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Prerequisites, effects and opportunities of Internet-distributed software development

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Abstract

The rapid growth of the number of its users makes the Internet a promising opportunity as far as business-to-customer relations are concerned. Commercial Internet use was started by information technology related enterprises advertising their products. Nowadays, both products and services are advertised. To date, a variety of businesses are present on the Internet. Corresponding examples for the service industry are travel agencies, consulting firms, insurance companies, and law firms. Beyond making use of the Internet for the sale of products and services there is an opportunity of a completely different nature. If regarded as a means of production, the Internet could be used as a distributed development platform for software products. This paper outlines a new form of software development and focuses on its economic impacts. Furthermore, the results of an Internet questionnaire are presented.

Keywords

Internet, world-wide distributed software development, project management, questionnaire

1 WORLD-WIDE DISTRIBUTED SOFTWARE DEVELOPMENT

1.1 Technical prerequisites and project management challenges

The idea of world-wide distributed software development is not entirely new. The vision of the Global Software Highway (GSH) and a prototype of a suitable toolset called WebMake has

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already been described elsewhere (Baentsch et al., 1995). The GSH approach focuses on technical aspects of world-wide distributed software development. The integration of applications and the World-Wide Web (van Dooren, Eliens, 1995) is another approach which enables distributed development. Technologies such as Sun Microsystems' HotJava Browser and the programming language Java support this idea. The World-Wide Web serves as a global client/server architecture, being the development environment and the runtime environment at the same time. Objects (in Java called 'applets') on remote nodes might be invoked and might invoke other objects themselves. However, there are some unsolved problems about this idea, e.g. the dynamic supply of objects when at least one Internet connection which is crucial for inter-object communication is down.

Project management represents another area of interest in such a distributed production environment. On the one hand, there might be the typical problems of international cooperations, for example cultural differences such as divergent life rhythms and different attitudes towards the significance of time (Schneider, 1995). On the other hand, the problems of coordination in software development (Kraut, Streeter, 1995), e.g. the importance of informal communication, are aggravated in a distributed environment which does not facilitate face-to-face communication.

1.2 The economic viewpoint

From an economic viewpoint, world-wide distributed software development has some advantages over 'conventional' software development. The producer, the better term in this case is 'seller', enjoys the following advantages:

- **Concurrent Software Engineering**: Executing independent development tasks simultaneously reduces the time-to-market and therefore induces competitive advantage.
- Shifting development tasks to countries with **lower labour costs** (e.g. India, Philippines) reduces overall production costs and increases competitiveness. Knowledge about local software markets might as well enforce the development of products "that better satisfy the needs of local customers" (Rafii, Perkins, 1995).
- Due to different time zones across the globe, **continuous development** up to 24 hours a day becomes possible. Centralised hardware resources which are possibly crucial to the development process could be used in a more efficient manner. A corresponding example of off-shore software reengineering can be found elsewhere (Dedene, De Vreese, 1995).

The economies of other countries and especially enterprises abroad providing software modules or even performing 'higher' development tasks are taking advantage of these options as well (Bhatnagar, 1994). First of all, software development requires lower investments for means of production than other industries such as, for example, manufacturing. In India, for instance, a dynamically growing software industry can be found. Secondly, in contrast to other industries the value addition of software development and maintenance is relatively high.

Beyond the advantages mentioned above, internationalising software development raises problems of economic dimensions as well. An effect also known to other industries, e.g. automobile manufacturing, is that procuring intermediate products abroad (global sourcing) goes along with a loss of value addition at home and might possibly add to unemployment. However, we must not overlook the fact that such structural change is not to be halted but rather to be kept under control. In other words, we have to carry out cost-efficient tasks by ourselves and shift other tasks abroad simultaneously.

2 INTERNET-DISTRIBUTED SOFTWARE DEVELOPMENT (IDSD)

The underlying idea of our approach is to increase efficiency by modifying software project management and organisation. Thus, the first step is to establish a temporary virtual enterprise comprising the Principal Software Producer (PSP) as we call it and freelancing agents; both parties can either be represented by individuals or corporations. The Internet is used as a medium for coordination and communication within the virtual enterprise. By employing worldwide distributed manpower, efficiency can be increased due to different labour costs. Three main factors cause reduced labour costs:

- **Differences in wage costs**: Depending on the country in which the agent is located wage costs can differ. A programmer in India is likely to demand less than one in the US.
- **Differences in non-wage costs**: Due to the agent's freelancing status, non-wage costs can be partially eliminated.
- **Competition**: The level of the wages to be paid is balanced by price mechanisms. As a consequence, it can be assumed that the highest possible wage will not exceed the average wage paid in industrialised nations.

