3ADVANCED CAD/CAM TECHNOLOGIES ASSESSED FROM A USERS POINT OF VIEW – RESULTS OF A SURVEY –

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Abstract

Sophisticated CAD/CAM technologies for advanced product modeling in the sense of designing complete product variants become more and more relevant in future. Variational design techniques to support interdisciplinary design activities in different engineering domains as well as subsequent processes have to be developed. An essential task to reach this aim is to permanently investigate the current state of the art, new approaches, emerging trends, as well as industrial problems and requirements concerning the whole CAD/CAM community. In order to direct future R&D activities as close as possible to the continuously increasing requirements of a global market we carried out a comprehensive national study in cooperation with one of the Germans leading CAD/CAM magazines. In this way, it became possible to reach a representative amount of users, to receive their experience-based assessments on today's most important aspects of CAD/CAM technology. The results of this survey are summarized in this paper to give engineers, system developers, and researchers an overview of the current situation as well as to serve as an orientation for decision-makers in the IT-field.

Introduction

Over a period of nearly six months, the Graphical Engineering Systems Department of the University of Stuttgart has accomplished a comprehensive study on modern CAD/CAM technology. Within this study a broad users questionnaire was developed, the focus being on different aspects of parametric product modeling [1]. Via mail and telephone discussions numerous enterprises were analyzed in regard to both presently employed methods and technologies as well as their point of view on emerging trends for achieving technology thrusts. Since the whole branch is being under radical change for some time, specific problem definitions were considered and empirical reports were evaluated. The topics of the standardized questionnaire can roughly be divided into four categories:

i) Enterprise profile.

ii) Parametric and variational design.

iii) Product variants as well as parametric product and process modeling.

iv) Interdisciplinary global engineering processes and other trends.

This paper summarizes the results of the accomplished study and makes them accessible to the public. Apart from a statistic evaluation illustrated by associated graphics, causes for the achieved results shall be explained. Beyond this, the relevant technical background is described and range-spreading connections between the individual questionnaire categories are revealed. In order to judge the statements and results of this study appropriately, this report starts with some necessary statistic information concerning the enterprise and personnel profile of those taking part in this study.

Profile of interviewed persons and analyzed companies

Examining the analyzed companies and persons who participated in this study, the following profile can be observed: As expected, the biggest response was obtained from the branches of general mechanical engineering and the automobile industry, which made up a total of approximately 75%. The remaining 25% of those taking part were almost symmetrically split up into the branches plant engineering, tool and molding industry, electrical engineering and electronics, as well as precision engineering (cf. figure 1).

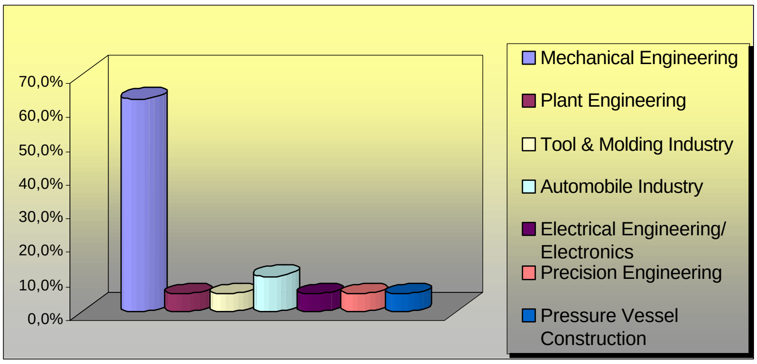

Figure 1: Branches participating in this study

Considering the number of employees, small enterprises having less than 50 employees and middle class enterprises having up to 500 employees yielded approximately 70% and hence the bulk of questionnaires to evaluate. The percentage of large companies with more than 1000 employees amounted to 16% (cf. figure 2).

In order to proportionally judge the answers given, also the participants position within their company was under scope. Over 50% of those taking part were heading an engineering or design department. The percentage of managing and technical directors amounted to approximately 16%. The remaining part was uniformly distributed on chief designers and other design employees.

To get a better assessment of information concerning the time for a product to pass the whole process from order through design and manufacture up to delivery, the number of design employees involved in this chain was also important to take into account. In 40% of the consulted companies the design department employed less than 10 collaborators. In the remaining 60%, the number of design employees ranged from 50 to 100. At this, the companies with larger design departments were counted among the well-known branch giants of mechanical engineering and automobile industry, of course.

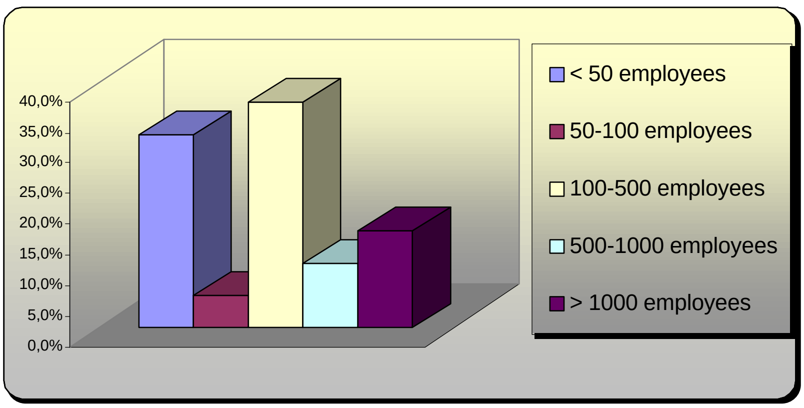

Figure 2: Number of employees of the participating companies

Regarding the number of employees involved in the whole design to manufacture process, the share of design employees in contrast to other staff turned out to be relatively small. However, in future a lot of new jobs will arise in this engineering domain as well as in many other fields associated with modern IT. Even today, the whole branch is imploringly looking for qualified specialists. A primary reason for this is the radical change the whole branch has to endure at the moment. The difficulties resulting from this deal with both technology and staffing. On the one hand more and more old served specialists experienced in conventional design techniques are prematurely retired whereas on the other hand not enough highly qualified specialists being familiar with contemporary methodologies can be acquired and educated at the same degree. Beyond that, graduates usually have a lack of professional experience that only can be gained over the years of a whole working life. Such practical experience can be essential for a company in order to optimize their product design, even using latest technologies and tools. However, it must be admitted that meanwhile the education of designers and design engineers has become a rather difficult task since their job outline changed enormously in recent years. In the past, usually a parallel process of learning was performed that allowed to learn both technical knowledge and handling of necessary tools and equipment at the same time. Over the following years of professional life, technical know-how was gained and extended by and by, whereas equipment and tools often remained unchanged over several decades. In these days, however, a design engineer has to be a real all-rounder. Of course, it should be taken for granted that a designer's technical knowledge always has to be excellent and up to date. Today, design tools and other equipment is often out-dated at the end of the training period. Beyond that, in these days design employees have to handle floods of small and large software packages performing various tasks to facilitate their work. As well, there have been serious changes in respect to design strategies and even fundamental design philosophies. This aspect will be picked up again later to be discussed under another point of view.

Design departments – staff, equipment, methodologies

Today rationalization processes have become one of the most powerful means to increase productivity in almost any industrial domain. At the beginning of the rationalization era, approaches focused mainly on the manufacturing part of product development. Meanwhile rationalization processes more and more affect fields that used to be controlled by humans in the past. In this context rationalization means that parts or even entire subprojects of a product to be designed more frequently become subject to outsourcing.

