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ICT-TEX
ICT IN TEXTILE AND CLOTHING
HIGHER EDUCATION AND BUSINESS

Map of ICT technologies in the textile industry

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1 Executive summary

This report was made in the framework of Work Package 6 in ICT in Textile and Clothing Higher Education and Business (ICT-TEX) project, funded by the Erasmus + Programme of the European Union. Purpose of this document is to present more details about the main Information and Communication Technologies (ICT) areas that have impact in the Textile and Clothing Industry (TCI). For this purpose, an overview of ICT and TCI is made with respect to mutual dependencies of the two domains. An analysis results from this which maps relevant ICT areas into TCI subdomains. Results from a survey performed within Work Package 4 of the project are used to make a clustering of digital needs of TCI enterprises and their staff. The document is supposed to serve as a starting point of the analysis of needs for digital skills and hence preparation of learning materials in ICT in the scope of the ICT-TEX project.

Structure of the document is as follows: Section 2 presents more details about the purpose of this document; Section 3 will make a brief introduction to the area of ICT and outlines the approach taken for this report; Section 4 presents fundamentals of the main ICT areas with respect to TCI; Section 5 overviews the essentials and needs of ICT in different textile industry domains, Section 6 makes the mapping of ICT techniques into TCI domains; Section 7 analyses results of the study and outlines the clustering of digital needs and at the end, Section 6 concludes the report and states some directions for future work in the area.

2 Introduction

2.1 Information and communication technologies

ICT stands for Information and Communication Technologies and it is remarkable that a universally accepted definition of this term does not exist. However, it is broadly considered as a generalization of the term "information technology" with stress on the "communication" aspects which include networks, internet, and cloud systems [4]. In fact, ICT is a very dynamic discipline with many researchers and practitioners working on it. Possibly, the main reason about the lack of a strict definition is that ICT has quite an extensive usage in many aspects of modern society and in each domain, it has a different perspective. For example, in everyday life it has to do with internet browsing, social media, electronic documents and communication, while in software engineering it deals with software requirements, design, programming, algorithms and so on. These are the main reasons that methods and practices of ICT, together with its subdomains are constantly evolving and subject to change, this way leading to vague and sometimes ambiguous perception of the term of ICT.

On the other hand, Textile and Clothing Industry (TCI) is an engineering discipline that stresses on the various aspects of design, production and marketing of clothes and clothing materials. Introduction of ICT technologies that need additional digital skills is one of the key elements of the common breakthrough technologies in TCI. The very fast development of ICT requires that current and future staff (students) of the textile companies and universities acquire new approach to digital knowledge & skills. This mapping analysis and clustering of Information and Communication Technologies (ICT) practices in Textile and Clothing Industry (TCI) is essential to understand the role of ICT in the area and very important for the implementation of the whole ICT-TEX project as well.

Throughout this report we will look at ICT from an academic perspective and regard it as a broad term that encompass a large number of areas in terms of computer technology and science, software engineering, networking and information exchange, data science, etc. For more information about meaning of these terms, the reader should refer to the respective ICT courses, part of the curriculum also developed within the project.

2.2 Methodology

Methodology for the research presented in this document was based on the following main activities:

- Literature survey (desk research)– search over documents on the web has been done both on general purpose search engines and scientific ones (Google Scholar, Scopus, etc.)
- Findings of a survey (field research) – as part of WP4 of the ICT-TEX project, an extensive survey has been conducted within the TCI industry [22]. The survey aimed to make a so-called gap analysis and has been implemented as a questionnaire completed by personnel within TCI companies. An important part of the survey was the section with ICT related questions. Results were used to perform mapping and clustering within the area to identify the most important ICT topics with respect to TCI.
- Internal expertise – expertise of project members in the areas of ICT and TCI was used.

The main result of the research is expected to be a mapping of ICT technologies in the textile and clothing industry. As already stated, ICT is a very broad field and that's why to achieve relevant results we should narrow out possible ICT sub-areas to be included in the mapping. For this purpose, to identify these subareas, we have used the findings of the survey performed in the field research at WP4. A questionnaire has been submitted to European textile and clothing companies belonging to the project partners' countries. An integral part of the questionnaire were questions about elaboration and expectations about ICT techniques and methods within TCI companies. Questions were aimed at analysis of maturity level for various kinds of ICT technologies, their integration in the respondent company and the skills that employees need to develop in order to introduce ICT innovations in the company.

Fig. 1 presents the perceived relevance of the distinguishable ICT domains for TCI enterprises. As seen from the picture most answers for each domain fall into the neutral (orange with value of 3) category. This should probably mean that there does not exist a particular ICT domain that professionals find particularly important for their business. It is also notable that Artificial intelligence and Programming skills are outlined as not relevant for TCI. However, the high rate of neutral answers may lead to a conclusion that these domains are not known in details to the respondents and in consequence there is lack of ability to benefit from them.

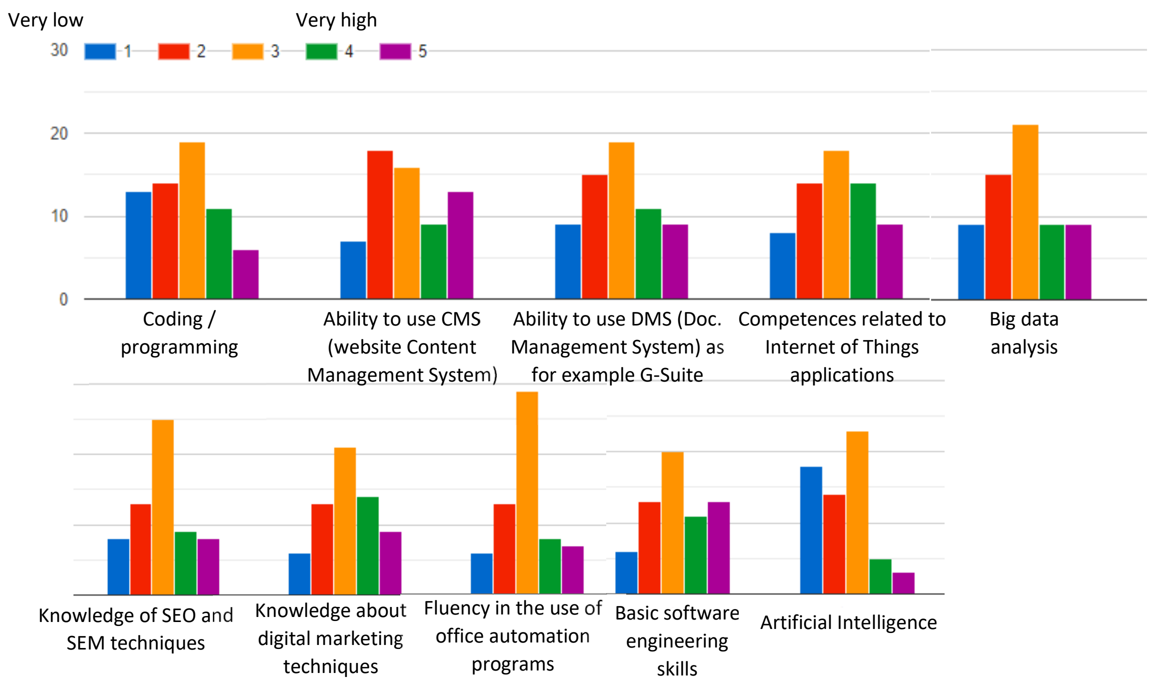

Fig. 1: Importance of ICT skills in TCI
(according to TCI professionals)

Further with the survey analysis, on Fig. 2 is shown distribution of already implemented ICT methods within TCI companies. It is worth mentioning that more than 40% has already introduced advanced systems of production (processes, technologies, materials) and automated production systems, which permit better exploitation of materials. IoT is also well implemented. Also, many companies are planning to acquire these in near future. On the other hand, low importance is given to virtual/augmented reality and RFID (Radio Frequency Indication) technology even if most companies recognize their importance and some of them have already introduced them in their productive reality or are planning to introduce them.

