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A New Textile Production Type - Urban Apparel Production In Microfactories

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Abstract

The World of production has changed due to the events of 2020 and 2021. The aftermaths are still being felt in many sectors of the economy. In addition to delayed deliveries due to lack of resources and production stoppages, logistics costs have increased. In addition to these uncertainties in the supply chains, the demand for sustainable and emission-free production by politicians and end consumers is rising. One way of improving the resilience of textile production and at the same time avoiding time-consuming, costly, and emission-intensive delivery routes is to relocate production to the immediate vicinity of customers. In urban hubs, products can be manufactured according to demand and customer-specific requirements. With the digital integration of the customer and progressive development of textile manufacturing technologies (e.g. digital printing and laser finishing), batch sizes between 1-1,000 pieces can be realized, avoiding overproduction. In addition, storage costs and delivery routes are eliminated due to customer proximity. A formal description for microfactories (MF) in the textile production context does not exist yet. This paper aims to define and classify the production form “microfactory” in the production landscape. For this purpose, known types of production are first identified and textile MF is delineated against them. Subsequently, the term microfactory is defined by the Institut fuer Textiltechnik (ITA). For this purpose, the requirements are first defined, and then a textile application and possible business models are considered.

Keywords

Textile; Production Technology; Microfactory; Flexible Production Systems

1. Introduction

The textile industry is one of the most globalized industries in the world. The events of 2020 and 2021 have changed this industry. The aftermath of the Covid 19 pandemic and the Ever-Given disaster highlighted the lack of preparedness of companies for crises and the resulting disruptions. Nowadays, due to globalization, companies operate in an increasingly volatile and uncertain environment and are often confronted with various types of disruptions. These impact multiple areas of the supply chain. To name but a few, there are delivery delays due to resource shortages, production outages, and increasing logistics costs. The latter is particularly noticeable as the price of a freight container from China to Europe has risen to as much as 15,000 euros in the past year [1]. This represents a 1,500% increase in costs.

However, these are not the only challenges that the textile industry is facing. Its value chain has always been complex, due to the high number of production steps and the associated specialization of the individual companies as well as the high proportion of manual production steps [2]. In the past two decades, the complexity of the textile value chain continued to increase. Customers are also much more aware of trends

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in the fashion world and demand shorter lead times [3]. In response, the fast fashion business model has been widely accepted and implemented within the industry [4]. Fast fashion requires a quick response, frequent assortment changes, and fashionable designs at low prices [5]. Shorter product life cycles and increasing demand mean that more products and parts need to be coordinated [6]. It can take up to 60 weeks from the planning of the collection to the sale of the goods. Fast fashion brands such as Zara and H&M offer up to 24 collections a year. In 2000, the average was two collections per year [7]. Due to cost pressure, around 90% of clothing is produced in Asia [8]. The labour-intensive goods are then shipped by sea in quantities of several tens of thousands per model and size to the main sales markets in Europe the USA. This results in high capital bindings due to full warehouses and long delivery times. The increasing branching and complexity of supply chains limit the companies' ability to react to local effects and disruptions.

Additional challenges in the context of textile production are new policies regarding sustainable and emission-free production. Besides long supply chains, textile waste contributes to the negative environmental footprint of the industry [9]. Since 2000, global textile production has doubled. In 2014, 100 billion garments were produced [7]. As the productions in low-wage countries are bound to high quantities, a large part is produced beyond the order. This and the sometimes-low-quality results in an enormously high volume of textile waste. Consequently, about 30% of the produced goods are directly down-cycled into low-quality goods such as cleaning cloths [10].

A solution to improve the resilience of textile production whilst avoiding time-consuming, costly, and emission-intensive delivery routes, is to relocate production to the immediate vicinity of customers, for example to Europe. In comparison to Asian suppliers, the EU manufacturers can produce in a shorter lead time. Because of their investment in technology and automation, they can also have a quicker market response. Together with the U.S. industry, they represent the safest sourcing basis in terms of social and environmental compliance. However, Europe is one of the most expensive sources especially because of the high labour costs. Additionally, flexibility and agility are subjects of improvement [11].

