplier will be higher for integrated solutions than stand-alone products.

Another common trend is the development of product families. The main benefit of product families is the possibility to configure the software product to the needs of a specific application domain. The development of product families relies on exploiting the commonality and variability in customer requirements [15]. This means that several different customer segments can be targeted by the same family of products. For example, mobile phone manufactures have developed several product families of phones to target different market segments.

Typically, the research community is less involved in the final stage of the technology trajectory. In fact, at this moment, the research arena is focusing on inventing another discontinuous technology and hence, forcing a new technological cycle to begin and replace the current technology [16]. The end of section III is characterized by the gradual decline of the technology.

3. FINAL REMARKS

In this paper, we have addressed the problem of technology transfer from the perspective of product innovations being originated at universities and subsequently transferred to industry. We believe this analysis is well suited in the context of commercial development of software products. We argue that emerging technologies lifecycle can be divided in three key stages. We have adopted the S-shape curve, which has been vastly described in the business strategy field, to model the evolution of emerging technologies in the context of market-driven software products. We have discussed that each stage of the S-shape curve is affected by different strategic decisions that will determine the success or failure of software products based on a particular technology.

Market-driven software product development brings new challenges to technology diffusion. On the one hand, researchers need to propose interesting and useful solutions to problems perceived by customers which, in turn, may lead to likely success of commercial products. On the other hand, researchers are forced to develop disruptive and unexpected solutions as a way to create new opportunities for technological and business growth for an originally inexistent consumer market. Thus, such situations involve high risk and uncertainty to be managed by researchers and developers. An additional complication is that researchers do not necessarily have a deep understanding of the customer market in which their innovation will target.

The potential consequences of the model we describe in this paper for technology transfer are twofold. Firstly, by having a better understanding on the factors involved during the lifecycle of emerging technologies, researchers may align their efforts (specially during the first section of curve) to manage market expectations, and hence, promote successful commercialization of technology innovations. Secondly, by reflecting on the dynamics of technology evolution may give valuable insight to developers on how well a particular technology is performing in the marketplace.

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