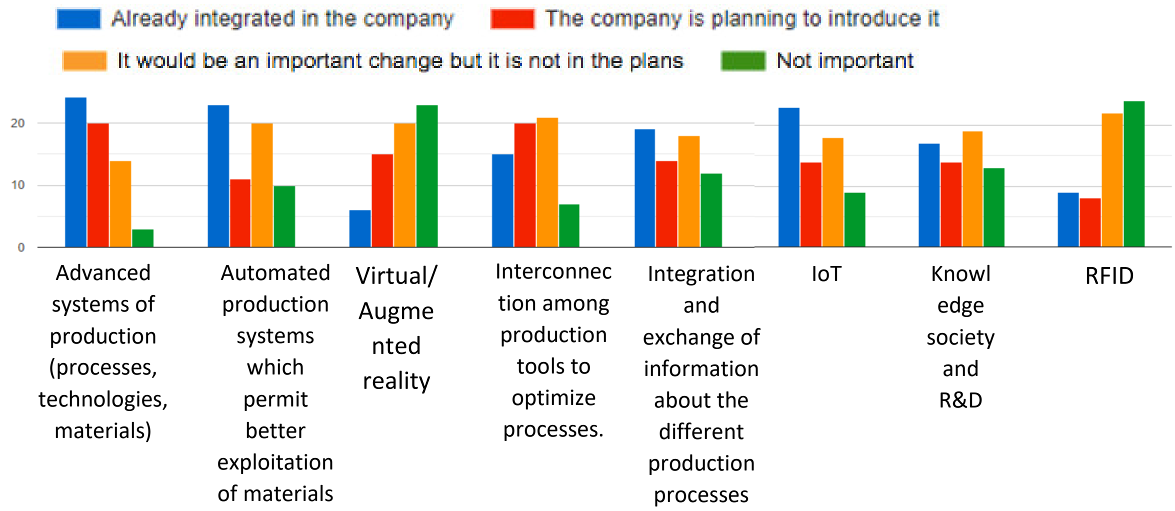

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Fig. 2: Current state of implementation of different ICT methods and techniques

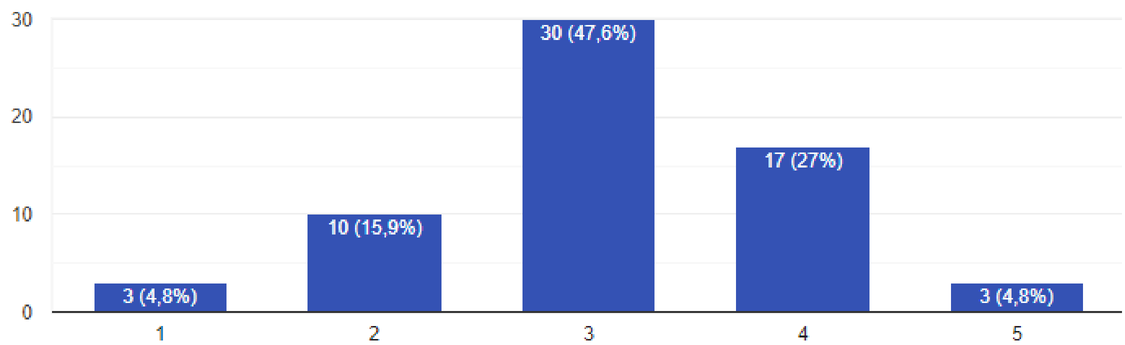

Fig. 3: Level of integration of ICT in interviewed TCI personnel companies (1 – low; 5 – high)

Further, Fig. 3 presents the self-evaluation of the interviewed personnel about ICT integration in their company and Fig. 4 presents the extent of belief that the company personnel has the required knowledge to introduce ICT technologies into the company. These two figures present the so-called self-confidence of interviewed personnel both in their ICT skills and the ICT potential of their company. Again, having the median estimation close to the middle could be a measure that there is some knowledge about ICT, but still a significant effort should be done in terms of education both in ICT and technological entrepreneurship in order to make foundations for ICT innovations into companies and to maximize their potential and competitive ability.

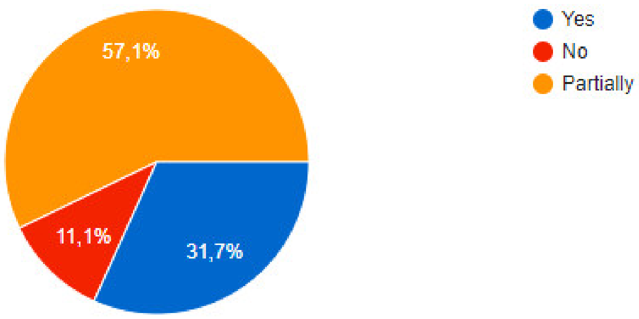

Fig. 4: Do company employees have required competencies to introduce ICT into it

Observations from the survey show the general conclusion that training in all ICT areas is needed in the TCI domain. Moreover, it is difficult to distinguish important ICT areas solely by the field research. For this purpose we have made a literature research review in order to map ICT into textile and clothing industry.

In next sections, this document continues with general description of the ICT technologies used in the TCI enterprises. This is needed for identification of the difference between TCI product specialization, for instance: clothing, wearing, knitting, etc. from digital tools perspective. After that an overview of the general TCI domains is made in order to position the mapping and clustering.

3 Main areas of ICT

As stated in the introduction, ICT is a very large area and by the time of making this report, there was a lack of scientific research on the application of ICT in TCI. In this respect, in order to prepare mapping and clustering, we have narrowed down the vast ICT area to the following number of subdomains, which have relevance to TCI:

- Software engineering
- Embedded systems and IoT
- Cloud systems
- Big Data
- Computer graphics
- Artificial Intelligence and Machine Learning
- Software quality

3.1 Software Engineering

The ultimate goal of the software engineering community is to be able to develop software systems that have both a predictable quality and a predictable cost, in terms of time and efforts for the development. However, experience gained shows that this is a challenging task and requires spreading of research efforts in many different directions. Software engineering comprises several areas such as software development processes, requirements analysis, design and architecture of software systems, means to attain software reuse, software testing.

More formally software engineering is defined by Ian Sommerville [14] as "an engineering discipline that is concerned with all aspects of software production from the early stages of system specification through to maintaining the system after it has gone into use." There also exists an initiative called SWEBOK (Software Engineering Body of Knowledge) which is an international standard ISO/IEC TR 19759:2015. It "characterizes the boundaries of the software engineering discipline and provides topical access to the literature supporting that discipline." [19]. SWEBOK states the following main areas in software engineering:

- Software requirements
- Software design
- Software construction
- Software testing
- Software maintenance
- Software configuration management
- Software engineering management
- Software engineering process
- Software engineering models and methods
- Software quality
- Software engineering professional practice

- Software engineering economics
- Computing foundations
- Mathematical foundations
- Engineering foundations

With respect to many industries and also TCI, software engineering should enable systematic reuse of software artefacts like code, design, documentation etc. and this way to achieve previously mentioned goals. Different techniques are developed to serve this purpose, and the main are:

- Open standards
- Rigorous documentation
- Software processes and agile methodologies [23]
- Software architecture and software product lines [3]
- Design and architectural patterns [24,25]
- Component-based and service-oriented software engineering [26]

3.2 Embedded software & IoT

Another important area of contemporary computing systems is the domain of embedded software systems, which is the basis of the so-called Internet of Things (IoT). Embedded systems cover a broad range of computer systems: from very small computer-based devices such as wearable electronics, or home appliances controldevices to large systems monitoring and controlling complex processes. It is believed that a major part of all computing systems today (more than 98%) belongs to the embedded systems domain. A popular vision about this area is that an embedded system is nearly any computing system other than a desktop, laptop, or mainframe computer [6]. However, a stricter definition about embedded systems is given by [10]: *a mixed hardware/software system dedicated for a specific application and part of and reactive to a larger, physical system to which it is at least logically connected*. Examples of embedded systems include an air conditioner microprocessor control or electronic ABS in cars.