In the meantime the majority of companies have realized that potentials for efficient and economic product development in respect to manufacturing side are nearly exhausted and that from now on progress can only be obtained by finding really pioneering innovations. This situation is comparable to that in design and development departments. In the early stages of product development far-reaching decisions concerning the entire product life cycle from design through manufacture to recycling have to be made. There, enormous potentials in respect to time and cost reduction can be released by using advanced IT systems and solutions. The idea to rationalize the early stages of product development has not been considered for a long time since employers used to have a more manufacturing oriented way of thinking having its origin in the age of industrialization. To release the above mentioned potentials, advanced mechanisms, approaches, and systems to support designers and design engineers have to be used. Apart from the employment of contemporary 3D-CAD-Systems, efficient variational design techniques such as parametric modeling as well as approaches to computer aided idea processing, sketching, and drafting [2] are examples to mention here.

Addressing the situation from another point of view, it turns out that there are also physiological and psychological aspects of design work that can affect a project in regard to efficient and successful proceeding, and therefore should be taken into account. Some examples to support this are the issue of a decree concerning guidelines for visual display units of work stations as well as recommendations for the arrangement of graphical user interfaces [3] derived from special examinations. Among other aspects, these recommendations serve to protect the users eyesight, to maintain its power of concentration, and to achieve a preferably intuitive system handling.

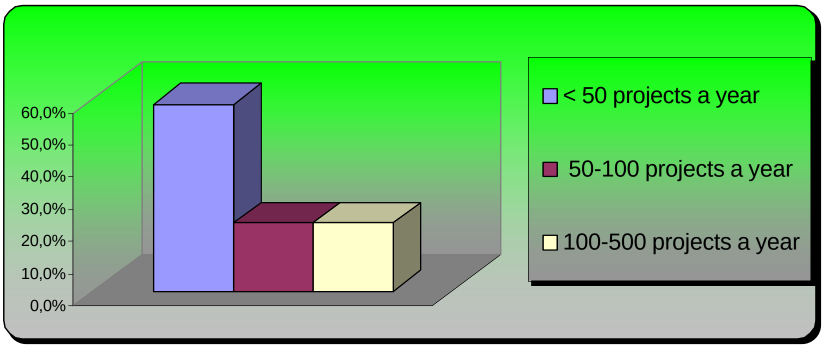

Figure 3: Average number of projects per year

In order to analyze the actual state of affairs on current design activities of those participating in this study, several questions had to be answered; the number of projects to be transacted within a year and average times needed for the entire process from order to delivery. Hereby, especially the percentage of different kinds of design such as design from scratch, redesign, adaptational design, and variational design in respect to their percentage of the overall design expenditure were taken into account. Beyond that, the relevant statements concerning the aspects mentioned before were considered in connection to the design systems and tools used (conventional drawing boards, 2D CAD systems, 3D CAD systems) and yielded the following results:

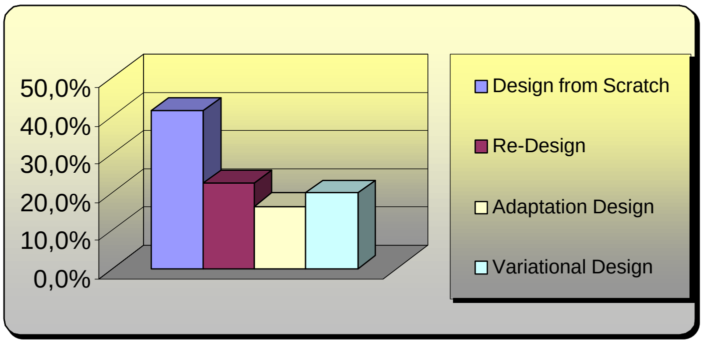

Figure 4: Overall percentage of different design types

Based upon the yearly number of orders and projects to deal with, three categories could be derived. In approximately 60% of the analyzed companies, design departments have to deal with less than 50 orders/projects a year. The remainder conclude they would have to deal with 50 to 100 or 100 to 500 orders/project per year, respectively – each at a percentage of 20% (cf. figure 3). The percentage of different design types emerged in a way that was not expected at all. In comparison to studies carried out in the late eighties and early nineties, a temporary new trend could be observed. For the part of new design we evaluated a percentage of 41% whereas the above mentioned studies of the past usually came up to a share of about 20%. The remaining 59% were almost equidistantly distributed on the three other design types (cf. figure 4). At this point it has to be stressed that the terms redesign, adaptational design, and variational design were not always understood and used in the same way. Often all three terms were considered as nuances of variational design and hence it may have been sufficient to distinguish between design from scratch and variational design. Appropriate definitions for the mentioned design types can be inferred from the relevant technical literature [4].

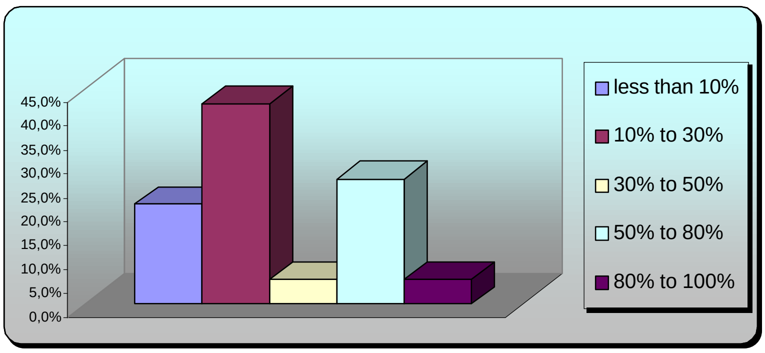

Figure 5: Percentage of design from scratch

After evaluating questionnaires it can roughly be emphasized that the overall ratio between design from scratch and variational design (in the above mentioned sense) amounts to approximately 40:60%. A more detailed classification relating to the percentage of the different design types is illustrated in figures 5-8. This rapid raise in the field of design from scratch in contrast to earlier studies may result from the following circumstances: At the beginning of the nineties, Germany became a reunited state after being separated for more than 40 years. As a direct consequence a growing industrial landscape was formed and lots of new companies were founded. The majority of those companies had to start their engineering from scratch, so the field of design from scratch became very active.

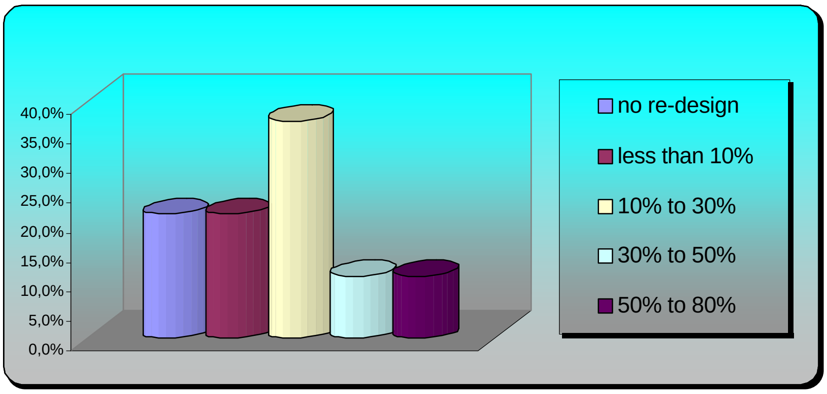

Figure 6: Percentage of re-design

But there was also another, more technological aspect that caused increased design from scratch activities: As generally known, the first half of the nineties brought along a technical change that mainly affected the majority of companies already established on the market for a long time. At that time, CNC (computerized numerical control) machine tools and other kinds of automatic control engineering gained broad acceptance and were phased into production plants. In design departments well-tried design methods using rulers and compasses for pen-and-ink-drawings on conventional drawing boards were replaced by two-dimensional CAD systems and computer aided FEM (finite elements method) tools. However, professional tools for converting technical paper drawings into digital CAD models were lacking. Hence, many times parts and products were simply re-designed using the new CAD technology. Strictly speaking, this design methodology should better be called re-engineering or re-design instead of design from scratch.