The basic structure of Internet-Distributed Software Development (IDSD) is depicted in Figure 1. The PSP keeps an eye on the consumer market for software products (external software market). If a lucrative opportunity can be expected the PSP initiates a development project. This is the starting point for the virtual enterprise.

From the PSP's point of view, the virtual enterprise is managed as a project. As a consequence, the producer is responsible for project management. In the following, the PSP investigates the requirements and specifies the intended application system. Moreover, he carries through further preparatory steps depending on the chosen software process model. Once an adequate degree of detail has been achieved, the PSP delegates the resulting development tasks. Two different kinds of agents are addressed, depending on type and complexity of the respective task:

- Software producer (corporation): The more complex the task, the better it is to delegate it to an agent with more manpower and expertise available.
- Internet user/programmer: Simple tasks can easily be executed by individuals.

Furthermore, there are two different kinds of tasks to be delegated because of their modest requirements concerning communication and coordination among the agents: first, development of components, such as modules or subroutines, and secondly, the testing of components. Quality is assured by not assigning development and testing to the same agent. A thorough documentation, however, is essential to both tasks. Agents executing development tasks are paid dependent on software quality. Agents assigned to testing are paid according to the achieved test coverage.

This procedure requires a very precise specification of the component functionality, its quality attributes and their measures. In the next step the tasks must be assigned to agents. Therefore, the PSP announces the specifications via Internet (e.g. on WWW pages). Among the potentially interested Internet users and software producers (representing the internal software market together with the PSP) the best choice might be determined by an auction scheme.

Having completed their individual tasks, the agents send the documented modules and the test documents to the PSP. The following tasks, such as overall quality assurance and integration testing, as well as validation and verification, should remain centralised at the PSP. Customer support and maintenance are also provided by the PSP, although maintenance can also be organised as another virtual enterprise.

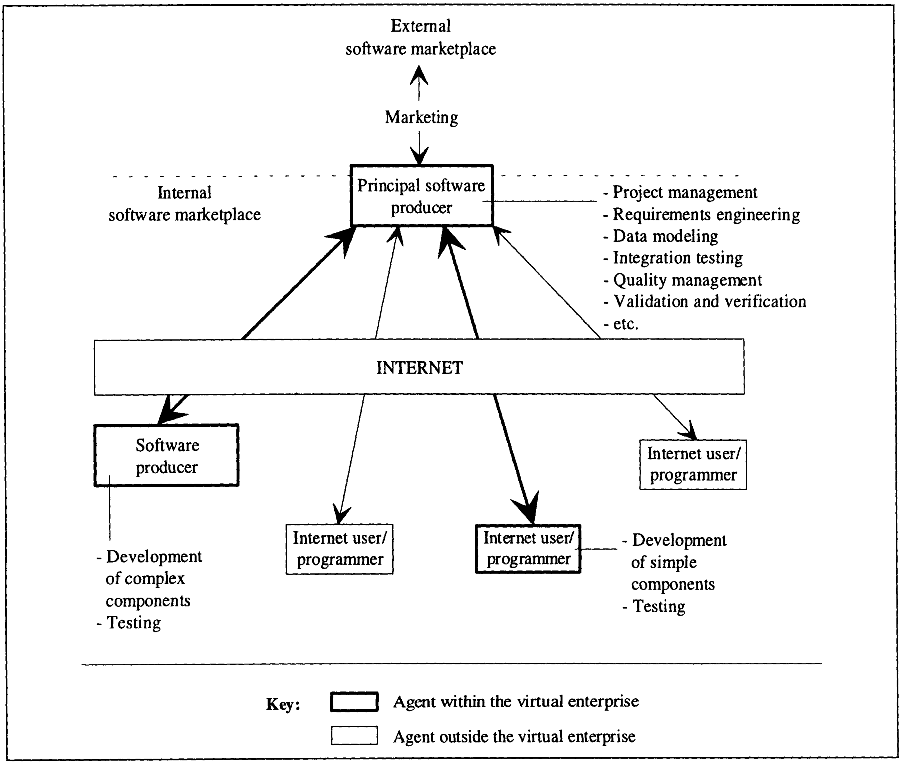

Figure 1 Basic structure of Internet-Distributed Software Development.