On the other hand, IoT [12] represents interconnection via internet and cloud of various kinds of embedded object (i.e., things), which includes sensors, smart appliances, automotive devices, industrial automation objects etc. IoT also includes communication protocols and media that make the exchange of information between these so-called *things* possible. IoT can be found in a lot of applications including smart homes and cities, digital twins, wearable technology and textiles, digital healthcare, autonomous vehicles and so on.

Embedded software systems are the building blocks of IoT and possess characteristics that particularly distinguish them from general-purpose software systems. Among them are [6, 16]:

- Limited functionality – this means that the system offers a same set of features to the users. Usually, no additional programs may be installed to execute together with the initial software on the embedded system.
- Tightly constrained – embedded systems have very high restrictions on available CPU performance, memory, power consumption, etc. These determine also high requirement towards software quality and non-functional characteristics, especially dependability and security.
- Safety-critical – some embedded systems may be integrated into hardware, responsible for safety critical operations. Such systems have very high requirements for safety, availability, reliability, etc. Additionally, in some of these systems the product life cycle is very long – in can stretch to several decades (for spacecraft software).
- Reactive and real-time – many embedded systems are designed to react to changes in system's environment and should produce output following some hard deadlines, i.e. – to work in real-time manner.
- Hard-to-change – Embedded software systems are usually tightly connected with the underlying hardware platform and written in low-level programming language, which makes them very difficult to change.

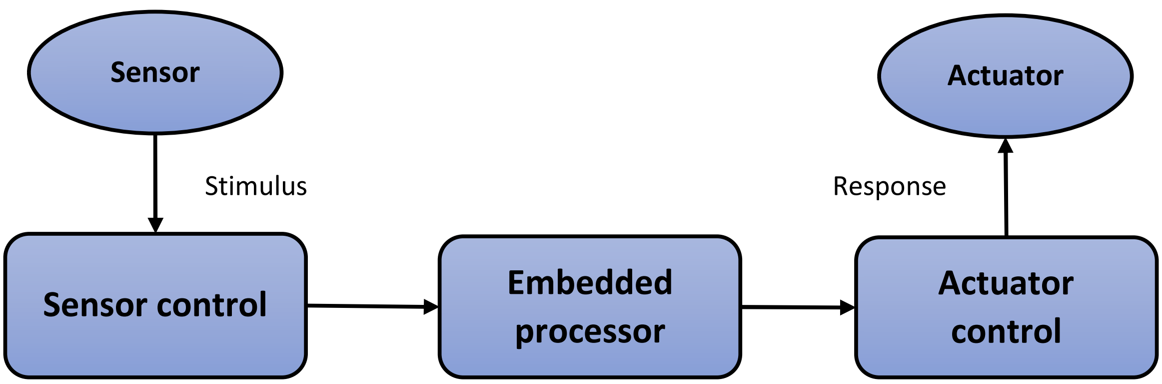

Fig. 5: Basic structure of an embedded system (adapted from [14])

Embedded and IoT systems usually have a basic structure as shown in Fig. 5, where a measurement device, called a sensor takes data and converts it into a measurable electrical signal, about the phenomenon under control and the sensor control compares this measurement with a desired value. Further Data Processor is the embedded computer system which makes the decision what should be done given the comparison and instructs the actuator to make appropriate changes. For example, if one wants to control the temperature in a textile lab, they should employ a temperature sensor and a heating and cooling device. Given the difference between desired and actual temperature, the Data Processor should implement an algorithm about when and for how long to switch the respective device on.

There exist various types of sensor devices – electromagnetic converters, thermo-couples, Radio-Frequency Identification (RFID), proximity sensors, Infrared sensors, etc. Actuators are usually based on so called servomotors, which have the ability to position their rotor very precisely and this way execute the control over the system.

3.3 Cloud systems

Cloud is a general term that encompasses interconnection of many computer systems, network equipment and storage into a common environment, that offer standard and transparent services to users. More formally, "cloud" is defined by the National Institute of Standards and Technology (NIST) as [20]: "*a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction*". This cloud vision, proposed by NIST is characterized by several other properties and most significant between them are the service models provided by the cloud:

- Software as a Service (SaaS) provides applications running on the cloud to end users via various devices (both mobile and desktop) via a browser or a dedicated application. Users do not have control over the cloud and or applications they are using, except some user-specific application configuration settings.
- Platform as a Service (PaaS) is the capability provided to users (mostly software developers and/or system administrators) to deploy onto the cloud infrastructure various applications, created using programming languages, libraries, services, and tools supported by the cloud provider. Users do not manage or control the underlying cloud infrastructure but are able to control the deployed applications and some limited configuration settings for the application hosting part of the cloud.
- Infrastructure as a Service (IaaS) provides users with processing, storage, networks, and other fundamental computing resources within the cloud. Users of SaaS should be able to deploy and run arbitrary software, which can include operating systems and applications.

Depending on privacy mode, clouds may be private (dedicated to a single organization), for a community (dedicated to a group of individuals or several organizations with similar privacy and/or security requirements) or public. Some examples may also include hybrid clouds that share multiple of these infrastructures.

Content Management Systems (CMS) and site building platforms could be considered as part of cloud computing in terms of TCI. Additionally, topics like Search Engine Optimisation (SEO) and Search Engine Marketing (SEM) may provide added value for the TCI business in terms of better positioning of the enterprises within the web and cloud contents this way facilitating their access to various customer groups.

3.4 Big Data and data management

Managing data is one of the most important tasks of information systems. From functional perspective data could be managed by applications in one of the following ways [27]:

- Store data so that they, or another system, can find it again later (databases).
- Remember the result of an expensive data access/processing operation, to speed up reads (caches).
- Allow users to search data by keywords or filter it in various ways (search or indexing).
- Send a message to another process, to be handled asynchronously (stream processing).
- Periodically crunch a large amount of accumulated data (batch processing).

In recent years growing importance are gaining different non-functional factors for data management like reliability, scalability, maintainability, performance, security and privacy. For more information on these topics, see Section 4.6. of this report.

Modern systems should collect, process and maintain data in a distributed way, which means that data may be spread across different machines and processed by various applications. This should be done transparently and in a uniform way. Usually from a user's perspective such data distribution is achieved via Cloud-based services, that can be consumed either via web interface (like Google Drive, OneDrive or DropBox) or an Application Programming Interfaces (APIs), like Amazon S3 or Google Cloud, used in programming for automatic usage of functionalities exposed by the interface.

Big data is a term that raised with the development of other ICT fields like Cloud, Internet of Things (IoT) and Artificial Intelligence (AI). Size of data is regarded as big with respect to the so-called three Vs – Variety, Velocity and Volume of data [7]. Volume of data means large scale data sets, containing petabytes of data. Velocity means highness of speed with which data is modified. Finally, Variety of data means differences in structure and presentation, when data comes in various syntactic formats, schemas, or meanings.

With respect to data storage, there exist two models for data storage and hence methods for data retrieval rely on these methods:

- Relational data model – this is the classical model for organization of data, where data is organized into tuples (i.e., rows), and columns (i.e., attributes), which are part of relations (i.e., tables) [28]. There exists a plethora of technologies that support that data model – Oracle Database, MySQL, Microsoft Access and so on. The most widespread technology and language for access of data organized in the Relational data model is SQL (Structured Query Language) [29].
- Document based data model – in the 21st century better alternatives of SQL emerged and are increasingly used in information systems, mainly due to problems of SQL with scalability and relevance to Object Oriented Programming and Design. Such alternatives are called NoSQL [30] databases and find applicability in big data and real-time processing systems. Document based NoSQL databases use JSON (JavaScript Object Notation) to represent data. Popular NoSQL database management systems include Hadoop, Cassandra, etc. Document based data model is appropriate when data objects have little or no relationships with each other.
- Graph like data model – another NoSQL model for data organisation is when data does not come in independent self-contained documents, but different data objects rather have many and sometimes complex relationships with each other.