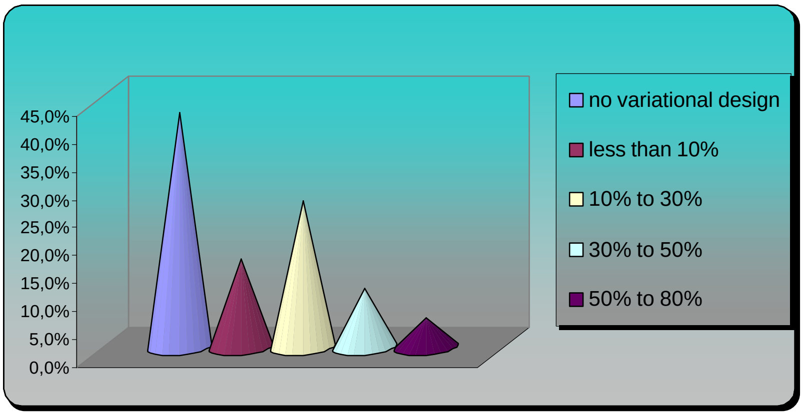

Figure 7: Percentage of variational design

Today, a similar situation becomes apparent: For now about three years, the whole CAD/CAM branch has to overcome a radical change in regard to replacing 2D CAD systems by 3D CAD systems. However, this replacement seems to be more difficult than the past transition from drawing boards to 2D CAD systems. To overcome the latter, engineers

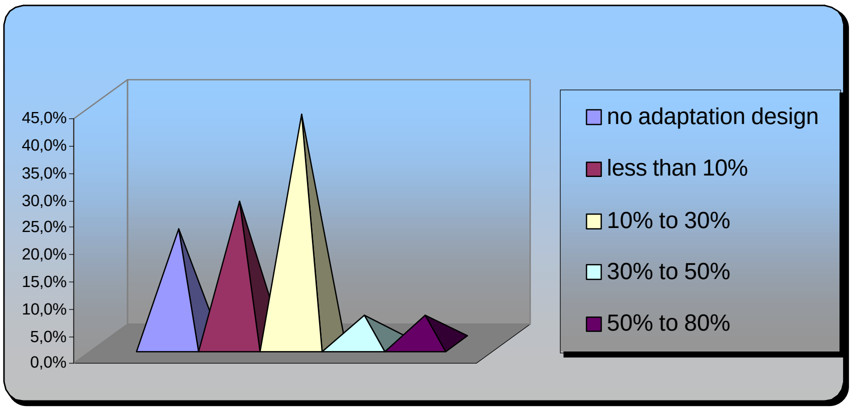

Figure 8: Percentage of adaptation design

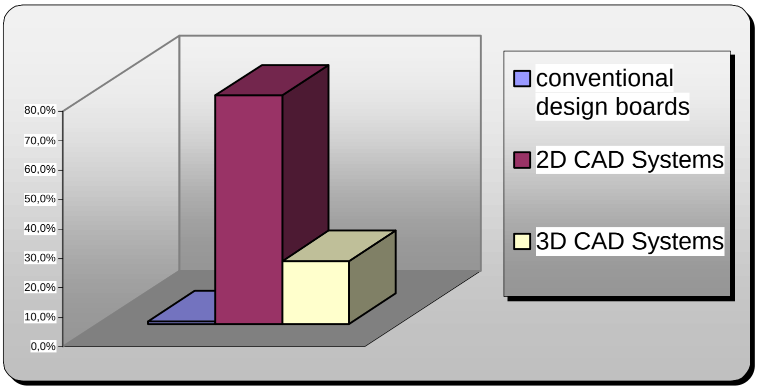

Figure 9: Average overall percentage of used design devices

only had to learn the handling of a computer system and an associated software package for CAD. With the exception of the electronic devices and tools, changes concerning the basic fundamentals of design were negligible. However, the technology change in respect to contemporary 3D-CAD technology requires a little bit more to take into account. Handling the advanced features of a new generation of CAD systems partly means to learn advanced design methodologies in respect to performing design activities.

The development of new products is more and more done in an object-oriented manner. That means, that products are designed using an object-oriented hierarchy representing assemblies and components to make up a building-block-system. Later, such components can be standardized and parameterized to be stored and re-used in other projects in case of need. This kind of product development based on modularization and standardization is very well suited to support variational design techniques and configuration-driven automatic design [5]. Furthermore, today components and parts are often designed on a more abstract level, i.e. by using manufacturing oriented commands for their generation (e.g. mill, extrude, turn, etc.) and/or parametric form features [6] to place them on desired locations having the specified shape. In recent years, designers have considered two-dimensional technical drawings as “the measure of all things”. Nowadays models are generally created in three dimensions, so two-dimensional drawings are only of minor relevance. Besides that, 2D drawings typically can be semi-automatically derived from 3D models.

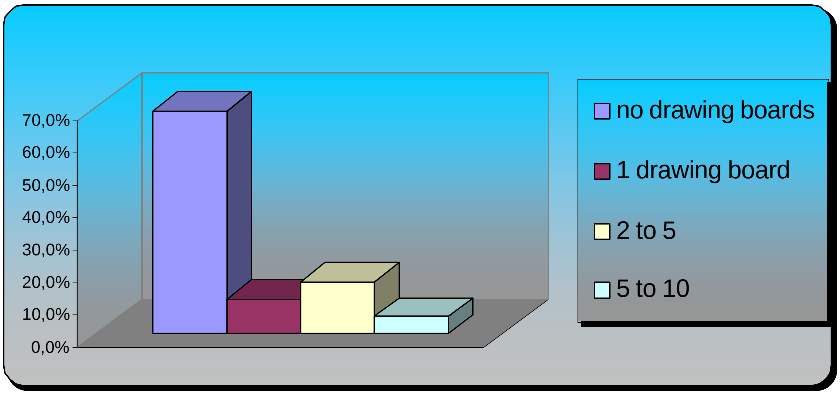

Figure 10: Number of conventional drawing boards used

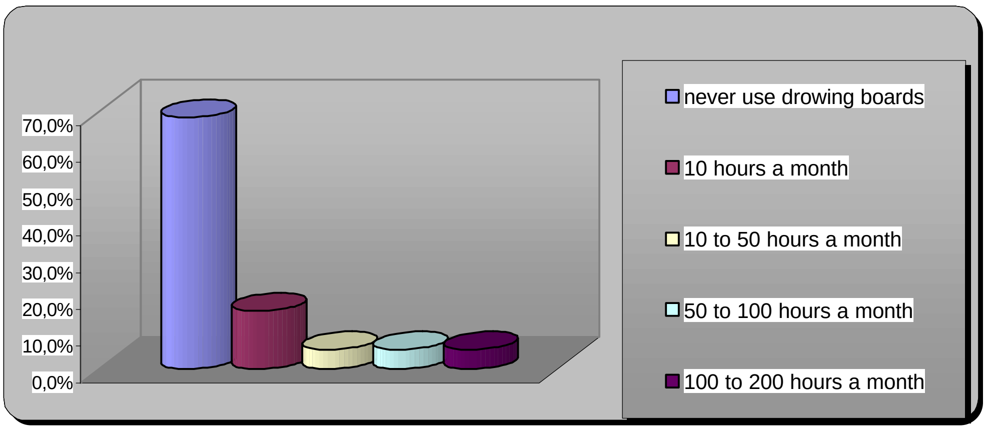

Figure 11: Average usage of conventional drawing boards in hours per month

Considering again the increased share of design from scratch, the following can be stated: For the time being, an automatic generation of 3D models out of existing 2D models is not supported in CAD systems. Hence, the bulk of existing 2D drawings is either used only within 2D environments or, if

