# STEM COMPETENCIES

## ALONG THE TEXTILE VALUE CHAIN

What Role Do Mathematics, Computer Science,
Natural Sciences and Technology
Play in the Fashion Industry?

Co-funded by
the European Union

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# 3D MODELLING & COMPUTER-AIDED DESIGN (CAD)

**3D modelling** refers to the digital creation of three-dimensional objects, such as clothing, accessories or technical textiles, using specialized software.

**Computer-aided design** (CAD) is the umbrella term for computer-supported construction, drawing and modelling – in the textile sector, for example, it is used for digital pattern making, surface calculation, material adjustment and product development.

# HOW DOES IT WORK IN PRACTICE?

**3D modelling and CAD software are used in various areas of the fashion industry.**

## PATTERN MAKING

In pattern making, CAD systems such as Gerber AccuMark enable precise digital creation of patterns and automated size grading.

## FASHION DESIGN

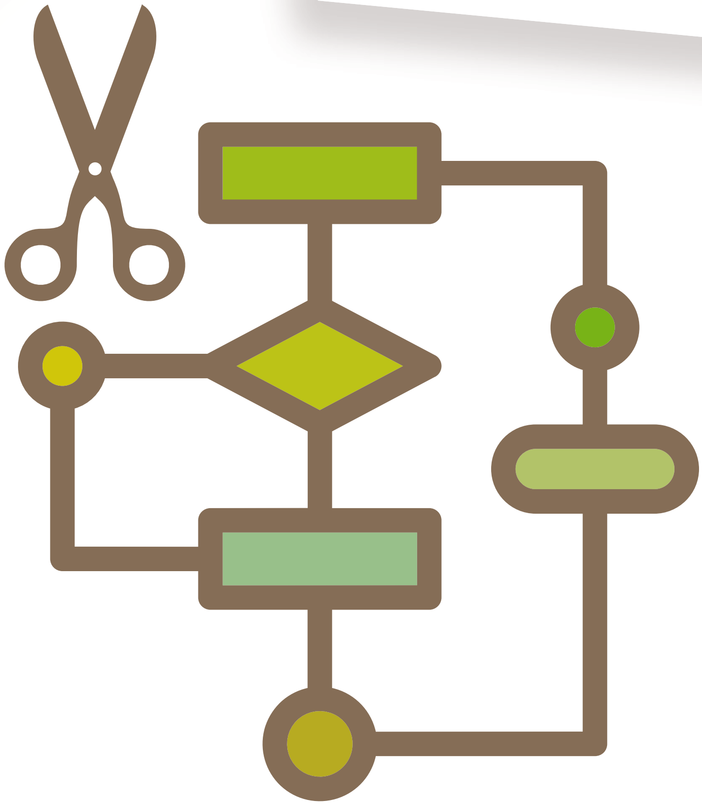
In fashion design, garments can be created directly on a digital avatar – programs like CLO3D, Browzwear or TUKAcad allow realistic simulation of fabric properties, drape, movement and fit on screen.

## PATTERN

3D modelling also offers major advantages in prototype development: pattern pieces can be virtually checked and optimized without the need for physical samples, saving time, material and resources.

## PHASE 0

### CONCEPT PHASE – THE DESIGN



# ALGORITHMS FOR PATTERN OPTIMIZATION

(ZERO WASTE DESIGN)

Algorithms for pattern optimization are mathematical procedures and programming solutions used in automated or semi-automated fabric cutting to minimize material waste, plan cutting layouts efficiently, reduce production time and lower costs.

They are applied in CAD systems for the apparel industry or in industrial cutting machines.

## HOW DOES IT WORK IN PRACTICE?

**A company plans to produce 100 T-shirts made of jersey fabric. The pattern pieces (front, back, sleeves, collar) are created digitally.**

## THE ALGORITHM AUTOMATICALLY CALCULATES:

+ how to arrange the pieces on the fabric in the most space-saving way (so-called "nesting")
+ the optimal cutting sequence to save time
+ whether the fabric is correctly aligned with the grainline, which may vary depending on the pattern or stretch

**The result is up to 20 percent less fabric waste, a faster process and fewer errors.**

# MATERIAL SIMULATIONS

(PHYSICALLY ACCURATE BEHAVIOUR)

**Material simulations** are computer-based methods used to digitally replicate the behaviour of fabrics and materials under real conditions (such as movement, stretch, or gravity).