3.5 Computer graphics

Computer graphics and digital image processing deals with presentation of images with the help of computers. In TCI computer graphics find application in presentation of colours and clothing designs. Computer graphics may be represented either in raster or vector formats.

Table 1: Most popular computer graphic formats

Raster image formats	Vector Image formats
psd (Adobe Photoshop Document)	ai (Adobe Illustrator document)
jpg (Joint Photographics Expert Group)	eps (Encapsulated PostScript)

png (Portable Network Graphic)	svg (Scalable Vector Graphic)
gif (Graphics Interchange Format)	pdf (Portable Document Format)

Raster images are a matrix of pixels, where each pixel represent a specific colour in the final image. Quality of such images is determined by the number of its pixels, which is also denoted as resolution. The higher the number of pixels – the higher is the quality. On the other hand, **vector formats** represent images as a combination of paths and arches, which are defined by geometrical representations in a coordinate system. Vector images represent shapes more accurately when they are zoomed in. Table 1 represent some of the most popular file formats used to store raster and vector images, respectively.

3.6 Artificial Intelligence and Machine Learning

In computer science and software engineering, Artificial Intelligence (AI) is a general term that describes any human-like behaviour, performed by a computer or any computer manipulated machine. This is quite a large area of different applications, for example artificial intelligence is implemented in robots, drones, as well as self-driving cars, autonomous software systems that take actions without human intervention, speech and image recognition and so on. In fact, due to the enormous variety of applications, there does not exist a common definition of what AI is.

A rapidly evolving part of AI is the so-called machine learning, which enables computers systems to gain knowledge by themselves about different phenomena. Machine learning encompass different techniques and methods mainly based on statistics. In machine learning a computer program actually modifies itself without human intervention. There exist three main types of Machine learning:

- Supervised learning - given an input, for example a photo with a specific clothing, and the software gives an estimation of what exactly kind of clothing is on the photo.
- Unsupervised learning – the software should determine input data structure, like grouping similarities into clusters, or reducing the data to a small number of important "dimensions".
- Reinforcement learning – software should take actions in an environment, where no feedback is given immediately, so it does not know if the decision is good or bad. For example, particular application area for reinforcement learning is self-driving cars.

3.7 Software quality

Software quality may have different definitions depending on the domain. For example, in terms of domain of software services (i.e., Service Oriented Architecture [9]), it is referred as *Quality of Service*, which covers a wide range of techniques that match the needs of service requestors with those of the service provider's based on the network resources available [1]. In other domains quality requirements are called non-functional requirements and should be distinguished from functional requirements. The latter defines what the system should do, and the former puts some additional conditions (in form of constraints or specifications) on how the system should perform or deliver its functionality. From the customer's point of view, software system quality should be more abstract notion and generalize all meanings of software quality, regarding the relevant characteristics just as *system qualities*.

Traditionally, quality of software is given a primary importance with respect to such application domains like embedded systems, safety critical systems, real time systems and so on. However, in recent times, terms as *testability, maintainability, time to market* and others that look at the system, not during its execution, but during design time, gain bigger attention. Another interesting characteristic is system *usability* or also *learnability*, which look at the system from users' point of view.

Although important, software quality is still a general and quite abstract notion, which may have different meanings. One may ask the question "What does it mean that the system is usable?". For example, console interface may be regarded as more usable than graphical interface by advanced users, while beginners or intermediate users would prefer GUI. Another example is maintainability, which may be regarded as part of programming complexity, but may also have its own meaning, like system ability to undergo changes.

Currently, there does not exist a universally accepted measurement framework of software quality, although there exist a lot of examples for software metrics in general. From general client or user point of view it is however important to be able to communicate with IT professionals in a uniform way. A popular framework to define the quality requirements for a particular software system has been proposed in [3]. Most important parameters there show that it is of big importance to be able to quantitatively measure software quality. Strict measurement will help to better define customer requirements and this way result in effective software development and successful production of software.

Among the most important quality characteristics of software systems are:

- Reliability
- Scalability
- Performance

- Security
- Privacy
- Maintainability

Software **reliability** is part of the more general framework of software dependability [2] and is defined as probability that a software will behave as per specification over a specified time period, given that it was doing so in the beginning of this interval. Practically, reliability could be seen as a measure that enough testing of the software has been performed and we are confident that it could be released to users as no failures are expected in near future. Various, mostly statistical, models for software reliability exist [31], although most of them have only academical importance and are not widely used in software industry.

Scalability reflects the ability of information systems to respond in changes of their load in terms of user requests or size of data they process. Scalability is different from performance as it deals with dynamic aspects of system's ability to cope with load, for example an online trading system may experience high loads during promotions or holydays and have very little number of requests during other specific periods of time. This way a scalable system may allocate less resources when it has less users and thus make them available for other systems. We may differentiate between two types of scalability – horizontal and vertical scalability. A system is said to be able to scale horizontally when it is capable to seamlessly spread over more computing resources, like virtual machines for example. Horizontal scalability received much higher attention in terms of cloud-based systems. On the contrary vertical scalability means that existing infrastructure is preserved but more powerful components are allocated (higher amount of memory, more powerful processors, etc.).

Performance represents the ability of systems to behave appropriately in time. Although it may have different dimensions in different ICT domains, it is usually measured as a quantity of work performed by a software system over a specified period of time (e.g., number of user requests processed per second).

Security is very popular term in modern ICT systems. Software security deals with design methods, infrastructure, and technology to prevent unauthorized or malicious access, modification, removal or usage of information. Various organization publish yearly rankings of most severe or important security risks for information systems. However, the most significant factor and threat for security is a result of social engineering by hackers. Under the term *social engineering* we mean various actions leading to users voluntarily give control of their machine or resources to hackers. Methods for such attacks include phishing, trojans, email scams and many others. Possibly from the viewpoint of clothing industry vital aspect is **privacy**. Privacy is a quality of software systems that defines how well they prevent unauthorized access to sensitive user data. For example – user interests, geographical movement (in case of systems that has access to location information), personal data and so on.

Maintainability defines the level of ability of the system to change and undergo repairs, due to corresponding changes in the user or environment requirements or errors found in software code or representation of data.

4 Overview of Textile and Clothing Industry

"Textiles" is a word coming from the Latin word "textilis" that means "woven" and Textile and Clothing Industry (TCI) is mainly based on the following main technological processes and industries:

- Design and Production of Woven Fabrics
- Design and Production of Apparel
- Design and Production of Knitwear
- Design and Production of Technical Textiles

In this section we give a brief overview of these areas with respect to their interconnection with ICT.

4.1 Design and Production of Woven Fabrics

Technological processes for manufacturing of woven textiles are based on products, which are gradually formed and converted from fibres into yarns and from yarns into a wide range of fabrics.

The modern weaving technology is based on the following processes:

- Winding: the process aims to check and omit yarn imperfections, creating a suitable for warping yarn packages.
- Warping: the process aims to prepare the warp set of threads (on the warp beam), suitable to produce the required fabric design.
- Sizing: the process aims to increase the strength of the warp yarns , preparing them for the action of the forces during the formation of the shed on the weaving machine.
- Looming: the process involves the drawing-in and tying of the warp yarns, aiming to prepare the yarns correctly for the weaving and to assure unimpeded weaving performance.

- Weaving: the process involves the fabric formation on the weaving loom, involving all weaving machine's mechanisms and aiming to form the grey fabric.

