The Japanese Software Puzzle Revisited

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The so-called "Japanese software puzzle" is revisited by analyzing various factors that affect the state of software development in Japan. International cross-comparisons explain how and why countries like the United States and Japan differ from the perspective of software process improvement. Considering the Japanese market and institutional settings, the costs and incentive mechanisms at work are starkly different from those found in the environment that enable the development of global platform products. However, this did not impede innovation and product development in the Japanese software industry, especially in the flourishing embedded software application business. Discussion of the embedded software developed by the Japanese also explains the close link with the hardware manufacturers as well as certain institutional characteristics of the Japanese software industry; this route could give rise to a strong orientation towards a global market.
Keywords: Japanese software industry, software factory, Sw-CMM, CMMI, embedded systems.

1. Introduction

In a recent article, Cusumano [1] described the "Japanese software puzzle" that resounded the gong calling the attention of industry observers. Several previous studies [2, 3] have noted the issues surrounding the lack of Japanese packaged software exports. Apart from the lucrative market for animation and games, Japan still holds unrealized potential in global software production, with the great majority of the applications being homegrown, one-of-a-kind designs. Ohsuga [2] pointed at the cultural, organizational, technical, educational, and research factors that contributed to the late development of software exports emphasizing the need for improvement in all aspects.

Cusumano further observed that apart from embedded systems and computer games, Japanese software performance have been lackluster. The Japanese software industry's fragmented structure, characterized by incompatible platforms provided by major systems integrators, has been cited as one of the reasons for its lackluster competitiveness in the global market [4]. Nevertheless, there is also a belief that the Japanese had special characteristics that have helped them in software development. Japanese software firms have performed well in some areas, and it is clear that the quality of the software they produce is very high, even for Japan's low CMM-rated companies [6], and that ad-hoc software development is not the norm.

Over the years, there have been several attempts to analyze the Japanese software industry and to draw comparisons with U.S. standard practices [7,8,9,10,11]. Such analyses are based on comparing the processes employed, the product standards in place, the quality of the software generated, the business approach, etc. Two observations can be made:

(1) The software process improvement (SPI) movement that has raged in the U.S. since the mid 80s, and that was inspired, in part, by the Japanese continuous process improvement experience in manufacturing, has not been popular in Japan.

(2) Conversely, the Japan introduced concept of industrializing the production of software through software factories (SF) has not found many adepts outside Japan, although it has inspired research in product lines particularly in the U.S.

What can we learn from this dichotomy and other relevant aspects of the Japanese software industry?

Ohsuga [2] pointed out socio-cultural factors, including the language capabilities as well as organizational aspects that influence the software engineer psyche and consequently affect the utilization of process improvement methods especially in training, education and research. Aside from the traditional culture, which many believe, is a rich source of spin-offs, there also exists several manufacturing companies holding strong keiretsu affiliations among intermediate manufacturers and trading companies with a strong focus on quality in their approach.

Does the observance of these quality control standards and other implicit rules crowd out innovation in the Japanese software development market? As Cusumano implies: "...so few bugs may suggest an overly rigid style of development and a preoccupation with "zero defects" rather than innovation and experimentation, at least at the firms we sampled…" "Creating bugs is a cultural "no-no" in Japan, but innovative software always requires some trial and error." [1].

The Japanese may well be risk averse by nature, but we find it difficult to agree with any observation hinting that the Japanese have not done their share of trial and error on the path towards innovation. Particularly in developing custom-built embedded systems, much innovation has been achieved by software companies collaborating with large manufacturing

companies in the automobile, mobile computing and household electronic sectors. If there is anything that can be learned from Japanese "monozukuri" experience, it is the continuous "kaizen" and trial and error process done systematically, albeit perhaps inefficiently.

It is however true that a different kind of mindset may be needed to improve on the innovation necessary to enable access to the world market for software packages. The confluence of these keiretsu factors and the dominance of large software vendors who dictate the pace of the industry, do not seem to be conducive to "thinking outside the box." Inherent incentive and risk structures that influence actions, decisions, and behavior have crucial economic implications. As such, incentives for process improvement implementation are weak; the need to develop an environment to cultivate intrinsic motivation is therefore crucial.