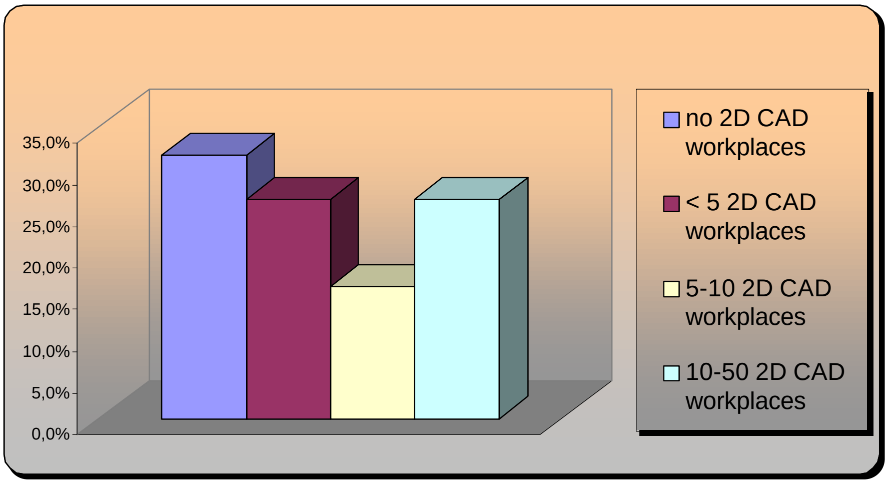

Figure 12: Number of 2D CAD workplaces used

necessary, be re-designed within a 3D environment. Analyzing the connection between the lead time of projects, applied design methodologies, and used tools, the following results were found: Apart from the projects nature and the relating size of order, lead times in general strongly depend on the kind of design (design from scratch, re-design, adaptational design, variational design) to be applied. Variational design usually requires the lowest amount of time, followed by re-design and adaptational design. Practicing design from scratch is most time consuming, of course. Another point of significant importance is the kind and the degree of computer assisted tools employed.

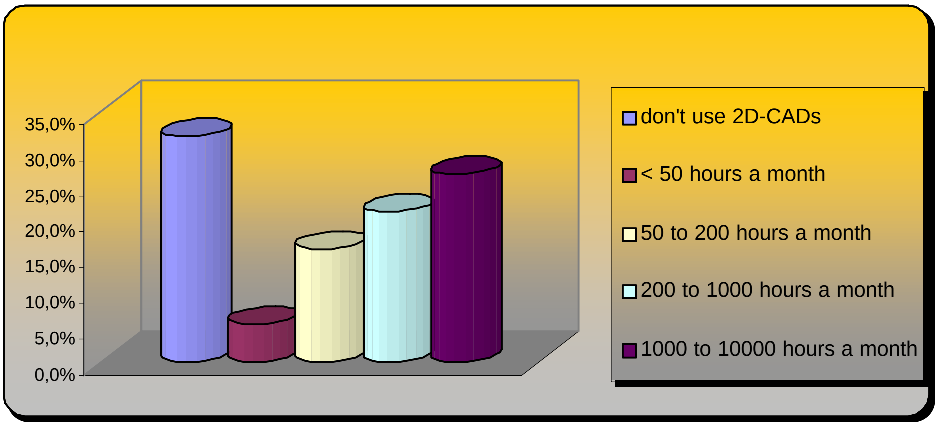

Figure 13: Average usage of 2D CAD systems in hours per month

Comparable project requirements assumed, worst lead times could be observed at companies employing mainly 2D systems, supported by some conventional design boards. This indicates that the change from drawing-table-design to 2D CAD still has not been realized completely in those companies. The best lead times could be observed at companies using 2D and 3D systems in a ratio of approximately 75:25%. Here, the entire design process is reliably handled by 2D systems and the change to 3D systems technology is performed in well organized steps. In this way, the share of 3D designed projects can be increased by and by, according to the gained knowledge and practical experience. Unfortunately, no representative company that exclusively uses 3D technology took part in our study. This indicates that even today 2D CAD systems are still relevant and widely used in practice. To summarize from the users point of view, for the time being, a combination of a majority in numbers of 2D systems

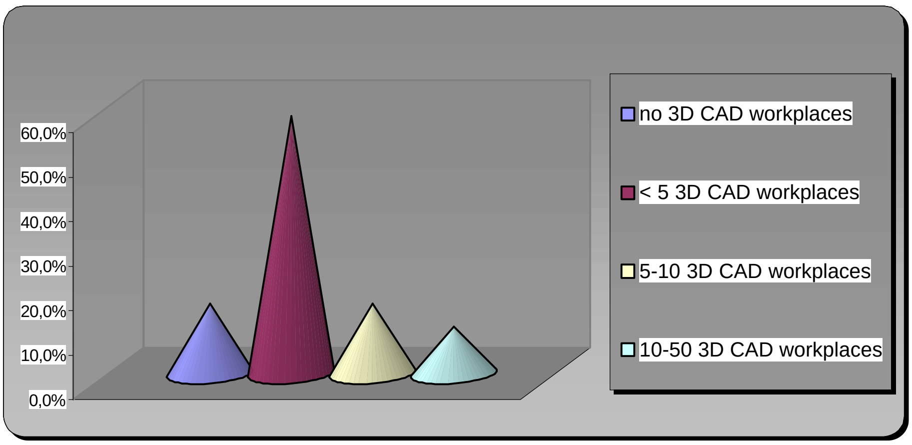

Figure 14: Number of 3D CAD workplaces used

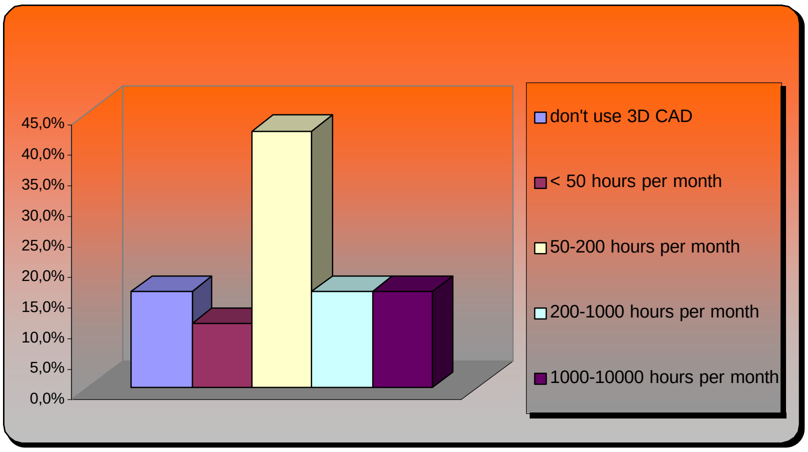

Figure 15: Average usage of 3D CAD systems in hours per month

and a successive increase of 3D systems seems to be a promising choice. However, from a competitive point of view a general use of 3D systems should be aspired as a long term target. Taking into account the total number and time of use of employed design devices from a statistical point of view, a percentage of 1% conventional drawing boards, 78% 2D CAD systems, and 21% of 3D systems was averaged out (cf. figure 9). A more detailed breakdown of the average use of devices put into total hours can be inferred from figures 10-15.

Parametric and variational design

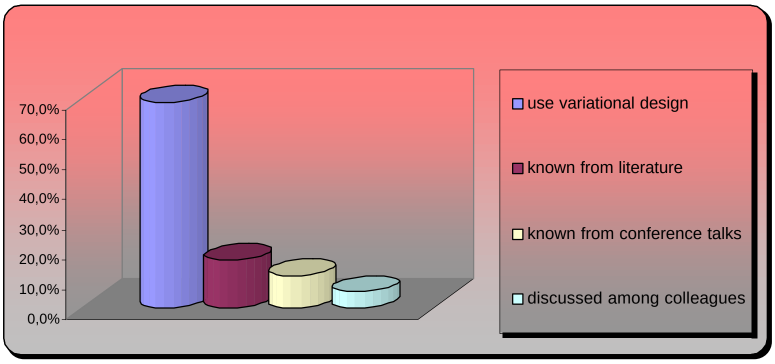

Figure 16: Knowledge of variational design techniques

As already mentioned at the beginning of this paper, the second part of our survey focused on parametric and variational design [7]. It was the intention to find out whether the participating companies were familiar with variational design or not, which kinds of variational design currently are being used, and to what degree an efficient re-use of existing drawings is possible at the moment. Furthermore, the future importance for variational design as well as the expected potential of cost and time reduction within different engineering domains should be examined.