Apart from increasing efficiency, the most important advantage of integrating external agents (Internet participants) as freelance programmers is the increased flexibility as far as programming capacity is concerned. To date, dynamic markets such as the software market require such flexibility. The tendency to reduce fixed costs, in other areas common practice, will also reach software producers. IDSD might be a suitable approach to this challenge. Beyond the more organisational and technical problems such as described above, there are a few questions to be dealt with:

1. What mechanisms are required for the internal software market?
2. What savings could be expected?
3. Are there enough Internet users with the required skills?

In order to get an insight as far as questions 2 and 3 are concerned, we have conducted a questionnaire within the Internet. Some results are summarized in the following section.

3 RESULTS OF A QUESTIONNAIRE

In December 1995 we started a questionnaire on world-wide distributed software development. The questions deal with the interviewee's software development skills, Internet access and readiness to join world-wide distributed software development projects. The questionnaire was conducted via a WWW-browsable form (URL: http://www.uni-muenster.de/WiWi/quest.html). It was announced in programming-related newsgroups as well as in newsgroups with a completely different subject (e.g. groups concerned with games). The following analysis is based on replies from 108 Internet participants. When interpreting the results it is important to consider that this kind of survey has some specific restrictions. Due to the fact that newsgroup postings can be retrieved without a notification to its originator, the total amount of addressees and therefore the response rate can not be calculated. Furthermore, no generalisation can be made based on the results.

3.1 Basic descriptive results

Some basic descriptive results of the questionnaire are presented in Table 1. Amongst other details, the interviewees were asked to

- give a self-assessment of their skills concerning different programming paradigms and development platforms;
- judge the feasibility of IDSD;
- state whether they could imagine themselves becoming active in such projects. If their answer was "yes", they would be asked how much time they could spend and what hourly payment they would expect.

Table 1 Some basic descriptive results of the questionnaire

Age (years)	Mean 30.6	Std. Dev. 8.70	Median 29.0	Min - Max 13 - 54
Sex	Female 7.4 %	Male 92.6 %		
Professional activity	Employee 43.0 %	Scientist 16.8 %	other 14.0 %	
	Student 26.2 %	Home-worker -		
Programming paradigms	expert	experienced	some knowledge	novice
• Procedural skill	50.9 %	35.8 %	10.5 %	2.8 %
• Object-oriented skill	24.5 %	32.1 %	33.0 %	10.4 %
• 4GL skill	4.0 %	17.8 %	32.7 %	45.5 %
Feasibility of idea	feasible 94.4 %	not feasible 0.9 %	no answer 4.7 %	
Readiness to participate	yes 79.6 %	no 13.9 %	no answer 6.5 %	
Expected payment cluster (US$/hour)	Mean '22 - 30'	Median '22 - 30'	Min - Max 'less than 6' - 'more than 38'	
Time available (hours/week)	Mean 19	Std. Dev. 12.48	Median 15	Min - Max 5 - 65

Even without the analysis of relationships, the figures show interesting tendencies. The upper age limit of the respondents seems to be relatively low (the oldest respondent is 'only' 54 years old). An explanation for that might be that the 'pre-computer generation' is more interested in applications rather than in their development. Another interesting fact is that the majority of respondents belongs to the group 'employee' and not, as could have been expected, to the groups indicating academic background, namely 'scientist' and 'student'. The question concerning the country of residence resulted in the following shares: 45.4 % North America, 42.6 % Western Europe, 4.6 % Eastern Europe, and 7.4 % others.

The answers dealing with programming paradigms indicated that the knowledge about object-oriented programming or programming with 4GLs is comparatively lower than about procedural programming. Therefore, it seems to be realistic to consider IDSD based on the procedural paradigm (cf. question 3, previous section).

The positive feedback regarding the feasibility of IDSD is obviously highly correlated to the answering of the questionnaire. Thus, although this result should not be overinterpreted, it is encouraging from the authors' point of view.