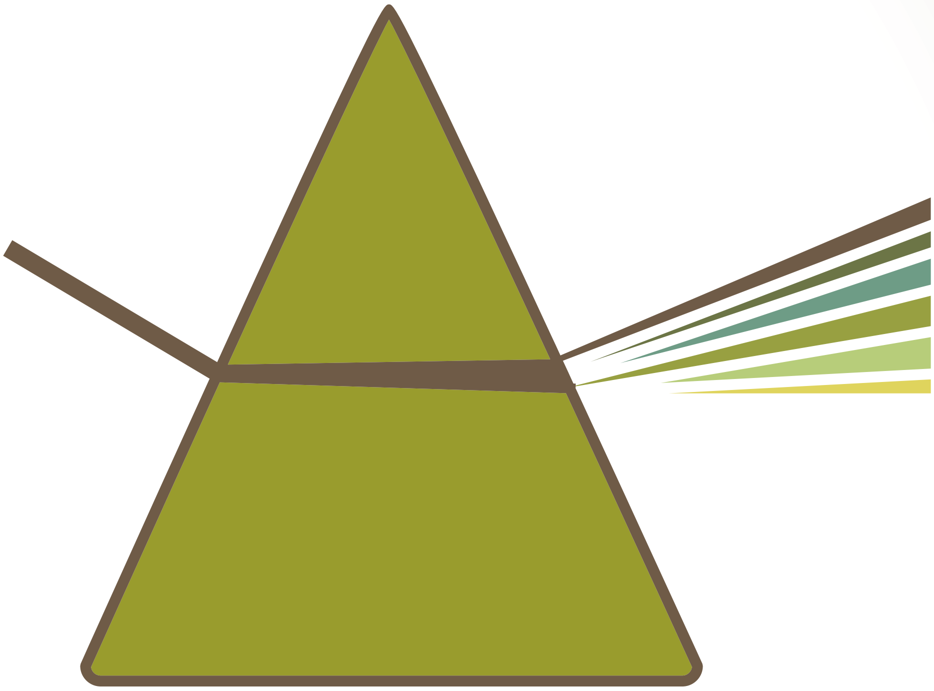
In the textile industry, these simulations are used to visualize how a garment drapes on the body without having to sew it physically in advance.

# HOW DOES IT WORK IN PRACTICE?

**A fashion designer wants to visualize a dress in 3D and uses software that realistically simulates fabric behaviour.**

The software calculates how different textiles respond to movement, wind or gravity based on physical material parameters.

This allows the designer to make informed decisions about cut, fabric choice and fit already in the design phase – saving time, material costs and physical prototypes.



# COLOUR THEORY & PHYSICS OF LIGHT

**Colour theory** is the study of how colours are perceived and how they affect us.

**The physics of light** is a branch of physics that deals with the properties, propagation and interaction of light.

In textile practice, this refers to how colours are created and perceived under different lighting conditions, and how fabrics reflect, absorb or transmit light.

# HOW DOES IT WORK IN PRACTICE?

**A fashion company produces fabrics in different batches. The fabric is supposed to appear in a specific shade of olive green. The colour tone must remain consistent, regardless of whether production takes place in summer or winter, and whether the fabric is sold online or displayed in a store.**

**To ensure this, the following process is carried out:**

## COLOUR MEASUREMENT

A spectrophotometer measures the colour value in the CIELAB colour space. The CIELAB model is device-independent and perception-based. It defines colours based on their brightness and their position on the red-green and blue-yellow axes, and is primarily used for precise colour comparisons and colour management.

## COLOUR COMPARISON

The colour difference between two fabric batches is calculated mathematically. If the value is low, the colour tone is considered identical.

## LIGHT INSPECTION

Fabric samples are tested in a light booth under various light sources (daylight, supermarket lighting, etc.). The goal is to avoid any visible colour deviation.

## COLOUR MANAGEMENT

The measured values are digitally stored and used globally for quality assurance.

# POLYMERIZATION CHEMISTRY

## (FOR SYNTHETIC FIBRES)

**Polymerization** is a chemical process in which small molecules (monomers) are joined to form long chain molecules (polymers).

These polymers are the basic building blocks of synthetic fibres such as polyester, nylon or acrylic.

Without polymerization, there would be no synthetic textiles like those commonly used today in clothing, sportswear, outdoor materials or technical fabrics.

# HOW DOES IT WORK IN PRACTICE?

**Polymerization – the chemical reaction in which many small molecules (monomers) join to form long chains (polymers) – is used in various areas of the textile industry:**

## PRODUCTION OF SYNTHETIC FIBRES

for example for sportswear, outdoor textiles or medical applications

## FUNCTIONALIZATION OF TEXTILES

through chemical modification, such as making fabrics water-repellent or antibacterial

## RECYCLING PROCESSES

where existing polymers are broken down into their original building blocks (monomers) through depolymerization to produce new fibres

**PHASE 1**

**FIBER PRODUCTION**

# MICROSCOPY & ANALYSIS

(FIBRE MORPHOLOGY)

**Microscopy and fibre morphology analysis** refers to the examination of fibres at the microscopic level to make their structure, shape and physical properties visible and measurable.

Analytical methods such as light microscopy, scanning electron microscopy (SEM) or Fourier-transform infrared spectroscopy are used to study and compare fibres in detail.

Fiber morphology describes both the external and internal structure of a fibre – for example, whether it is smooth, crimped, hollow or scaly.

# HOW DOES IT WORK IN PRACTICE?

**A textile technologist wants to determine whether a garment is made of cotton or viscose. This distinction is important depending on the intended use of the garment or what should happen to it later.**

In **quality control**, fibres are examined for damage, tears or contamination. This helps identify defective goods at an early stage.

In **research and development**, new fibre blends are analysed to create materials with improved properties – for example, softer, more tear-resistant or more environmentally friendly.