Market access depends on the degree of tailoring required, availability of bilingual specialists, and the degree of customer technical familiarity, for which the keiretsu is not the most appropriate. However, these large keiretsu holding companies have extensive networks abroad —factors that will actually be advantageous to Japanese software companies for overseas ventures.

2. A Brief Overview of the Japanese Software Industry Structure

In 1968, when the whole world was pointing out at a major crisis, Japan had no software crisis: there were only a few software development centers and with very limited programming capabilities. To catch up, leading Japanese industries adopted many U.S. standards and contracted with some American firms. They also tried to adapt their success in other industries to the development of software, when large computer manufacturers such as Toshiba, NEC, and others explicitly decided to implement the software factory [12,13] concept, i.e., Japanese style quality control into industrial software production, as a metaphor emphasizing the need to integrate and standardize good practices and techniques systematically. This represents the launching of long-term efforts by Japanese major software producers to industrialize software production and quality control.

The Japanese found its comparative advantage in developing quality control standards for custom-built software to service the domestic market. However, this focus can only be found in a small portion of the industry, those large highly competent software factories. The rest of the industry seems to be made of small, much less competitive and less mature development groups, with an overemphasis on homogeneity and cooperation and adherence to social norms that may have hindered unique and creative advances in the Japanese software development. For these Japanese corporations preserving the secrecy of their processes and adhering to internal business procedures was first and foremost. The predominant mindset of "How can we modify the software to fit our operations?" set the tone for developing basic systems software as well as custom applications early on in Japan [4].

The Keiretsu Effect on Innovation

The institutionalized long-term relationships between software and hardware suppliers, i.e., the vertically affiliated software developers known as the keiretsu, is said to heavily influence the preference for custom-built software solutions. These companies succeeded by subcontracting services to smaller companies and applied the traditional "factory concepts" of the manufacturing sector to computer programming to lift technology standards comparable to those existing in Japanese manufacturing. According to the Sofutowea Sangyo Kenkyukai (Software Industry Research Forum) [13], more than half (58%) of software company's project volume is made-to-order from other software companies. The second- or third-tier contractors rely mostly on orders from the big companies contributing to the subcontractor's income stability albeit preventing them from developing original software products.

Market penetration of traditional Japanese companies, limited by obligation, community, and a conglomerate-like keiretsu-based system, is conditional to adherence to group-based norms, i.e., unwritten and implicit rules. Rossi [14] cites that intrinsic behavior plays an important role in encouraging process improvement or innovative behavior.

For as long as the company philosophy allows individuals to challenge norms, innovative behavior is possible. In so doing, parent firms absorb transaction costs involved in the innovation process. Otherwise, engaging in innovative behavior that incurs wide-ranging development costs and unforeseen frictions, such as intellectual property rights settlements, is negatively branded as "going against the grain" in Lindenbergh's obligation/common- based framework. Lindenberg (as cited in Rossi) further distinguishes between two kinds of intrinsic behavior: a) enjoyment-based, that is, actions done for inherent satisfaction — fun and challenge, rather than due to pressures and rewards; and b) obligation-based, those actions done in the context of intrinsic benefits associated with adherence to social or community norms and codes of ethics.

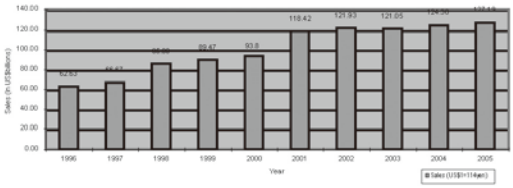
Software Process Improvement in Japan

Inspired by the Japanese focus on quality and process improvement so successful in other industries in Japan, the U.S. has pushed for a focus on software process since the mid-to-late 1980s, based on the premises that (1) the software development process can be defined, managed, measured, and continuously improved following statistical control, and (2) the quality of the software produced is largely driven by the quality (maturity) of the process used.