3.2 Analysis of relationships among the data

The further exploratory data analysis was primarily conducted (a) to investigate the relationship between 'age' and 'time available' and (b) to explain the respondents' answers regarding 'expected payment'. In Figure 2 the relationship between 'age' and 'time available' for those respondents willing to take part in IDSD projects is depicted. As the median of the variable 'age' of this group is 30 and the availability of time is very high in this 'area' of the scatterplot the group of interest to IDSD projects might be persons around 30 years of age.

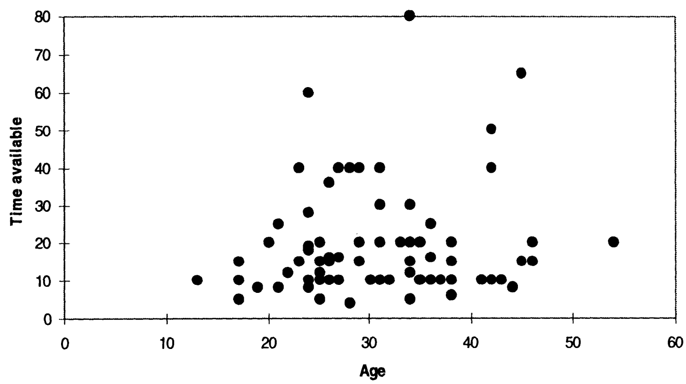

Figure 2 Scatterplot for the relationship between 'age' and 'time available'.

Our main focus was to investigate how the respondents implicitly tied up the expected payment. Therefore, we interpreted the 'age' variable and the variables concerning the respondents' skills regarding programming paradigms and development platforms as explanatory variables. In order to be able to carry out statistical tests, the answers to the questions concerning skills were transformed into numerical values ranging from 1 for 'expert' to 4 for 'novice'.

Furthermore, the answers indicating the expected payment were transformed according to the following rule:

- '1' means: expected payment smaller than US$ 6/hour;
- the subsequent values '2' to '5' represent intervals of US$ 8 each;
- '6' means: expected payment larger than US$ 38/hour.

The analysis of relationships among the data was carried out by means of correlation coefficients. We applied Spearmans rank correlation coefficient because the lowest scaling level of the variables under examination was 'ordinal'. The numerical results regarding the effect of these variables on the response variable ('expected payment') are depicted in Table 2.

Table 2 Effect of explanatory variables on the response variable ('expected payment')

Explanatory variable	Spearmans rank correlation coefficient	Significance
age	0.45172	0.00001
skill (procedural)	no evidence (-0.18136)	0.09669
skill (object-oriented)	-0.25416	0.01891
skill (4GL)	-0.34940	0.00129
skill (MS-DOS)	no evidence (0.01158)	0.91883
skill (MS Windows/NT/95)	no evidence (-0.17664)	0.11940
skill (OS/2)	no evidence (-0.05968)	0.65922

We have only assumed an effect if the significance level was 0.05 or better. Therefore, we were able to draw the following conclusions. There seems to be a strong effect of the 'age' variable on the response variable. The older the respondent, the higher the expected payment is. This can be put down to the fact that experience in general is considered to be a valuable qualification. An alternative explanation might be that the answers were under the influence of the respondents' current income which is positively correlated to the age as well. The coefficients and significances for object-oriented skill and 4GL skill also indicate an impact. The better the knowledge as regards object-orientation and 4GLs, the higher the expected payment is. This might be attributable to the rarity of this kind of skill. A correlation between the other skills and the response variable could not be proved, because the significance levels exceed 0.05.

4 CONCLUSION

IDSD seems to offer a new kind of division of labour. Each member is responsible for his or her part of the entire product although not being part of a 'real' enterprise. In the age of cost reduction (Benjamin, Blunt, 1992) and lean management this is obviously a promising approach towards developing software efficiently.

Virtual enterprises or IDSD projects as described above can principally be carried out based on the procedural paradigm. Qualified Internet users obviously are available ('qualified' according to their assessment). The age-group around 30 years seems to be especially interesting. The respondents of our questionnaire, at least, showed a rational attitude towards assigning expected payment to individual attributes.

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6 BIOGRAPHIES

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