Production of woven textiles is a complicated process that involves several steps with many unforeseen problems and appearance of obstacles, which depend on the input materials (yarns, chemicals for sizing), machinery, settings of the production processes, labour forces, and management. The design of the fabric is also critical, the multi-coloured patterns, jacquard fabrics and 3D fabrics being among the most complicated ones. Embedded systems have big share in automation of this process. Usually specific technologies like Controller Area Networks (CAN) could be used to interconnect various devices and support fast production of high-quality fabrics with different applications.

4.2 Design and Production of Apparel

Anthropometric data of human beings differ from each other. Therefore, while designing apparel for mass production, it is important to know for which market the apparel product is supposed to be designed. For example, human body proportions vary between different populations and there is no universal size, which is suitable for all countries. There are various sizing systems in the apparel industry that are used by apparel brands to launch into respective markets. Data analytics techniques are used in order to establish a sizing system for a given country or region.

The clothing industry also increasingly prefers to use computer-aided design (CAD) techniques for both fashion design and pattern creation as it offers greater efficiency and time-saving solutions to many complicated tasks as well as facilitating Internet-based communication amongst designers, manufactures, and retailers. Specialized 2D CAD software support geometrical pattern drafting from first principles using only anthropometric measurements of the target size and shape. In the apparel industry, the designs are made in digital form with the help of CAD software. To check if the fit of the pattern designed the prototyping on that basis is done to check if the product is suitable for bulk production. It is usually an iterative work, which is performed until the desired results are achieved.

An increasingly used alternative is the 3D fit simulation where the fabric properties are given to material in a software environment and 2D patterns are digitally sewn and draped on an avatar. In this way, the prototyping work is reduced to save time and resources. Modern 3D CAD software also offers 3D simulation during motion which makes the product realization even more realistic during the design phase [13].

The apparel production starts from getting prepared for cutting fabric layers. The process of cutting starts from the lay planning for cutting. The cutting lay plan or commonly known as a marker is generated in a way that maximum efficiency of fabric lay is achieved to reduce the fabric wastage as much as possible. Cutting lay planning is carried out in combination with 2D CAD software which was prior used to design pattern pieces.

The following important computerized cutting technologies are in practice in cutting departments of apparel production:

- Knife cutting
- Laser beam
- Waterjet
- Plasma

Apparel companies with larger production volumes usually prefer computerized cutting. Computerized cutting is performed on a special cutting surface, which has a suction function that keeps the whole lay of fabric firm at its place while the cutting function is performed and sucks the small particles of fibres produced during cutting. In the apparel industry usually, knife cutters are used to perform CNC cutting. It has been observed that lately Chinese companies are getting a good share in automatic cutting in the Asian apparel industry due to their price competitiveness as compared to European and American suppliers. Other cutting technologies like laser, waterjet and plasma are used for special materials. After the cutting has been performed, the cut parts are grouped according to their sizes and labelled accordingly for the sewing process.

Digitalization in the apparel industry is taking place. To keep the sewing production line in full view, German sewing machine manufacturer Dürkopp Adler has presented its Qondac system, which keeps the record of each stage of the production stage and its efficiency in real-time. Productivity of sewing machines and their status can be analysed and machines can also be maintained virtually. The interface can be connected with the ERP system of the organization e.g., SAP to exchange the status of production to other relative departments [8].

Computer vision and image recognition is a well-developed AI area that is used in order to analyse fabrics and more specifically fabric photographs. By examination of the photo, machine learning algorithm is capable to recognize and locate potential defects that could damage quality of produced clothing. Additionally, predictive analytics, based on data gathered from machine sensors and logs is a good way to prevent future malfunction in textile production equipment.

4.3 Design and Production of Knitwear

Knitting as one of the methods for forming a textile structure and ranks second after weaving. The skeleton of fabric construction is composed by loops intertwined with each other. In some groups of machines, working on the weft principle of knitting, one thread is enough to form a knitted structure. Except loops with modern knitting automats could be knit and other structural elements such as floats, tucks, split stitches, as well as transferring loops from one needle to another. In the context of this report, it is worth mentioning that one of the first programmable machine in modern industry is the Jacquard machine.

The ability to transfer stitches by flat knitting machine allows the creation of structural effects in the fabric like aran and cables, and also getting cut details and fully knitted 3D products directly. Both technologies, 2D shaped fabric knitting technology and 3D knitting technology led to short production process, high knitting efficiency and material waste reduction. Only by fully fashion technology there is a lack of sewing threads on the fabric surface. The 3D knitting technology could also be applied to other groups of knitting machines.

One issue is currently computerized knitting is not being used to its full commercial potential [15]. The challenge is to create new epistemologies in terms of effective processes in design development for knitwear; increasing the technical knowledge of the designer and the programming skills of the technician will ultimately result in an increase in innovative functional design in both apparel and beyond. The German company Stoll has proposed partially solution to this problem by including additional functionalities in the software of the designers, suggesting the limitations that must be observed (for example, the maximum number of colours that can be used in knitting intarsia or jacquard).

4.4 Design and Production of Technical Textiles

Technical and smart textiles are textiles that are created for a specific functional need, and hence have a non-aesthetic purpose. Technical textiles include textiles aimed for use in healthcare, automotive, geo-technical applications, agriculture, and protective clothing. They require specialized production machines and chemistry.

Following sectors are distinguished within technical textiles [11, 18]:

- BuildTech - Construction textiles
- AgroTech - Textiles used in agriculture
- ClothTech - Technical textiles for clothing applications
- GeoTech - These are used in reinforcement of embankments or in constructional work
- HomeTech - Textiles used in a domestic environment - interior decoration and furniture, carpeting, protection against the sun etc.
- InduTech - Textiles used for chemical and electrical applications and textiles related to mechanical engineering
- Medtech - Manufacturing and application of medical and hygienic textiles

- MobilTech - Textiles used in the construction of automobiles, railways, ships, aircrafts, and spacecrafts
- OekoTech – Textiles for environmental protection applications
- Packtech - Packaging, silos, containers, bags, lashing straps, canvas covers, marquee tents
- Protech - Technical protective fabrics to improve people's safety in the workplaces
- Sporttech - Textiles for shoes, sports equipment

Technical textiles target high volume markets as well as niche applications. Products consist of finished textiles such as clothes, uniforms, bags, belts but also yarns, ropes and fabrics.

As a special extension, smart textiles embed a further embedded electronics component into the textile, which can be for MedTech, BuildTech, or any of the other technical textiles. Furthermore, they are used in normal apparel.

Smart textiles are based on embedded systems and as outlined in Section 3.2 they include 3 generic functions measurement (done by sensors), data processing (done by microprocessor unit), and control (done by actuators) in addition, they need effective energy supply and connectivity for communication. Several generations of smart and functional materials and smart textiles are distinguished [18]:

- First generation: textiles with added functionalities, which make them smarter and are always active (e.g., antibacterial, UV PPEs, plasma treatment, conductive, stain resistant, ...)
- Second generation: passive smart textiles, able to perceive data on condition or stimuli of the environment, such types of textiles contain only sensors; include e.g., PCM, colour change materials, shape memory
- Third generation: active smart textiles (comprise both sensors and actuators), e.g., temperature regulating, bioreading (heart rate, oxygen, muscle tension, …), light emitting, antenna, ...
- Fourth generation: ultra-smart textiles (able to sense disparate data types and forecast and feed external conditions without preliminary tuning), e.g., space suit, musical jackets, …

As technical textiles and smart textiles are so diverse, no unified history of it can be sketched. Mostly, as chemical understanding of polymers and technical production processes increased, technical textiles were a logical consequence, with ultra-strong fibres, heat resistant fibres, conductive fibres, carbon fibres and other high-tech fibres as trailblazers for the TechTex applications.

In order to work with TechTex, several important skills must be present:

- Ability to simulate the effect of the specialized fibres, yarns and fabrics for the use case at hand.
- Ability to verify the properties of the resulting textile product.
- Ability to construct the end products.
- Ability to program the smart textiles.

