An approach to an individual product development using advanced measurement and human modeling technologies

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Abstract

With the most recent development of information, communication and manufacturing technologies, industrial production of customised products is rapidly becoming recognised as major factor, affecting the efficiency and therefore the competitiveness of industrial companies. The heart piece of industrial individual production is the customer tied together with the infrastructure, of being able to communicate and serve him individually. There is a complex process chain behind the development from collecting *individual customer data* to reaching a *product with an optimised fit*. In order to make an efficient and cost-effective implementation of the individual technological steps possible, the overall concept is to be integrated into an adequate information and manufacturing structure.

In this paper, an integrated process chain for individual production is introduced. In order to fulfill industrial requirements a *complex measurement system* has been developed, which combine high precision perception with high degree of automatism as well as minimal user interaction. The activities concentrate on both the development of a *fast body scanner* for three dimensional perception and the use of a *three dimensional CAD human model* as a necessary prerequisite for the interpretation of the range readings.

The principal goal is the „personalisation“ of the human model, i.e. the parameters describing the body model are adjusted automatically according to the sensor data. This personalised human model is then used for product design and manufacturing within industrial companies.

Keywords

Integrated process chain, 3D measuring system, personalised human models, design of dress and shoe patterns by means of virtual products, efficient low cost manufacturing, short time availability

1 INTRODUCTION

By the end of the 20th century a growing number of American and German scientists declare the *new paradigm* of individual production. Until now, the customer could only choose between hand crafted expensive products on the one hand and cheap uniform industrially mass-produced articles on the other. Individual production combines the respective advantages of these two, until now contradictory, approaches: *Individualised products at a low price*. More than ever, extensive customer information (for example the body type, the personal imagination about the product shape, taste, etc.), is being used in the design and manufacturing phases. By combining the individualised products with corresponding customised services, such as style counselling and body measuring, the value for the customer is further enhanced. This can cause a long lasting trust in the manufacturer's competence and is also the base for establishing a long-term business relationship with the customer.

The market strength of individual production compared to craftsmanship and mass production is defined in a trade-off from different criteria, as shown in Table 1 (Ovtcharova, 1998). The combination of *use*, *costs* and *availability* are crucial factors for the success of a product. Until now, companies in both areas (craftsmanship and mass production) could not comply with all criteria. So on the one hand, the production of tailor-made articles - in its historically developed variant of craftsmanship - exactly addresses the individual customers needs with regard to the product itself. It of course suffers from higher costs and longer delivery times. On the other hand industrial mass production can guarantee low costs and short delivery times through a world wide distribution network. This however happens at the price of standard products which cannot satisfy the individual customers' needs.

<i>criterion</i>	<i>craftsmanship</i>	<i>mass production</i>	<i>individual production</i>
technology	handcraft	series production	versatile production
product	unique product	standard product	individual product
longevity	high	low	high
costs	high	low	average
availability	long delivery times	immediately available	8-10 days
production	limited	over production	production on demand
sales			
organisation	single enterprises	various enterprises	virtual enterprises

Table 1. Strength of individual production compared to craftsmanship and mass production

The heart piece of industrial individual production is the customer tied together with the infrastructure, of being able to communicate and serve him individually. There is a complex process chain behind the development from collecting

individual customer data to reaching a *product with an optimised fit* (Figure 1). In order to make an efficient and cost-effective implementation of the individual technological steps possible, the overall concept is to be integrated into an adequate information and manufacturing structure.

Until now, research and development activities were mostly concentrated on the manufacturing phase. Important questions about customer data acquisition and support had not been sufficiently answered. To solve this problem, TECMATH, a company for the development, application and programming of mathematical methods situated in Kaiserslautern, has been developing a new powerful technology capable of measuring and modelling individual humans for quite some time now. The activities concentrate on both the development of a fast body scanner for three dimensional perception and the use of a three dimensional computer model of a human as a necessary prerequisite for the interpretation of the range readings. In the following, the basic tasks to be handled within an integrated process chain are outlined.

Figure 1. An integrated process chain for individual production

2 HUMAN BODY MEASUREMENT

In contrast to already existing systems for digital measurement of mechanical parts the human body scanning requires new system characteristics with respect to both *minimal measurement time* and a *large measurement volume*. Whereas measurement time does not influence the quality of the acquired sensor data when digitising mechanical parts, there are substantial requirements concerning measurement time when scanning persons. In order to minimise measurement errors caused by small movements scan cycles of about 1-2 seconds should be kept. Regarding the size and shape of the persons to be measured there are considerable requirements with respect to the density of the 3D scan points. Several ten-thousand points are necessary for a sufficiently complete description of the body surface. On the other hand, existing systems for digitising mechanical parts generate highly accurate measurements, which are far beyond the requirements in human body measurement. The renunciation of these extreme preciseness offers the potential for the optimisation regarding measurement time and volume (Trieb, 1997).