One solution to this problem is the so-called "microfactory". In urban centres, products can be manufactured according to demand and customer specifications. A reduction of emissions, as well as textile waste, can be achieved. With the digital integration of the customer and progressive development of textile manufacturing technologies, batch sizes between 1-100 pieces can be realized, avoiding overproduction. In addition, storage costs and delivery routes are eliminated due to customer proximity, which also disconnects the textile production from problems due to global events such as the Covid pandemic.

The aim of this paper and the ITA is the definition and classification of a flexible production form "microfactory" for batch sizes of 1-100 in the textile production landscape. For this purpose, a literature review is first conducted. Known production types are identified and the textile MF is distinguished from them. Based on this, the concept of a MF, which has been missing so far, is defined by the ITA. For this purpose, the requirements are first defined, and then a textile application and practical examples of textile MF are considered.

2. Literature Review

The literature review was led by the guideline by VOM BROCKE ET AL. (2015) [12]. Therefore, we first established the criteria for including studies in our review and conducted the literature search based on these criteria. Subsequently, we have established a scheme for analysing the studies. The search is concluded with the deduction of the current state of research. The search aimed to find out if there was already a generally applicable definition for a textile production small in space for batch sizes from 1 - 100. This means the produced goods should be adaptable to the specific needs of individual customers. Plus, the production should be sustainable. Therefore, we set three search criteria; 1) The unit of analysis must refer to the production industry; 2) no time restriction on the publication dates; 3) Restriction to previously defined databases and search terms.

The literature review process, therefore, consisted of identifying synonyms for the term "microfactory" and relevant keywords that have a similar meaning. The selected words were: “microfactory”, “mass customization implementation”, “engineer to order” in combination with “manufacturing textiles”, “production planning”, “factory layout” and “waste management”; “circular economy microfactories”, “flexible production” and search strings including the word “container”, such as “manufacturing residential container”. For each of these search terms, the databases, such as Google Scholar, returned several thousand to a hundred thousand results. From these results, we picked only one to eight papers for each notion to check the respective understanding, which resulted in 50 papers read in total. Due to the page limitation, this paper is restricted to the results regarding the term “microfactory”, which was found to appear in two different contexts.

Only using “microfactory” as a search string leads to around 3,500 papers revolving around the original definition of an MF that describes a very small production system to manufacture microscopic items such as computer chips [13]. Since there are no microscopic goods in the textile sector, this search path is of no interest to this paper.

Nonetheless, there is another understanding of an MF in the literature that surfaces when using the search words “microfactory custom” on Google Scholar, but does only include two papers ([14], [15]) and a third associated one ([16]). In [16], the notion “microfactory” was first introduced in the automotive industry and refers to a type of production that is intended to be more ecological than previous ones. In this concept, production and retail functions are combined in one location. This creates several smaller facilities that can serve local markets [16]. A development of this term is made in [14]: The MF no longer only pertains to the automotive sector but can be found wherever a set of diverse products should be produced on a small to medium scale; for example, also in the appliance and footwear industries. This creation of goods should be highly digitalized [14]. An MF bridges the gap between artisanal manufacturing and mass production. Therefore, the characteristics of an MF are low and medium production volumes (100-10,000 units per year), local value chains, heterogeneous products and economies of scope, weaker intellectual property protection, and high innovation rates. In addition, the number of employees in an MF is usually between 4 and 25 and the required floor space is less than 50,000 square meters [14]. In a later paper, the authors stress the importance of digitalization for MF and divide MF into categories according to whether they are driven by innovation or customization [15]. In online secondary sources, an MF is the embodiment of digitalization, where small processes run fully automated [17].

In summary, an MF is located somewhere between artisanal manufacturing and mass production, producing small batch sizes close to the customer, while heavily relying on digital technologies. This latter characteristic is problematic in the textile industry, because up-to-date, the processes of textile production cannot be fully automized, especially in the cut-make-trim (CMT) processes. Overall, the concept of MF remains vague in German and English literature. There is no uniform definition for this form of production. Therefore, the ITA considers it necessary to design a production typology for the concept of MF in the textile industry for customer-oriented production.

3. Analysis of known production types and principles

In the following, known production types and production principles are identified and the requirements of a textile MF identified by the ITA are distinguished from them. Production systems are described by the production type and the production principle. The production type is defined by the lot sizes. In make-to-order production, a difference is made between one-time production and repeat production, which distinguishes the frequency of repetition of a product. The production types variant production, repetitive manufacturing, and mass production enable the production of multiple goods. The spatial and organizational structure of the work system, on the other hand, describe the production principle [18].