All of these require specialized skills. Digital tools are very worthwhile in the design process: concept, materials to be used, textile structure, position of the smart devices. For wearables, comfort and fit may be additional features.

In order to understand the effect of the TechTex in the engineering application at hand, physical simulation is performed. Tools and languages like Abaqus, OpenFoam, Fluent, SolidWorks, TexGen, MatLab, Python are used to investigate the interaction between the textile and the engineering application. For example:

- A geotextile used in a waste disposal site must help maintain the structural stability and must have a low water permeability. Interaction at the waste disposal site is studied to determine thickness and construction of the geotextile needed.
- A fire protection layer and water absorption layer for use in a firefighter suit is modelled to determine the effect of a fire at 4 m distance, to determine the thickness of the layers and their placement in the suit to offer an optimal protection to the firefighter.
- A conductive yarn/fabric used in a patch antenna constructed from textile materials is modelled to obtain the correct size to allow the highest possible bandwidth with these materials.

It should be noted that very few standard software is available in the area. Most of it has been developed by researchers, causing it to be very specific for a given functionality, not very transparent nor user friendly, requiring high calculation times and several often expensive licenses.

Technical textiles are created for their function. They hence have to satisfy strict regulations, rules and standards. Standard testing and certification are required, with quality assurance. Good understanding of statistical tools and software packages is required to interpret the results of the testing. As for statistics, the data analysis tool in spreadsheets (e.g., Excel) will do in many cases.

Skills required in construction of technical textiles and smart textiles corresponds mainly with the tools arising in standard apparel: CAD software to perform and simulate the weaving / knitting / embroidery needed for the construction, as well as 3D product design and 2D pattern generation. An extra complication for technical textiles is the many different binding techniques that arise in these products: gluing, lamination, sonic bonding, thermal bonding, sewing, soldering, etc. [5]

On the other hand, smart textiles also require programming to capture the output of the sensors and use this to determine the reaction required. Textile engineers need to master the concepts of programming (Arduino IDE, C++, python) in order to unlock the full potential of smart textiles.

Extensive training of the future textile engineer is required in order to fully enable the potential of technical textiles, not only in the development of new technical textile fibres and coatings, but also in the use of modelling tools to determine the effect of the TechTex on the final product, the use of CAD software to construct and visualize the product, the use of statistical software to test the efficacy and do the quality assurance of the products, and the use of programming tools to program the function of the smart textiles.

For SMEs in house digital design is often very challenging. Therefore, it is also important to provide support in this respect.

In addition to the overview made in this section the reader is referred also to the appendix, where they can find a list of the most common software tools that have been used in textile and clothing companies. This list has been created with the help of all ICT-TEX partners.

5 Mapping of Information and Communication Technologies in Textile and Clothing Industry

Possibly the biggest advantage of application of ICT in industry is the increased efficiency in production. Computers and information technologies tend to reduce time taken to complete tasks, while also reducing their costs. Additionally, computing reveals new ways for communication and collaboration within and between teams. Map of ICT in TCI is shown on Fig. 6.

ICT may be used in pre-production of textile products when modelling fabrics or creating garment specifications. For example, one may use CAD/CAM software to design fabrics or make 2D/3D modelling for clothing. Additionally, semi-formal specifications could be made using Unified Modelling Language (UML) [21], in order to create diagrams that better visualize processes and introduce new employees into the company.

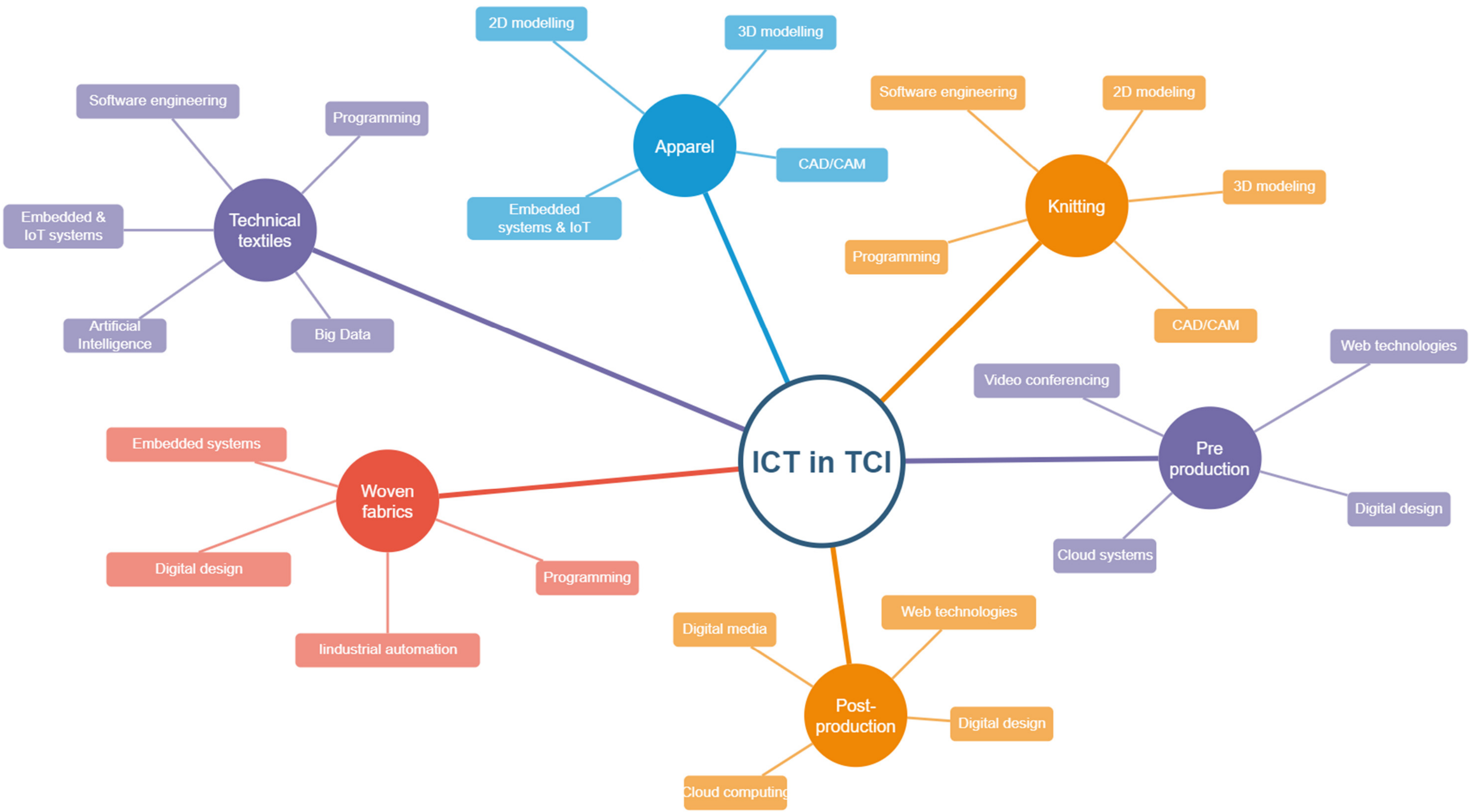

Fig. 6: Map of Information and Communication Technologies in Textile and Clothing Industry

In production phase ICT may be used for simulation and testing of virtual models, management analysis using product management or financial software. Product Data Management tools may be used to track raw materials and increase the efficiency of a production process. Embedded computer systems may better control the production process, as stated in Section 3.2 of this report. Cutting tables are used to cut fabrics with increased precision. Robotics and AI are used in product line management.

After production ICT helps in Sales and Marketing by employing software for visualization, virtual fashion shows, etc. In all phases of production ERP products like Oracle NetSuite or Microsoft Dynamic also provide valuable support in TCI.