Fortunately, 100% of the persons questioned confirmed to be familiar with variational design fundamentals. Going further into detail, we found out that variational design techniques – even though sometimes practiced in a simple and pragmatic manner – are used in about 70% of the examined companies. The remaining 30% stated they had read technical literature on variational design, listened to relevant talks on conferences, workshops and symposia, or had had discussions among colleagues (cf. figure 16). The fact that approximately 48% of the analyzed companies are able to create design variants of their

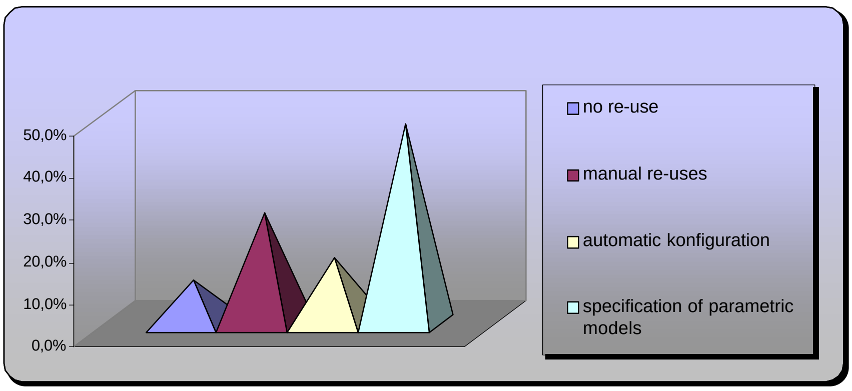

Figure 17: Re-use of existing drawings

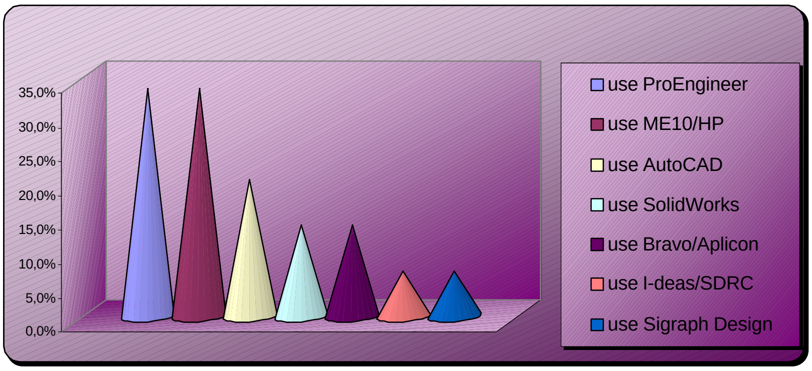

Figure 18: CAD systems used to practice variational design

products based on the principle of parametric modeling is an evidence for the industrial acceptance of the benefits arising out of variational design technology. Almost 16% stated to be able to create design variants of standardized and modularized products using an automatism for composing existing parts, components, and assemblies. Hence, a total of 64% disposes efficient mechanisms for reusing existing drawings. On the other hand, however, in 36% of the analyzed design departments existing drawings can either be reused only in manual manner (i.e. by copying and altering an existing project) or not reused at all (cf. figure 17).

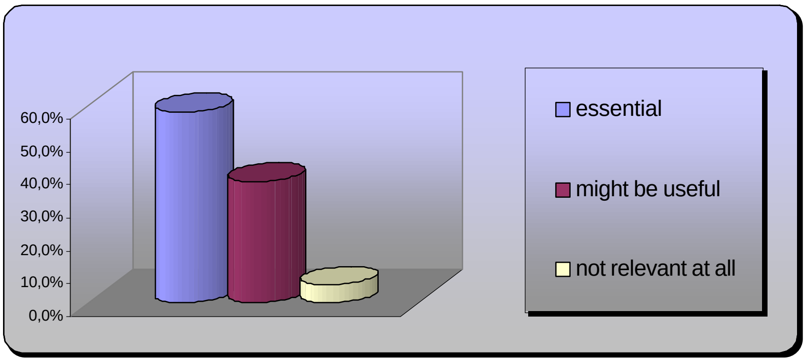

Figure 19: Future relevance of variational design

About 80% of the companies having variational design methods at their disposal use special parametric models as supported by their CAD-system packages (cf. figure 18). In the minority of cases add-ons from other independent suppliers are used. At this point is has explicitly to be stressed that figure 18 shows only those CAD systems which have been directly mentioned in regard to parametric modeling within this study and hence does not represent market shares of any suppliers of CAD/CAM systems. Also, many more suppliers offer professional tools for reusing existing constructions.

60% of those participating in this study stated variational design to be an extremely important technology for their future design activities (cf. figure 19). Assuming that appropriate tools can be developed and put on the market in time, the importance of variational design might raise up to 85-90%. Asked for their rating on the potentials of variational design to be released in respect to cost and time reduction the following answers were given: The

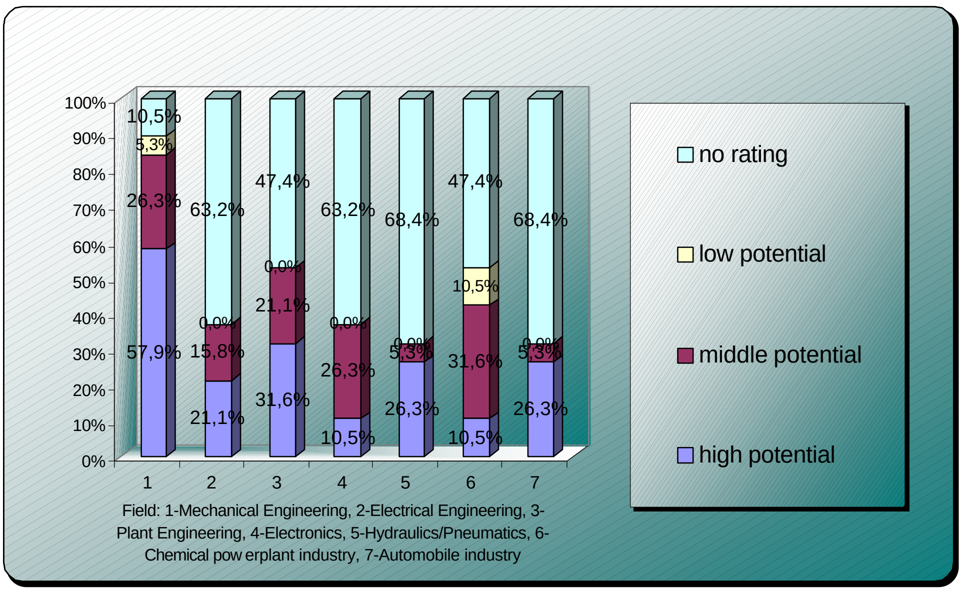

Figure 20: CAD systems used to practice variational design

highest degree of potentials to be released was predicted for the branches of mechanical engineering, plant engineering, automobile industry, hydraulics, and pneumatics. This rating reflects some positive experience with variational design techniques already gained in those fields. Other industrial branches having no or only inadequate variational design tools on their disposal therefore have a more critical tenor to this topic. More details on the predicted potentials from different industrial branches can be inferred from figure 20.