Producing goods only once, the production type one-time production applies, for example in shipbuilding. High costs and time expenditure are the results. Typical manufacturing principles used are the building site and workshop principle, where either all tools are brought to the product or production steps are clustered in technological areas [18].

In repetitive manufacturing, products are produced at irregular intervals, for example in aircraft construction. The repetition of orders leads to a reduction in the amount of preparation required. Compared to one-time production, a production cell can be used in this case [18]. In textile production, a flexible production system (MF) would also be applied in one-time production and repetitive manufacturing. The term flexible production can be used as an overarching term for the MF form of production, in which different production varieties and loss sizes can be produced.

In variant production, similar products of the same basic type are produced, inter alia in the furniture industry. Therefore, the production effort is the same for all variants. In addition to the flexible system, the manufacturing cells and the workshop principle can be used here. The flexible system refers to a production technology that consists of several different and complementary machines or machining centres, for example, several joining processes in one place. By integrating operations, the cycle time can be shortened. [18]

Series production enables the production of small, medium, and large series, amongst others in car manufacturing. The number of pieces is limited. It is usually a contract production of standardized products. The standard production principles used are the flexible system and the flow principle with or without cycle time [18].

Using mass production, large quantities can be produced, which leads to frequent process repetition, for example in the apparel industry. An adaptation to individual customer requirements is only possible to a limited extent during planning. The production principle used here is the flow principle, with or without a cycle time [18]. In the textile industry, this production type results in long production lines in Asia. Table 1 shows the known production types, which production principles are used in them, and ITA´s definition for a textile MF.

Table 1: Analysis of known production types and principles

Chart legend:
X: already defined in the literature
O: ITA´s definition for a textile MF

		Production principle					
		Building site	Workshop principle	Production cell	Flexible system	Flow principle without cycle	Flow principle with cycle
Production type	One-time production	X	X		O		
	Repeat production	X	X	X	O		
	Variant production		X	X	O/X		
	Serial production				O/X	X	X
	Mass production					X	X

However, due to the special challenges and requirements, the textile industry demands a production principle that can also be used for serial production. It requires a development of a new production typology, which is applicable both for the series production of small lot sizes and for individualized products. Besides rapid adjustment to local conditions and the market, it should also enable shorter production times and reduced storage costs. It becomes clear that the flexible system corresponds most to the requirements and goals of flexible urban production. They allow more variety and quick response to disturbances and the market [19]. Therefore, we enhance these systems in an MF to cover lot sizes from 1-100 pieces, making it a viable option for almost any textile product.

4. Approaches and concept development for a flexible urban production for textiles

From the comparison of the textile MF with already known production types, it becomes clear that none of them meets the requirements of the textile industry. Therefore, the concept of the MF is defined by the ITA. To fully develop the definition, several other concepts need to be defined. In the context of the MF, these are product, production, distribution, and personnel.

To achieve consistency in each element of the definition, it is crucial to determine the requirements for a MF. Figure 1 provides an overview of the positioning of MF in terms of important characteristics such as the targeted production volume, the location strategy, and the production stage on which this manufacturing method focuses