A Capability Maturity Model (CMM) is a reference model of mature practices in a specified discipline, used to improve and appraise a group's capability to perform that discipline (e.g., software engineering, systems engineering, security engineering, people, product development, etc.). The Capability Maturity Model® for Software, or Sw-CMM, is a five-level model that helps in the evaluation of an organization software process maturity. [15] SW-CMM is already in wide practice in Japan with 166 reported appraisals as of September 2005, in third place only to India and the U.S.

The Japanese Software Market

The METI recently reported the sales of the IT services industry from 2000 to 2005 (Figure 1) showing the market scale of the industry in Japan. Japanese total merchandise exports was at 61.2 trillion yen and imports at 49.2 trillion yen in 2004 .



Source of original data (in Yen) : METI [22]

Figure 1 : IT Market Trends in Japan: 1996-2005

This robust ratio, however, is not reflected in the software industry where exports continue to lag behind imports. Software imports in Japan in 2004 totaled 364 billion Yen, while exports totaled 31 billion Yen, i.e., a mere one-tenths of total imports . The JISA report indicates that exports comprise one-three hundredths of Japan's software industry's domestic revenues. This is mirrored in the recent data from JISA showing software development and system integration valued at 71% of total software revenues in 2004. Customized software registered an 82% bulk share of software sales, while a 7% share went to the games sector, and only an 11% share (approx. 742 billion Yen) was attributed to software product sales in 2004. Current rapid developments in ubiquitous and embedded systems show that this trend will continue, reinforcing the predominance of the large vendors such as Fujitsu, Hitachi, NEC, Toshiba etc., over independent small-to medium-scale software companies.

Figure 2 illustrates the industrial composition showing the software sector occupying more than half of the entire information services industry. The whole market in 2003 was valued at 14.17 trillion yen, with 8.08 trillion yen in revenues accounted for 55% of the whole IT services. Customized software production accounts for the lion's share (82.2 %) in revenues of the total software market. Within this sector is the viable market for embedded systems buttressed by strong consumption demand in mobile computing and consumer electronics. Business solutions sectors seem to expand every year and seem to have bright prospect for future growth in the global market.

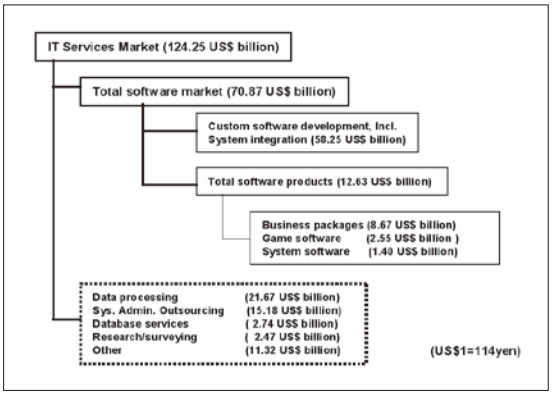


Figure 2 : IT Services Market in Japan (2003)

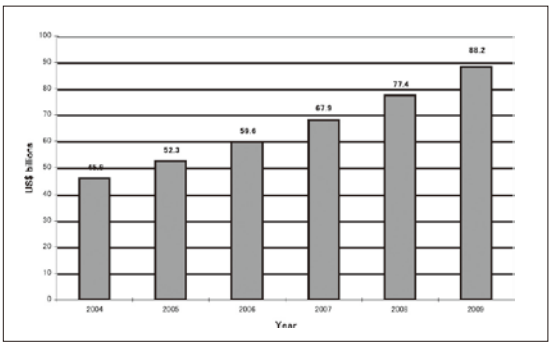


Figure 3 : Embedded Systems World Market (2004-2009)

Figure 3 illustrates the robust embedded systems market trends. METI also reports huge employment generation benefits derived from the embedded industry accounting for 9.2% of total employment in all industries. Furthermore, this large-scale expansion has led to increased production volume for all related industries comprising 10.2 % of 500 trillion yen of the total GDP in 2002. The 2005 survey conducted by METI reported approximately 89,000 corporations involved in the production of embedded software systems. The total employment generated was about 4.8 million jobs, and 3.6% (175,000) of employed personnel were software experts. This figure represents a 17% increase from the 2004 figures reported by METI. The increasing number of experts in the field indicates healthy prospects for the industry, a trend that is expected to continue for several years.