Product variants – parametric product and process modeling

Another important topic of the study focused on the generation of complete product variants. In order to realize such product variants, advanced approaches to parametric product and process modeling have to be developed in future. Currently more than 60% of the analyzed companies offer several variants of their products. 30% stressed their customers could choose several variants out of a range of products, even at the time an order is to be placed. About 20% of the companies offering product variants also produce their big sellers for storekeeping. Even 10% have techniques on their disposal that, apart from an automatic generation of a complete set of design documents, allow to support subsequent processes (e.g. manufacturing) starting from a specification of a concrete product variant in a placed order. However, 31% admitted product variants were not of economic relevance for their companies at all.

Statements like this may be caused by the following reasons: Adequate tools for parametric modeling are currently only available for mechanical engineering. In any other engineering domain, there is still a lack of such techniques. Another reason is that the idea of building a parametric model affecting the complete process of product development – which goes far beyond classical parametric modeling – is rated to be a quite difficult task in the opinion of most design engineers. Sometimes, people say that the CIM concepts developed in the mid-eighties had been to complicated to be realized, hence CIM had failed. Of course, this is not quite correct. On the one hand it has to be admitted that in those times visions about the comprehensiveness of realizing a full automatic product development process covering all phases from design to manufacture had been pretty utopian. On the other hand it has to be stressed that the ideas and concepts of those days were not bad in general, and that – even if simplified – many things have been put into practice in an outstanding manner. Meanwhile the real reasons for comprehensive computer integrated manufacturing to have failed have been recognized and can be avoided in future.

In the past the rapid raise of the requirements of a global market as well as the continuously increasing pressure of competition going along with it had always been underestimated. This keen competition enforced companies to produce not perfectly matured innovations faster and faster. But this phenomenon, however, was not the main problem. A significantly serious matter were the mistakes taken in translating the concepts into practice. Often the aspired realization concepts were too inflexible in their data processing nature, hence systems were hardly to maintain and extend. Furthermore, some large-scale enterprises had the illusion to be able to develop an outstanding and trend-setting CIM concept to serve as an orientation for the remainder of the over-all market. This way of thinking resulted in many power struggles and made companies fighting running battles with each other, explicitly in committees actually convened to generalize and standardize concepts, approaches, and technical terms.

From today’s standpoint the illusions of the CIM community of those days have remained almost the same. The things market demands for in general are nothing but the former requirements. Fortunately, in contrast to the past, today enough experience on fundamental base technologies to support each phase of the product developing process has been gained. Therefore, appropriate interfaces to link these phases can be realized. In future CAD/CAM systems, product modeling of complex product variants using parametric based design technologies mustn't be self-sufficiently performed in proprietary systems. Instead, the ideal case would be to connect several phases of the product developing process by using parameters and constraints in order to achieve a straight process. To put this into practice, among other things researchers demand for innovations in the following fields: Development of decentralized knowledge bases and active knowledge management systems, enhancement of the simultaneous engineering concept to be applicable to globally distributed locations, development of interdisciplinary constraint modeling approaches, i.e. methods to model and propagate dependencies between CAD systems of different engineering domains involved in a common product development process [8], as well as a considerable enhancement of current methods to support standardized product date exchange between different computer aided design systems located at different places in the world [9].

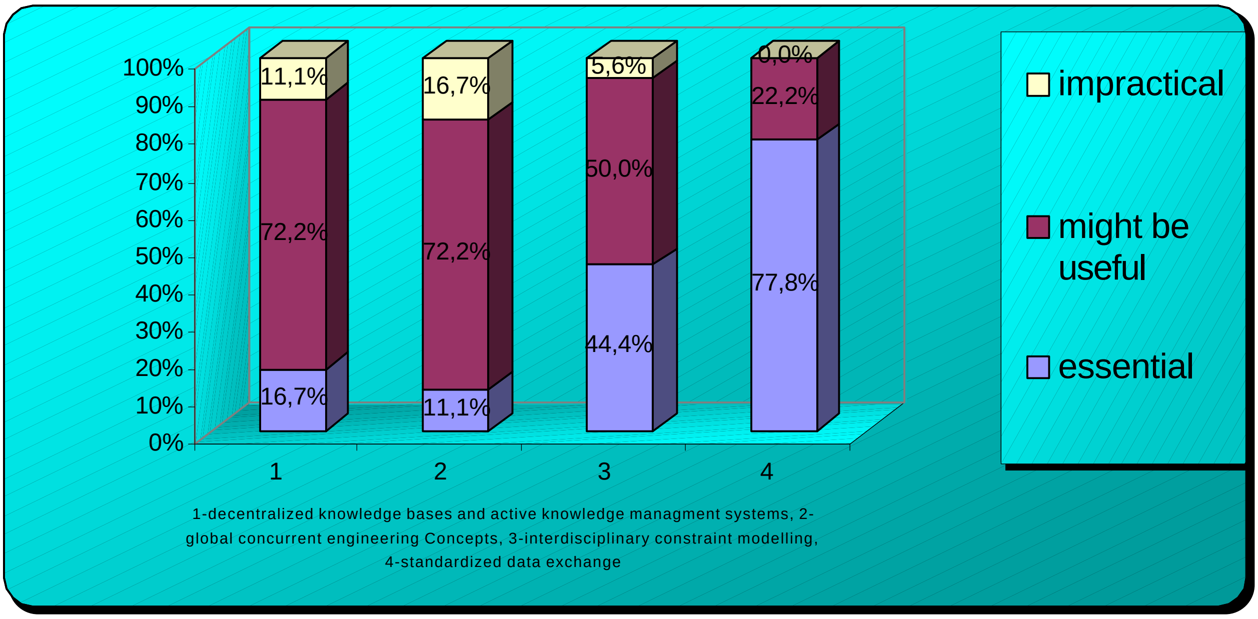

Figure 21: Assessment of approaches for developing product variants

Within this study, participants were asked whether they asses the above mentioned IGEP topics as essential, useful, or impractical. The given answers on standardized product data exchange were not surprising. 78% stated this technology to be revolutionary and essential for the future. The remainder stated the enhancement of product date exchange methods at least to be useful in the long term. This hundred percent agreement to standardized product date exchange expressed by the above stated percentages confirms explicitly the work done by STEP (Standard for The Exchange of Product model date) experts who often had a hard time of it with industries at the beginning of the STEP activities. Meanwhile mature STEP-based products are available on the market.

A similar positive feedback was determined in respect to interdisciplinary constraint modeling. 44% stated such approaches to be essential and 50% to be useful. Only 5% were of the opinion that constraint modeling and propagating between different engineering domains was quite impractical. The CAD/CAM experts statements on decentralized knowledge bases and global simultaneous engineering were also quite interesting: Approximately 72% rated these fields to be useful. More detailed information on these ratings can be inferred from figure 21. In order to get another impression on the future relevance of product variants, companies were asked about the number of product variants available now and the number to strife for in future. Unfortunately, no general result could be derived since the stated numbers were quite specific for the relating product. Most companies estimated the range of product variants to be offered between 200 and more than 1000. They also mentioned there customers would have a continuously increasing demand for more product variants.

A further point of scope in this study was to determine the main problems and difficulties for dealing with product variants from a CAD users point of view. About 50% said the CAD systems variant features would not be sufficient and professional mechanisms for variant management and versioning were either unsatisfactory or lacking at all. 17% of the questioned persons who are heading a design department stated their designers were poorly trained in respect to applying variational design methods. This is not surprising because modern variational design techniques are usually not taught at designers vocational training and an additional expert training as well as practical knowledge consolidation are not common practice. Now the question is how to find a way out this dilemma. This problem can be approached by both system developers and vocational training. To offer modern education and training, universities, vocational schools, and institutions for further education should - slowly but surely - delete some traditional methodologies from their teaching curriculums and replace them by contemporary concepts. First of all, this requires to amend courses of study and exam regulations what usually goes along with the difficult task to get over a high degree of bureaucracy. The second suggestion for improvement is mainly addressed to system developers and their training courses. Selling a CAD system usually includes a special training course for users. Unfortunately, in the past training courses often focused on giving users a short introduction to the (graphical) users interface and a rough overview of the systems features. Another important point to pay attention to is the explanation of the systems underlying fundamental concepts. Without any specific knowledge on this, an efficient and successful use often is hard to realize since many features require special design methodologies to be applied.