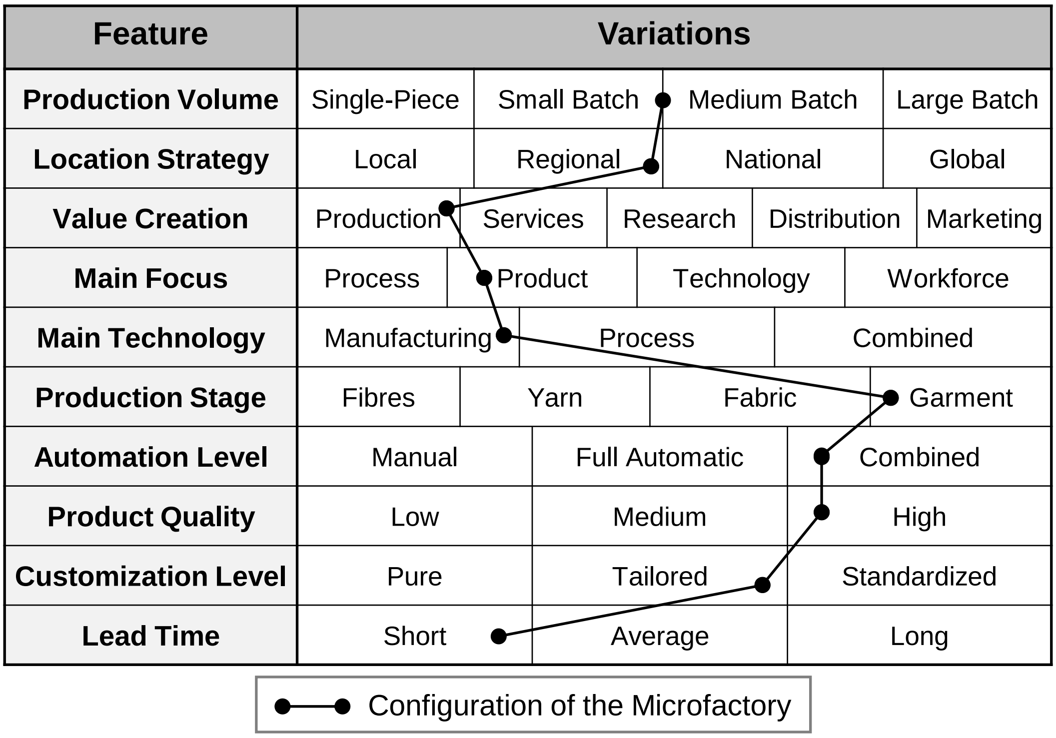

Figure 1: Morphological Matrix – Features of a microfactory

The integration of the presented potentials for success with the framework of the manufacturing method results in a clear vision that establishes a general requirement profile. This general vision represents a basis that is complemented by business interests and goals.

The MF manufacturing method aims to be a scalable and flexible manufacturing setup in the textile industry. The focus is on the manufacture of high-quality textile products on a small to medium scale. Priority is given to customer involvement and a localization strategy close to customers to ensure a short time to market. It also enables a flexible level of automation that fits the needs of each company. The size of a MF delimits the section of the value chain in textile manufacturing where this manufacturing method is concentrated. Figure 2 shows the process steps for a MF for apparel. The input materials are fabrics, either before or after finishing processes and treatments. And the output is a textile product with added value. This depends on the individual companies and the type of products they focus on. The development of the industry and the requirements of customers lead to a general requirements profile for textile products. The most important requirement for the MF is flexible production, which can be adapted to customer-specific orders as well as local effects and disturbances.

Lot sizes between 1 and 100 can be produced. The focus of the MF is to produce products with outstanding quality. In the case of a garment product, quality can be seen in the aesthetics, structural integrity, and potential for appeal. Due to strong competition for low-cost textile products, a MF focuses on creating a competitive advantage that justifies higher prices than mass-produced garments.

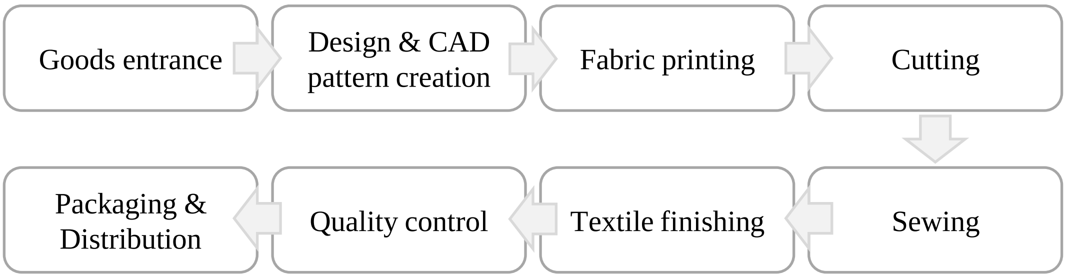

Figure 2: Process steps for a MF for apparel

To avoid high capital commitment due to full warehouses, production is on-demand. This enables efficient use of resources. As a result, the volume of waste can be reduced, and energy efficiency optimized. The warehouse should be only used for material and finished products just before they are shipped. The distribution networks must be designed simply and clearly to be able to guarantee short delivery times. Multiple MF will build a decentralized production network, geographically distributed and with a focus on different production steps. In addition to decentralizing production, the MF is also suitable for in-house applications. For example, prototyping for collections can be made faster and more cost-effective again without interrupting the current production schedule. To be able to decentralize production, several requirements must be met. Firstly, a high degree of automation is required at the individual production sites. Secondly, the networking of the individual plants is essential for successful implementation. Employing cloud-based technologies, a learning curve can already be determined for small batch sizes and the productivity can be evaluated and optimized [20].