An example of three dimensional body measurement is given in Figure 2. Based on these requirements and with respect to a time and cost effective application the developed fast body scanner is characterised as shown in Table 2.

Characteristic	Explanation
measuring range	Nearly 100% of the world population can be measured. Range in body height is 1 m (children) to appr. 2.20 m
measuring volume	Total measuring volume of appr. 2 m ³
measuring accuracy	Exact body surface measurement with a precision within 2 mm for a surface grid of appr. 1 cm ³
measurement principle	Light section principle, optical triangulation
light source	4 laser with diffraction lens, eye safe
measuring configuration	Simultaneous measurement of the person's front and back surfaces
computer system	Pentium PC
measurement time	1,5 seconds
measurement rate	2 x 85.000 3D points per second
measurement precision	An average, 1/512 of the object's depth (without subpixel interpretation)
data analysis	Simultaneous to measurement process. The 3D points are immediately available after measurement

Table 2. Functional characteristics of the body scanner

Figure 2. An example of a three dimensional body measurement

3 HUMAN MODEL ADAPTATION

The efficient perception and evaluation of human body data forms then the basis for an adequate *Human Model* of a customer as a necessary prerequisite for the interpretation of the range readings. Through automatic comparison with the three dimensional human model RAMSIS (**R**echnergestütztes **A**nthropologisch-**M**athematisches **M**odell zur **I**nsassen-**S**imulation, a leading CAD tool for ergonomic analysis of vehicles used by more than 50% of the world car manufacturers) (Seidl, 1997) a personalised virtual human is created. The concept of “individualisation” of RAMSIS consists in the automatical adjustment of the parameters of the human model according to the individual measurement data (Figure 3).

As a result, the individual body characteristics can be then obtained from the individual RAMSIS without any further user interaction. With regard to an industrial applications the advantages of this approach lies in the *automatic process flow from raw sensor data to an individualised human model*. This individualised human model can then be used in various branches (for example, in the design and manufacturing of seats, furniture, clothing, shoes, jewellery, etc.) to gain measurements for an individual product.

Figure 3. Adaptation of the human model

4 APPLICATIONS

4.1 Ergonomic Design of Vehicles

One typical application of the technology described above is the automatic simulation of human movements and ergonomic analysis of seats and car interiors (Seidl and Ovtcharova, 1998). In this case, the individual person is measured and the images are transformed into a computer. In the next step, the unknown anthropometric parameter of the human model are systematically varied until the images of the person and the computerised model are identical. Then, the designer describes the task to be fulfilled by RAMSIS by interactively defining model restrictions (e.g. hands on the steering wheel, feet on the pedals as shown in Figure 4). Additional constraints such as avoiding the penetration of body parts are also taken into consideration. Thus, the results of the analysis are raised to a new level of quality of car design and open the door to substantially improved results.

Figure 4. Realistic posture simulation

4.2 Individual Production of Clothing and Shoes

The affordable production of individually fitted clothing based on this technology is already possible today. Within the scope of the research project "Clothing Made to Measure" supported by the German Federal Ministry of Education, Science, Research and Technology an integrated process chain ranging from the acquisition of body measurements over the individual design of dress patterns to the actual production has been realised. The advantages for the clothing industry using this technology are among others, reduced measurements errors, fully automatic acquisition of desired body measures and lower production price (Trieb and Seidl, 1996, 1997).

Another field of application is the shoe production where shoes can be manufactured according to the individual wishes and measurements of the customer. In this case, the customer's feet will be measured three dimensionally using an optical foot scanner. The data will be transferred to the shoe manufacturer who then selects the best fitting last from his large pool, or created an individual one. The data acquired during the measurement process will be sequentially used to control the production. Soon after, the customer will receive his individually manufactured shoes (Ovtcharova, 1997).

5 CONCLUSION

Using integrated process chain based on advanced measurement and human modeling technologies customer data is automatically carried to the production line of the manufacturer. The use of flexible CAD/CAM systems plays a decisive part in this process. As a result, individual production brings a number of advantages:

- *Production close to the customer*, leading to a massive decrease in the time needed from reception of the customer request to the actual product and subsequently the delivery of the product.
- *Integration of the customer into the production process*, reaching a maximum of acceptance and customer satisfaction through high wearing comfort, resulting from individually designed optimal fitting products and short time availability.
- *An integrated view* of the product development process, optimising the overall workflow.
- *Fast availability* of the individualised products based on modern production logistics.

For the production company adopting such a technology, the risk of producing goods contrary to fashion trends or customer wishes is reduced to zero. Especially for the "small" and "medium" sized enterprises (SME's), the individual product philosophy is the answer to the increasing migration of production to the far east.

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7 BIOGRAPHY

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