Fortunately, herein a positive change can be observed for some time. Meanwhile more and more system developers hold their teaching courses directly on-site at their customers instead of inviting them to central training centers. In this way, customers can learn and check the features of the new system trying to work on concrete problems or projects of their daily work. Among others, this bears the following two advantages: On the one hand the persons to be trained are absolutely familiar with the technical aspects of the given problem and hence can spend their full attention to concentrate on the new CAD system. On the other hand this kind of course work is a good value to attending a course at another location. Considered from the stand point of cost control, the course time has not to be credited as hundred percent training time. Due to the fact that designers can proceed working on current projects in spite of being trained usually means a real benefit for the department concerned.

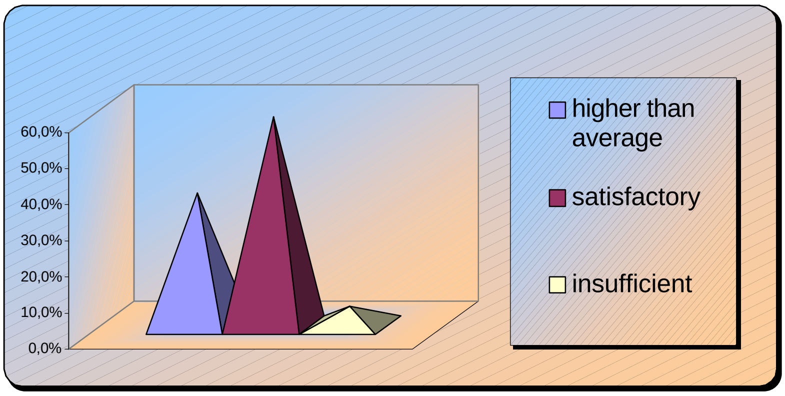

Figure 22: Companies readiness for innovations

In order to realize the concepts regarding an interdisciplinary global engineering process (IGEP) already mentioned in a previous section, companies are requested to increase their willingness for innovative work in future. As we found out in this study, small and middle-sized enterprises typically lack a minimum of entrepreneurial preparation to take risks. That means, they often are either not willing or economically not able to employ (and test) new developed design technologies and systems. However, especially for small and middle-sized enterprises a well timed courage for technology thrusts can play an important role in respect to succeed or fail in today's severe competition. Answering our questions on their companies readiness for introducing innovations (cf. figure 22) 58% stated this readiness to be satisfactory. Scarcely 37% rated the readiness for innovations of those responsible for IT in their companies higher than average. This indicates that the severe criticism referring to this in the past has borne fruit, and hence the bulk of companies meanwhile have realized that readiness for innovations has become a modern economic good.

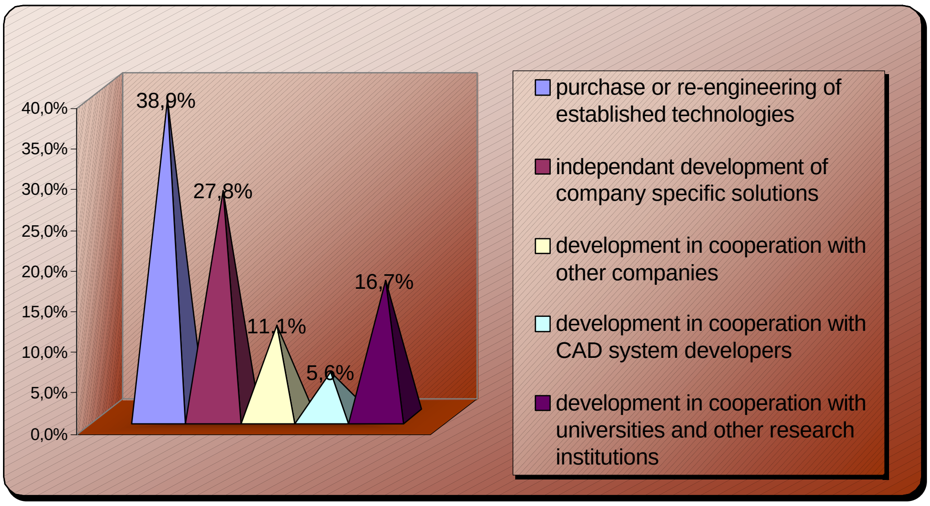

Figure 23: Ways of introducing innovations

A further interesting point to examine was to find out in which ways innovations usually are introduced. 39% stated their companies would keep an eye on the market to purchase a technology or to practice reverse engineering whenever something of value for their demands had proven to be successfully in use somewhere else over a period of time. In order to gather technological protrusion, approximately 28% of the analyzed companies independently try to develop technical solutions to keep any relevant Know-how on their own. At the moment an amount of 17% of the innovative work is done in cooperation between universities or other research institutions and representatives from industry. As expected, the amount of joint work projects in research and development between several CAD users or several CAD users and CAD system developers, respectively, was relatively small due to the fierce competition (cf. figure 23). Joint work projects between industrial partners are usually performed only in such cases that both partners have a common share of a special market segment.

Emerging trends

The final topic of this study was to examine which CAD/CAM technologies currently are being used, to what degree, and which technologies additionally or to a higher degree shall be used in future. Moreover, users were asked to make up their mind on the degree of benefit to be expected by those technologies. A point not to conceal is some criticism taken from the community of CAD users. They were asked which fields of computer aided design would leave a great deal to be desired and in which fields innovative work would have to be emphasized. Examining the technologies employed (cf. figure 24) about 90% stated to use 3D-CAD-system – even if sometimes just for proving.