Computer vision is also widely used in different stages of fashion and textile industry like modelling, segmentation and recognition, defect maintenance and retrieval [17].After production ICT helps in Sales and Marketing by employing software for visualization, virtual fashion shows, etc. In all phases of production ERP products like Oracle NetSuite or Microsoft Dynamic also provide valuable support in TCI.

As can also be seen from Fig. 6, programming an IoT are two areas that have a growing impact in more than one TCI areas. This is actually a common observation in other application domains like for example medicine, security, economics and etc. This observation is in contrast to the findings from the field research (see Section 2), where TCI professional does not seem to give significant importance to these ICT subdomains.

6 Conclusion

ICT finds place in the Textile and Clothing Industry into the following areas:

- Computer Aided Design and Computer Aided Manufacturing
- Software engineering
- Embedded systems and IoT
- Cloud systems
- Big Data
- Computer graphics
- Artificial Intelligence and Machine Learning
- Software quality

In this document an overview of mapping between ICT and TCI has been made with respect to corresponding main areas within each field. Research presented here is part of the ICT in Textile and Clothing Higher Education and Business (ICT-TEX) project, funded by the Erasmus + Programme of the European Union.

Directions for future work include analysis and classification of specific ICT tools from the previously mentioned fields and definition of processes for introduction of these technologies into TCI enterprises.

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8 Appendix: Software used within the textile industry

ICT-TEX consortium comprises partners of different European countries and they have expertise in various fields of Textile and Clothing Industry (TCI) and Information and Communication Technologies (ICT). As part of the research made in ICT-TEX project each partner has provided a list of the most common software tools used in particular areas where they have expertise. The list is sorted alphabeticaly.

Abaqus/CAE - https://www.3ds.com/products-services/simulia/products/abaqus/ - a software suite for finite element analysis and computer-aided engineering - used for both the modelling and analysis of mechanical components and assemblies (pre-processing) and visualizing the finite element analysis result. In textile research it can be used in studying and analysing precisely partial mechanical behaviors between yarn-level components.
Keywords: High-end engineering.

AccuMark, https://gerbersoftware.com/products/accumark-2d/
A cost-effective automation system for the pattern making, modeling and grading of patterns and for optimum planning of markers. It is mainly used by pattern makers.

AccuMark 3D, https://gerbersoftware.com/products/accumark-3d/
AccuMark 3D offers 3D simulation and visualization of clothing samples. Improve communication and eliminate errors with a direct connection between 2D patterns and 3D simulations, completely streamlining the design and development process. It is mainly used by Pattern makers.

Arhane- https://www.arahne.si/ CAD/CAM software for woven fabric used for complex design weave structures especially for dobby and jacquard, product simulation.
Keywords: Woven fabric structure.

AutoCAD - https://www.autodesk.com/products/autocad/overview - commercial computer-aided design (CAD) and drafting software application. It is used in industry, by architects, project managers, engineers, graphic designers, city planners and other professionals.
Keywords: Printing Pattern.

Autodesk 3ds Max - https://www.autodesk.com/products/3ds-max/overview - a professional 3D computer graphics program for making 3D animations, models, games and images.
Keywords: 3D design.

Bernina Designer Plus: https://www.bernina.com/nl-BE/Software-BE/Borduursoftware/BERNINA-borduursoftware-8 - design embroidery patterns for embroidery machines
Keywords: Apparel design, development, embroidery.

Brother PE Design: https://sewingcraft.brother.eu/nl-be/products/machines/pe-design-software - design embroidery patterns for embroidery machines
Keywords: Apparel design, development, embroidery.

CAD for textile designing, https://fkgroup.com/cad-for-textile-designing/
Computer Aided Design in textile industry can modify and analyse ideas as well as optimise productivity, cutting down on costs and time. In design software, the vector curves aid in creating perfect patterns and complex geometry in minimal time that is almost impossible to achieve through handwork.

Clo3D - https://www.clo3d.com/ - Real time fashion development software. Create patterns, assign materials, visualize on avatar, generate dynamic responses
Keywords: Fashion design, apparel.

Datacolor: https://www.datacolor.com/business-solutions/product-overview/datacolor-match-textile/
offers a variety of powerful formulation and correction capabilities with an improved user interface. It provides fast and accurate matches with the lowest-cost recipes for exhaust and continuous dyers alike. Powered by Datacolor's unique technologies SmartMatch and MatchCOM, and a proprietary collection of advanced colour formulation libraries, Datacolor Match Textile enhances accuracy and speed of recipe calculation, providing superior first-shot matches.
Keywords: Colour matching; dyeing.

DB-Weave, https://www.brunoldsoftware.ch/dbw.html - Free software for design dobby loom patterns. Used in Weaving mills with dobby machines, home design and education.

Dicentral, https://www.dicentral.com/
Dicentral is an Electronic Data Interchange (EDI) software. This is the digital exchange of business documents between companies using computers, replacing old school faxing and mailing methods. Standard documents exchanged through EDI include purchase orders, invoices, and shipping documents. EDI is used in a variety of industries by more than 100,000 companies, most of whom require their trading partners also to adopt EDI to ensure continuity, collaboration, and the standardization or ordering and communication. Mainly used by Designers, production and sail managers and shipping managers.

DigiFab Systems: http://www.digifab.com/systems/softtex.htm
is the complete turnkey solution for all your designing and coloring needs. Create or re-create your repeats & separations, and color them with our advanced color-matching system. Print sample yardage and presentation boards from your computer. Evolution allows you the flexibility to scan in the office, design at home and print anywhere. With Evolution, you will be able to decide where to perform and organize your work.
Keyword: Printing pattern design.

DySiFil - https://www.ugent.be/ea/match/textiles/en - Highly accurate filament simulation tool - aimed at machine optimization for weaving, knitting, braiding.
Keywords: High end engineering, machine optimization.

Embird: https://www.embird.net/
is an affordable must-have solution independent on any particular embroidery machine and designed for all embroiderers. Interconnect your embroidery realms with Embird's support for more than 70 embroidery file formats and 20 home and industrial embroidery machine brands. Explore the powerful tools for your creative embroidery designs digitizing, editing, customization, conversion, lettering and

cross stitch.
Keyword: Embroidery.

ERP software (Enterprise Resource Planning) - http://erptextiles.com/ - is a package of corporate wide software applications that drives **manufacturing**, inventory control, **production planning**, costing, finance, marketing, human resources and etc. The significant advantages of an ERP system is that it integrates all the functions to create a single unified system rather than a group of independent applications, thus creating a synergy between men, material, money and machine. Keywords: ERP software solution for textiles Industries.

Global PLM, http://globalplm.com/
PLM software can streamline entire business processes and enhance productivity. Global PLM can provide PLM configuration, implementation, and more. This tool is mainly used by Production and sail managers.

Grading for Knitting System (GKS)
https://www.stoll.com/en/software/grading-for-knitting-system-gks/ - Software for creating knitting designs and knitting patterns.

GRAFIS CAD clothing - https://www.grafis.com/ - starts with body measurements (either standard or an individual's measurements from your made-to-measure business) to create interactive basic blocks for bodices, trousers, skirts, sleeves, swimwear and more.Grafis works with the construction principle allowing for rapid iterations in various sizes and design variations.
Keywords: Clothing construction, body measurements, pattern, grading.

Ink/Stitch Embroidery extension, https://inkstitch.org/
Inkscape extension for generating embroidery stitch files. Used to select objects that you want to apply embroidery properties and using the extension, set the parameters for the desired object(s). Once all desired objects have embroidery properties, use the extension to generate the necessary stitch file.___Allows to design embroidery patterns for embroidery machines Keywords: Apparel design, development, embroidery.

k.innovation CREATE, https://www.stoll.com/en/software/kinnovation-create/ - Integrated shape and grading tool aimed at creation and customization of knitwear shapes.

k.innovation CREATE PLUS, https://www.stoll.com/en/software/kinnovation-create-plus/ - software for flat knitting machinery programming. Combines a fully featured advanced programming system with an easy to learn user interface will greatly enhance knitting capabilities.