Data Sources:
Ministry of Economy, Trade and Industry (METI) (2005:1). Status of Specific Service Industry Dynamics Statistics, 2005. (In Japanese).
Japan Information Technology Services Industry Association (JISA) (2005:1). Statistics of Specific Service Industry Dynamics
http://www.jisa.or.jp/statistics/download/dotai2004.pdf,2005.(In Japanese).
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A newer, more encompassing, process improvement approach, the Capability Maturity Model Integration (CMMI), was designed to help integrate software functions and systems engineering as well as other built-in organizational functions such as integrated product and process development, and supplier sourcing. A de facto standard used extensively around the world, CMMI is aimed at boosting a company's software development capability in a staged, integrated approach. There were Japanese companies assessed as early as 2002 in the CMMI. As of March 2006, there have been 131 CMMI appraisals reported in Japan, again falling third after India and the U.S. [16]

Despite these encouraging data, the Japanese software engineering community has resisted attempts by the METI to make the Japanese edition of CMM in 2001 [17]. According to results of a survey conducted by the Information-Technology Promotion Agency, Japan Software Engineering Center (IPA SEC) in June 2005 [18], Japanese software engineers chose quality control technology as the most important aspect for improving software quality; system modeling techniques ranked second, while testing and evaluation techniques ranked third. Software process improvement (SPI) technology ranked ninth —same as software development tool technology, while software process assessment (SPA), ranked 11th.

As we can see, Japanese software engineers put more emphasis on adherence to quality assurance standards over software process improvement or assessment. These results may partly explain why in spite of the capability of Japanese to produce high-quality software products, the number of companies that have reached level five of CMM are still very few. It will not be long, however, before this trend changes as the government is focused on setting up incentive programs to further increase the number of Japanese companies to get CMM certification. [19], and, more importantly, the Japanese government plans to require CMMI certification for companies participating in the e-government Japan project.

3. Trends in the Japanese Software Market

As many believe that neither the large software vendor nor the independent software company can ignore the path towards developing global products any longer, we are of the opinion that the key to the puzzle lies in updating or modifying incentive structures.

At the industry-level, re-examination of the vendor evaluation system is needed, and the standardization of proposal documents is on hand. The Software Industry Research Forum prescribed more concrete solutions at the industry and government levels as well as for the vendor and user companies. For the vendor company, the need to change business models and to acquire intellectual property rights for talented human resources with superior capabilities is emphasized. User companies, on the other hand, need to utilize software packages and to reexamine procurement and acquisition norms.

As for the government, there is a need to enforce education connected with the Skill Standards for IT Professionals (ITSS). Universities and graduate professional schools, would play a key role when compounded with extending chances for engineers in user companies to obtain education and training and support. This is paramount for success. The government is also expected to ensure the protection of intellectual property rights and prevention of violations thereof, and to streamline licensing procedures, oversee the improvement and acquisition of skills for software development and facilitate the establishment of links between the university-research sector and the private sector particularly small and medium scale companies.

One of the main differences between the U.S. and Japan lies in the institutional setting for education and R&D. In the U.S., there is virtually nothing that hinders exchange and collaboration between basic researchers and their more applied counterparts, particularly in industrial settings. In Japan, there is a pronounced dichotomy between basic research done by the university sector, and the more applied research engaged in by the private sector. A vital step needs to be taken by the government for designing and implementing the necessary incentive mechanisms to open the communication lines between these two sectors. This is notably vital in pushing R&D and innovation within organizations situated in an unfettered environment; in stimulating intrinsic motivation particularly among students; and, in encouraging the formation and operation of venture start-ups.