In addition to a wide range of products, an important requirement is the ability to respond to customer needs and thus create a competitive advantage in the industry. In the garment industry, due to the variety of sizes to be produced, there is a wide variation that is already considered standard and that corresponds to the diversity of customers. In some cases, sizes can also be a partially configurable feature, but in this case, they are completely standard. The use of sizing software and size libraries standardizes this variation. Customizable features allow the customer to individualize products. Fully configurable attributes include, for example, sleeve length, collar type, cuff type, and the addition of other components such as pockets. The partially configurable attributes in this case are the available fabric types and colours. The variation of these attributes is defined by the company and its objectives. For example, the fabric options depend on the quality of the products to be achieved. The qualities and characteristics of the fabrics also require different techniques, so a wide variety of fabrics requires a higher level of skill and technology. In the production of shirts, it is a great opportunity to include processes that allow for complete customization in the eyes of the customer. In this case, processes such as pattern printing and embroidery complement each other. The diagram of the structure described is shown in Figure 3.

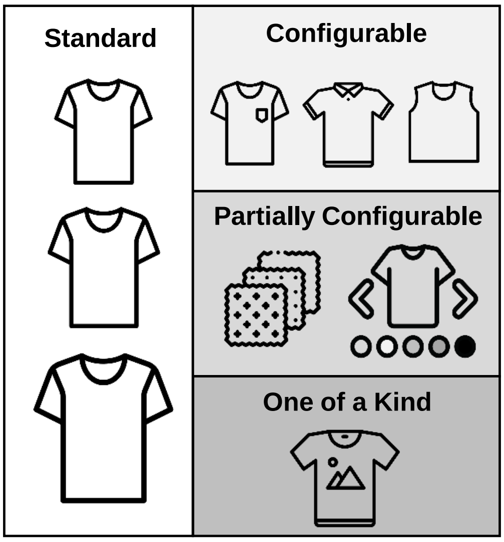

Figure 3: Example for product structure

The manufacture of the product requires a production system that includes all the elements necessary for its production (see Figure 4). Its internal framework depends on the structure of the products, their design, and their techniques. Fundamental to the selection of manufacturing processes is the clear definition of the product range portfolio. According to the derived process plan, the technology systems and capacities are planned [18]. In addition, the organizational structure and process organization determine the link between these elements. Other elements such as personnel and suppliers complete the production concept.

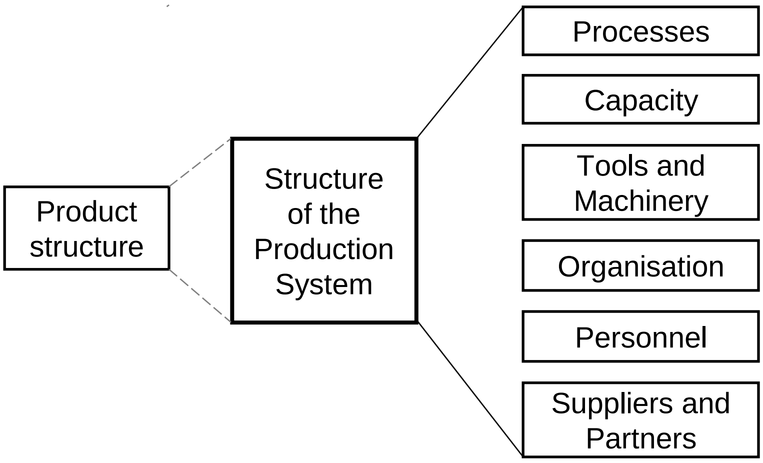

Figure 4: Production System Structure

Individualization being one of the goals of microfabrication, it is important to define where in the production process the customer´s intervention is possible. These points of involvement determine the degree of customization that can be achieved and also perceived by the customers [21]. Figure 5 shows this correlation between the starting point of connection with clients and the level of individualization. The earlier in the production cycle, the closer the product is to the customer´s requirements. The MF concept allows the participation of customers mainly in the design of products. In some cases, also in the inclusion of techniques in the manufacturing processes. The assembly and distribution stages are already defined by the business strategy. It is possible that within these there may be opportunities for customer participation, such as an express shipping option.