LECTRA MODARIS: https://www.lectra.com/en/products/modaris-quick-estimate - Deliver products of exceptional quality and fit by revamping product development and used 2D and 3D pattern making, grading and prototyping with quick estimating fabric consumption.
Keywords: Fashion, design, pre-production.

M1Plus, https://www.stoll.com/en/software/m1plusr/ - used for producing patterns for a highly optimized knitting process by designers in Knitting mills with flat knitting machines.

Marvelous Designer - www.marvelousdesigner.com/ - 3D design tool for clothes and fabrics, used in animated films and video game development for 3D character design, 3D art, and 3D Models. Create

patterns, assign materials, visualize on avatar, generate dynamic responses
Keywords: Fashion design, apparel.

Microsoft Visio - https://products.office.com/en/visio/flowchart-software - a diagramming and vector graphics application for diagrams drawing.
Keywords: Printing Pattern

Minitab: https://www.minitab.com/en-us/ Researchers set out to help producers find the ideal fabric mix by using the Design of Experiment (DOE) tools in Minitab Statistical Software. The ultimate goal: create the optimal recipe for fabric. With DOE, researchers can change more than one factor at a time, then use statistics to determine which ones are important and even identify the optimum levels for these factors. Because DOE reduces the number of experimental runs needed compared to one-at-a-time experimentation, it's an efficient and economical way to improve any process. Minitab is used to construct a factorial design and explore the effect of each factor at low and high settings. For each experimental run, they gathered data about required properties for multiple fabric specimens and it can be analyzed data that revealed how these properties were affected by differing factors and their levels. To make it easy to see how the variables and their interactions impacted/affected fabric quality, used Minitab to create main effects and interaction plots.

Using Minitab's regression tools, generated equations could be used to predict both optimal conditions for different properties of textiles. Textile producers are now using these equations to create optimal fabric mixes for high-quality, comfortable in textiles. The predictive capability of the equations also allows textile producers to forecast and evaluate current and new fabric mixes before putting them into production. With continued use and some fine-tuning, it is believed this predictive approach can be utilized more extensively throughout the textile industry.
Keywords: Ideal fabric mix, Design of Experiment (DOE), Optimal fabric properties, Predictive, Forecast.

Ned Graphics: https://www.nedgraphics.com/
Software for textile design solutions for the home, fashion, and flooring from NedGraphics. Software for textile design solutions for the home, fashion, and flooring from NedGraphics. It's their vision to inspire creativity & productivity while providing essential products & services. NedGraphics™ is a leading developer of CAD software solutions created specifically for apparel and retail, home furnishings, flooring design, and various other textiles. NedGraphics products allow designers to exercise full creative freedom while improving efficiency, productivity, and accuracy to create production-ready artwork. For 37 years, NedGraphics has worked directly with top companies in the retail and apparel, home decor, and floor design industries, inspiring creativity by developing new and improved solutions tailored specifically to customers' needs. NedGraphics provides dedicated tools for print, woven, and knitted fabric design, carpet and tuft, color management and calibration, merchandising and more.
Keywords: Printing, weaving, knitting, fashion, floorings, dyeing.

Production Planning System (PPS),
https://www.stoll.com/en/software/production-planning-system-pps/ - Tool for remote access for controlling, planning and optimizing knitwear production.

Penelope Dobby CAD, *https://www.penelopecad.com/dobby-cad/*
This is the best-known CAD software for the design, production and simulation of Dobby fabrics.

Penelope Dobby CAD offers all the tools needed for the creation, design, production and simulation of all kind of designs created with a dobby loom. Penelope is developed from the fabric designer point of view and includes multiple tools that facilitate their daily tasks and let them focus on their design creations, increasing their efficiency and reducing the time spent to introduce the yarns, colors, weaves and technical data into the system.

Penelope Jacquard CAD https://www.penelopecad.com/jacquard-cad/
Penelope Jacquard is the most complete, versatile and user-friendly software to design all types of fabrics that use Jacquard technology, including terry. It has been designed to make your work easier. It offers a powerful set of tools for each part of the fabric design process: from the creation and edition of the images and graphs, and the weaves and technical data application of the fabric, to the loom file generation and, of course, the best rated hyper-realistic simulation in the market.

PyFormex: https://www.nongnu.org/pyformex/ - design of meshes for woven, knitted and braided structures, for use in mechanical engineering simulation.
Keywords: High end engineering, 3D Design, simulation.

Sense – immaterial reality, https://sense-immaterialreality.com
Sense an innovative digital catalog of your fabrics and a first step in the immaterial world. It is a catalog of your fabrics on the web, smartphone, and tablet, easy and fast. You can upload your existing archive of fabric photographs and descriptive cards, with no further investment. SenseFabric 101 lets you experience amazing new views through Immaterial Reality technology developed by Sense.SenseFabric 101 is the new part of SenseFabric's offer dedicated to all professionals and companies in the textile sector who wish to take the first steps towards the digitalization of their collections.

Sphera's Life Cycle Assessment Software (GaBi ts) https://sphera.com/life-cycle-assessment-software-ppc/
Tool may be used to reduce product's environmental footprint, carbon emissions, water consumption and waste. Sphera's Life Cycle Assessment Software (GaBi ts) is the leading product sustainability. Read, understand and process Life Cycle Assessment results. Data collection and management, quantitative material and energy flows, supply chain organisation, information management (human errors, unit conversion, inefficient workflows, etc.). It is not specific to textiles but I know it is used a lot in textiles too.

Solidworks - https://www.solidworks.com/ - 3D design software. A 3D mode not limited to textile can be established in the software. Its document can be imported into a FEM software such as Abaqus to do simulations, and into a 3D printer to fabricate a physical model.
Keywords: 3D design.

TexGen - http://texgen.sourceforge.net/index.php/Main_Page - open source software licensed under the General Public License developed at the University of Nottingham for modelling the geometry of textile structures.
Keywords: High end engineering.

TexMind Braider: http://texmind.com/wp/products/ - design of tubular and flat braids. With free visualizer
Keywords: Apparel design, development, simulation.

TexMind Warp Knitting: http://texmind.com/wp/products/warp-knitting-software/ - design of warp knit fabrics
Keywords: Apparel design, development, simulation.

Tradestone, http://tradestone.webflow.io/
TradeStone's PLM solution is for retailers, brands and wholesalers looking for rapid, collaborative product design to drive growth, improve margins and reduce cycle times. From initial inspiration to technical specification, TradeStone facilitates the design and development of private label and branded merchandise. It is mainly used by Designers, production and sail managers and shipping managers.

TUKA3D: https://tukatech.com/tuka3d/ – Virtual Fashion Design and Fit.
Fit is analyzed in motion, emulating a real-life virtual fit session. Evaluate frame by frame, rotating the model to examine the tightness and looseness of the garment. TUKA3D models "talk" about the comfort of the garment through 3D virtual sampling in 5 visual ways, including stretch, warp, weft, pressure, and x-ray. Share 3D samples on the web, connecting everyone in the supply chain with **digital collaboration tools.** Reuse 3D prototypes as digital assets for the next cycle, to visualize new prints, graphics, and placements without re-draping the sample.
Keywords: Design, Develop, Deliver.

UniquePLM, https://gerbersoftware.com/products/yuniqueplm/
UniquePLM is used in Product lifecycle management to enhance data connectivity, Create and manage your designs in whatever program is most comfortable to you, collecting all of your information in one easy-to-access location.

VStitcher - https://browzwear.com/products/v-stitcher/ - 3D Software for Apparel Design and development.Create or modify patterns and translate into a realistic 3D prototype that showcases endless variations from physical fabric properties to material visualization, seams, pockets, layers, padding, creases, 3D rigid accessories, trims and more.
Keywords: Apparel design, development, simulation.