Challenges

As the demand for embedded systems increases (see sidebar article "The Japanese Software Market"), the performance, functional, and quality requirements also become more severe. Test and verification techniques covering both of the hardware and software are still insufficient, and may not scale-up. For example, the number of lines of code in cell phones is said to be more than 1 million.[20]

An additional problem is the lack of highly skilled human resources. The characteristics of embedded systems development are starkly different from those of conventional systems and presently, there is a great unmet demand for specialists with professional education and qualifications.

A third problem is the inadequacy of development tools. There is a need to encourage university researchers to get engaged in the development of tools for embedded systems in conjunction with more applied industrial researchers.

A fourth problem is the lack of concerted efforts across industries towards formulating standards particularly in software architectures. In this respect, there have been some isolated activities coming from the automotive industry which have began standardization efforts in layering software. However, the introduction of a definite real-time operating system (RT-OS) has not yet been obtained [21, 22]. Furthermore, the path towards standardization and the development of open source software, which seems to be the trend in the global arena, has not taken place, and has been largely avoided by the Japanese.

To address these problems, university researchers are conducting several projects with collaboration from the private sector and the government. The "ITRON Project" aims to

create standards for RT-OS used in embedded systems and for related applications. More recently in late 2003, the Toyohashi Open Platform for Embedded Real-time Systems or (TOPPERS) and the Empirical Approach to Software Engineering or (EASE) projects [, 10] were initiated to promote the development of embedded systems by releasing quality open source software. These projects include R&D, verification/validation of specifications, and OS development and publishing.

4. Conclusions

The discussion in this paper indicates widespread expectations for higher competitiveness in the Japanese software industry and for a market that is expected to improve with a customized software niche as a major market driver in the next few years. It is clear that Japan's software has little, if any, international reach, with the great majority of the applications being homegrown, one-of-a-kind designs. Following its tradition with other industries, the Japanese software producers emphasized quality first. This included two important aspects: (A) strategic management and integration of activities required to develop software; and, (B) planned economies of scope (so called software factories).

The very significant efforts by the Japanese government in implementing the e-Japan Plan in 2001— primarily aimed at elevating Japan's infrastructure to world standards —were rewarded with heightened user awareness and increased Internet penetration rates. This also set the stage for the e-Japan acceleration package aimed at making Japan among the countries with cutting-edge IT technology in 2005. As e-Japan succeeded in these aspects, it virtually set up the crucial incentive structures needed to promote embedded system development. Having fulfilled e-Japan's initial goals, the government engineered a shift in the focus of developing the IT industry towards the so-called ubiquitous society.

The Ministry of Public Management, Home Affairs, Posts and Telecommunications worked out the u-Japan package, which aims at "leading the world as the cutting-edge ICT state" by 2010. The keywords of the u-Japan package are the "4 U's": Ubiquitous, Universal, User-oriented, and Unique.[24] With these planned developments and strengthened links between the private sector, the university and the government, Japan is expected to concentrate on strengthening the embedded system market through increased standardization as well as human resource development through training. The concerted efforts not only from the government, but also from the universities and from the private sector, will further stimulate innovation in embedded systems and enhance value added of the automobile, mobile computing and consumer electronics industries not only for the Japanese market but for the global market as well.

The government has also started extensive efforts in connection with the standardization in embedded systems production. The Information Technology Promotion Agency, Japan, the Software Engineering Center, the METI and the Power Reinforcement Task Force for the embedded software development collaborated in working out the ETSS (Embedded Technology Skill Standards) which embodies "the cultivation and utilization of skilled human resources" in the field of the embedded software development and guidelines for "the efficient labor utilization" in 2005. [24]

Finally, as China is poised to produce much of the software consumed in Japan (60% of China's production in 2004) the question now becomes how skilled is the Chinese software development workforce? China leads competitors such as India in terms of basic indicators like concentration of researchers, proportion of tertiary students in STEM disciplines, and literacy rate [25]. Also, a higher proportion of Chinese engineers trained abroad are returning to China (e.g., 75% of U.S. Chinese graduates are expected back compared to 25% a few years ago). China is aggressively trying to achieve higher levels of international quality certification by, for example, providing incentives for software firms to attain CMM level 3 or higher. This remains the subject of our continued investigations.

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