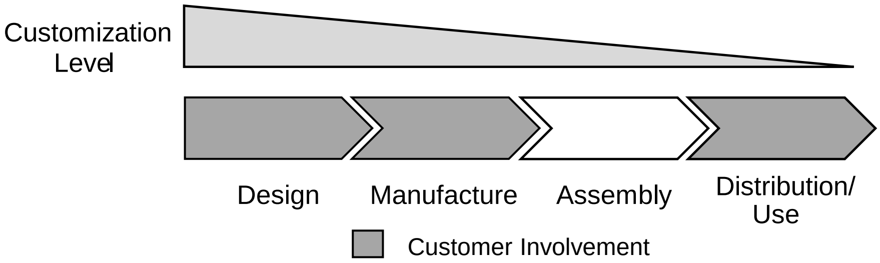

Figure 5: Customer Involvement on the Production Process

In addition to the production of clothing, the MF can also be used in a variety of other ways. In the past, there have already been MF in the textile industry, in which the ITA has also participated:

Table 2: Practical examples of textile microfactories

Digital Capability Center:	Laboratory at RWTH Aachen for the development and implementation of the latest sustainable and digital technologies for the textile engineering industry [22].
Adidas Speedfactory:	Producing running shoes using highly automated digital 3D techniques. Nowadays, relocation of the production concept into the supplier companies in Asia to increase flexibility and quantities while decreasing costs [23].
Adidas Storefactory:	Store with included mini-factory. Customers go through several stations, e.g. body scans, and motion detectors, to design their sweaters [24].
Smart Textiles Micro Factory ITA RWTH Aachen:	Production of a smart cushion from the design to the finished product [25].
SARTEX FiW RWTH Aachen:	Sustainable jeans refinement in Tunisia: sustainable water use, use of sun (photovoltaic technologies) and wind to produce energy, cooling of buildings via concrete core activation among others [26].

5. Summary and Outlook

In this paper, the challenges of the textile value chain were presented, namely resource shortages and production outages due to globalized production chains and unforeseeable events, coordination of large quantities of products and parts, as well as the need to adhere to new policies regarding sustainable and emission-free production. It was shown that flexible and urban production is an opportunity to overcome these challenges. A literature review revealed that a formal description for MF in the textile production context does not yet exist. The comparison with previous production methods confirmed the need for a new type of production. For this purpose, known production types were identified and the textile MF was differentiated from them. Subsequently, the areas of product, process, distribution, and personnel were considered, and, based on this, the concept of a MF was defined.

In future research work, a complete and measurable definition of the MF production form will be developed. For this purpose, a production layout will be created, and further framework conditions will be identified. To validate the developed definition of the production form of the textile MF, it will be applied to projects, compared with conventional production, and analysed in terms of economic efficiency. The knowledge gained from this is being applied in ongoing collaborative projects on the digital networking of production. This paper is initially limited to the German market. Therefore, the research of the ITA will be extended to international projects and research in the future.

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Biography

Katarina Winands (*1995) is a research assistant at the Institut fuer Textiltechnik of RWTH Aachen University in the Additive and Joining Technologies Group since October 2021. She received her M.Sc. in Textile Products and her B.Sc. in Clothing Technology at Hochschule Niederrhein (University of Applied Sciences).

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Carlotta Kollera (*1996) is a student assistant at the Institut fuer Textiltechnik (ITA) of RWTH Aachen University in the Additive and Joining Technologies Group since April 2021. She is currently working on her master’s thesis in mathematics at RWTH Aachen University.

Thomas Gries (*1964) is the head of the Institut fuer Textiltechnik (ITA) of RWTH Aachen University since 2001. He coordinates interdisciplinary research and acts as a reviewer and consultant. In January 2013, he was awarded an honorary professorship at Lomonosov Moscow State University in Moscow.