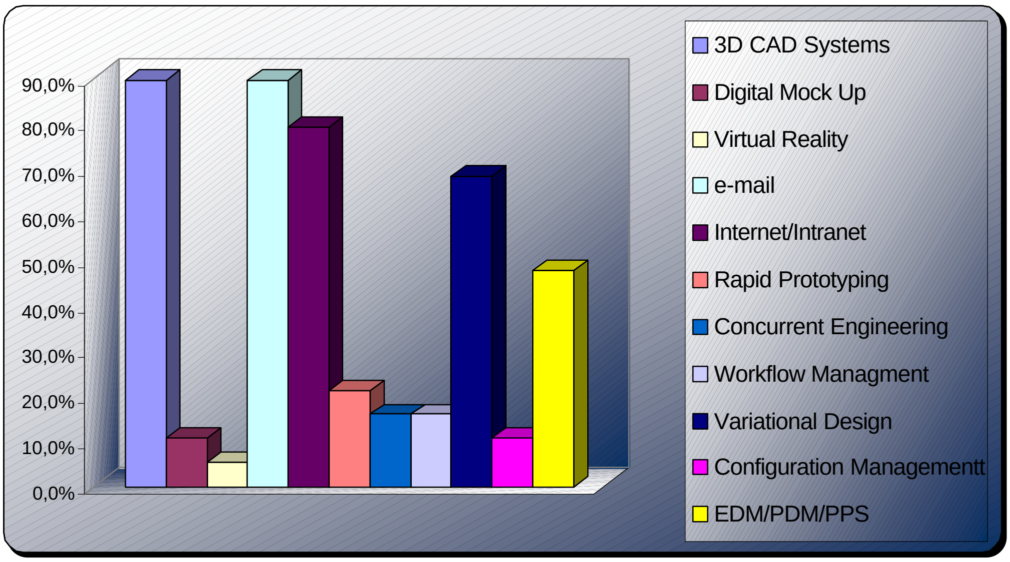

Figure 24: Currently used CAD/CAM technologies

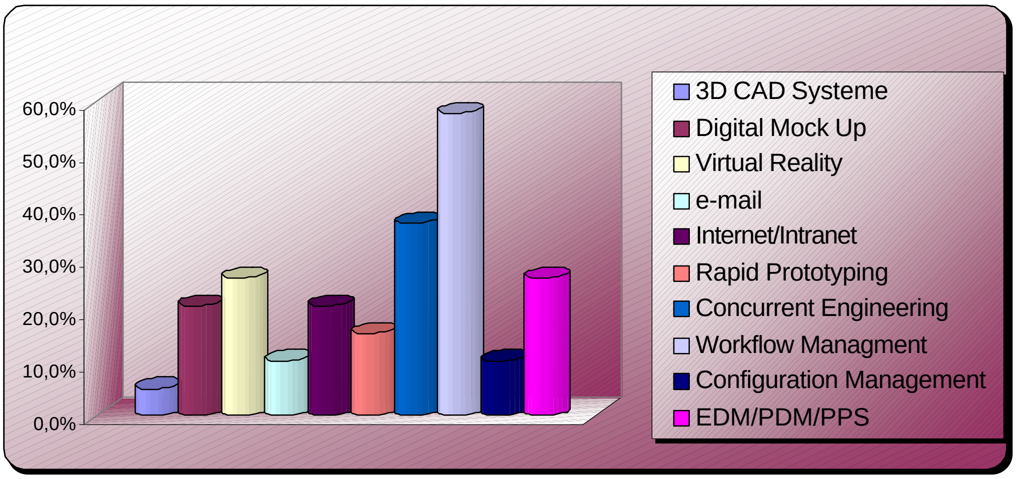

Figure 25: CAD/CAM technologies to be used at a higher degree in future

A similar high degree of usage could be determined for internet and e-mail. Hereby many employees mentioned they would have access to e-mail but they were refused to have full access to the WWW since their companies were afraid of misuse. At this point it shall be mentioned that the required amount of cost and time to check if WWW sessions are exclusively used for business probably is much more expensive than tolerating employees “to surf once in a while”. A more serious matter, however, is that refusing full access to the WWW also means to refuse access to the worlds most up-to-date and comprehensive information stock.

Our questions on the employment of variational design and EDM/PDM systems resulted in relatively high usage statistics of 68% and 48%, respectively. The stated amount for the current employment of digital mock-up, virtual reality, rapid prototyping, concurrent engineering, workflow and configurations management was only in the range of 5-20%. However, exactly these are the technologies stated be used additionally or to a very much higher degree in future (cf. figure 25). In respect to the expected benefits of modern IT technologies and approaches CAD users made up their mind as follows: Technologies to yield a middle or high profit are 3D-CAD-systems technology (83%), concurrent engineering (68%), standardized product date exchange (63%), digital-mock-up (52%), as well as rapid prototyping (52%). Technologies such as virtual reality and Engineering on the Web are expected to yield a lower profit. A simple reason for this may be that those technologies are currently not really public domain and therefore users don’t have enough experience with those technologies to rate them fair. More detailed information on this can be taken from figure 26.

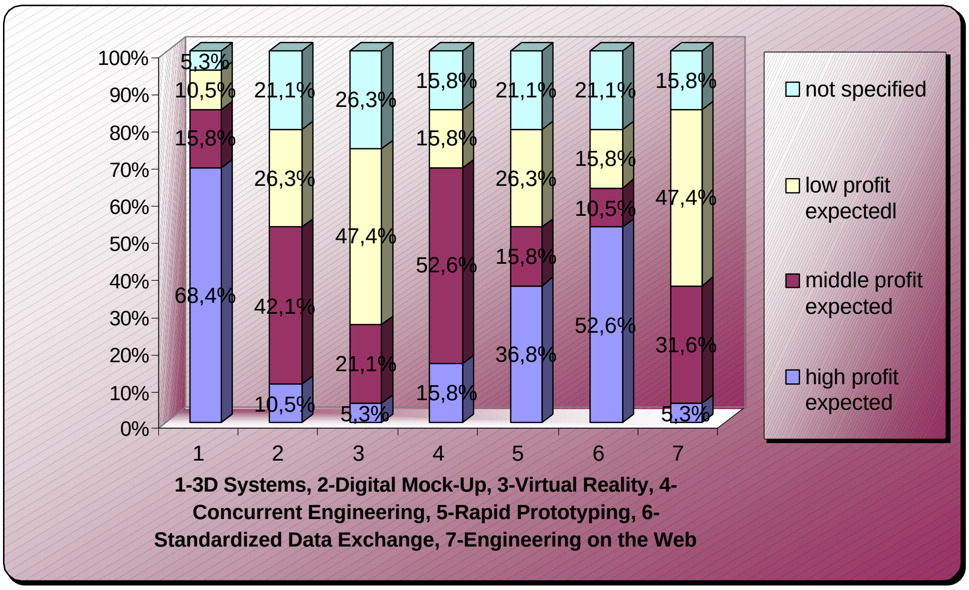

Figure 26: Expected benefits of modern IT CAD/CAM technologies

Conclusion

This paper summarized the results of a study concerning advanced CAD/CAM technologies in respect to developing product variants. It has been outlined which technologies currently are being used and which methodologies will be preferred in future. CAD users as well as designers have been asked to rate several modern CAD/CAM technologies in respect to practice relevance and the relevant degrees of profit to be expected. Furthermore, problems in respect to the realization of product variant design have been discussed. This survey is meant to give engineers, system developers, researchers and decision-makers in the IT field an orientation guide for their future decisions and activities.

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References

[1] Schäfer, D. ; Roller, D.: Parametrische Produkt- und Prozeßmodellierung. In: *CAD-CAM REPORT* 17 (1998), No. 10, pp. 74-84

[2] Roller, D. ; Stolpmann, M.: GRIPSS: A Graphical Idea-Processing & Sketching System. In: *IFIP Transactions on Interfaces in Industrial Systems for Production and Engineering*. Rix, J. ; Schlechtendahl, E.G. (eds.), North-Holland, 1993, pp. 13-25

[3] Roller, D. ; Richert, U.: Requirements analysis for next generation CAD user interfaces, In: Soliman, J. ; Roller, D (eds.): *Mechatronics - Efficient Computer Support for Engineering, Manufacturing, Testing&Reliability, ISATA Proceedings*. Automotive Automation Ltd., Croydon, England, 1995, pp. 359-366

[4] Roller, D.: *CAD. Effiziente Anpassungs- und Variantenkonstruktion*. Springer, 1995

[5] Roller, D. ; Dettlaff, B. ; Richert, U.: Rationalization in the Electrical Engineering Process. In: Roller, D. (ed.): *Mechatronics - Advanced Development Methods and Systems for Automotive Products, ISATA Proceedings*. Automotive Automation Ltd., Croydon, England, 1996, pp. 279-284

[6] Pratt, M.J.: *Aspects of Form Feature Modelling - Methods and Applications*, Springer, 1991, pp. 227-250

[7] Hoschek, J. ; Dankwort, W. (eds.): *Parametric and Variational Design*. Teubner, 1994

[8] Schäfer, D. ; Eck, O. ; Roller, D.: A Shared Knowledge Base for Interdisciplinary Parametric Product Data Models in CAD. In: Lindemann, U. ; Birkhofer, H. ; Meerkamm, H. ; Vajna, S. (eds.): *Proceedings of the 12th International Conference on Engineering Design : ICED 99*. Volume 3. Garching : Technische Universität München. 1999.

[9] Pratt, M.J.: The STEP Standard and its Extension to Parametric, Constrained-based and Feature-based-Modeling, *Proceedings of Advances in Computer Aided Design*, Hagenberg, Austria, 1996, pp. 2-12