In **recycling** or **sorting** of used clothing, it is essential to precisely identify the fibre type so that fabrics can be properly processed.

**Material testing** also includes verifying what the fabric is made of – for instance, in cases of disputes over product quality or to check compliance with regulations.

**Fiber analysis therefore provides valuable information for many areas of the textile industry.**

# AGRICULTURAL SENSING

(FOR NATURAL FIBRES)

**Agricultural sensing** refers to the use of technical sensors and measurement systems to collect, analyse and optimize plant-related data in real time, particularly in the cultivation of fibre crops.

Factors such as soil moisture, nutrient levels, weather conditions, plant growth and fibre quality are digitally monitored. The goal is to achieve precise, sustainable and efficient production of natural fibres for the textile industry.

# HOW DOES IT WORK IN PRACTICE?

**Modern sensor and measurement technologies are used in cotton fields:**

**soil sensors** and **weather stations** continuously record relevant environmental data. Measurements include soil moisture and temperature, air humidity and solar radiation.

In addition, **drones** equipped with camera systems determine plant height.

The collected data is analysed to determine the optimal harvest time, reduce water consumption in a targeted way, and optimize fibre quality – for example, in terms of length and fineness.

**Yields increase, fibre quality improves, and cultivation becomes more efficient while using resources more sustainably.**

**PHASE 1**

**FIBER PRODUCTION**

# BIOFIBRE DEVELOPMENT

(E.G. BANANA FIBER, HEMP)

**Biofibre development** refers to the research, extraction, and processing of renewable plant-based raw materials into fibres suitable for textile use that are ecological, locally sourced, or innovative.

It focuses on fibres that serve as alternatives to cotton or synthetic fibres – often derived from waste materials or underutilized plants such as banana fibre from the stem of the banana plant, hemp, pineapple leaf fibre, nettle fibre, or flax.

# HOW DOES IT WORK IN PRACTICE?

**The process from the banana plant to a textile fibre can be understood in several steps – from raw material use to ecological evaluation:**

## RAW MATERIAL

After harvesting, the stem of the banana plant is reused – a byproduct that would otherwise be considered waste.

## FIBER EXTRACTION

The fibres are separated from the plant material through mechanical peeling, enzymatic processes, or water retting.

## FIBER ANALYSIS

The extracted fibres are then tested for properties such as strength, lustre, and processability.

## FURTHER PROCESSING

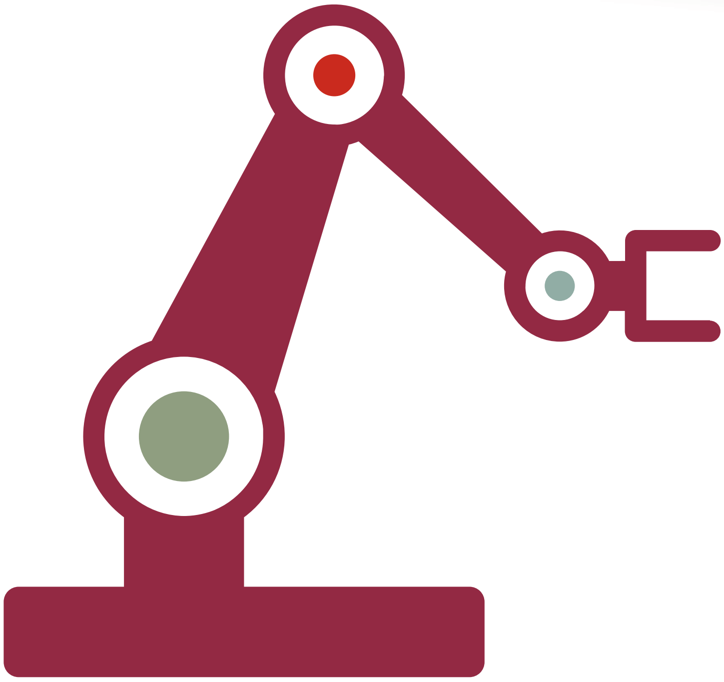
The fibres are spun into yarn, woven into fabrics, or pressed into nonwoven materials.

## EVALUATION

The overall ecological footprint is assessed and compared with established materials like cotton or polyester.

# PHASE 2

## YARN PRODUCTION – SPINNING



# PROCESS AUTOMATION & MACHINE CONTROL

**Process automation** refers to the automatic control, monitoring, and optimization of production processes with little or no human intervention.

**Machine control** is the technical component of this. It ensures that machines perform exactly as programmed – precisely, consistently, and efficiently.

In the textile industry, this applies for example to spinning, weaving, dyeing, or cutting fabrics, as well as to packaging and logistics. The goal is higher efficiency, consistent quality, fewer errors, and reduced resource consumption.

## HOW DOES IT WORK IN PRACTICE?

**A weaving mill wants to dye fabrics evenly and reliably. For this purpose, an automated system is used.**

**The dyeing process runs automatically, controlled by:**

### SENSORS

measure key values such as temperature, pH level, or dye quantity

### CONTROL UNITS

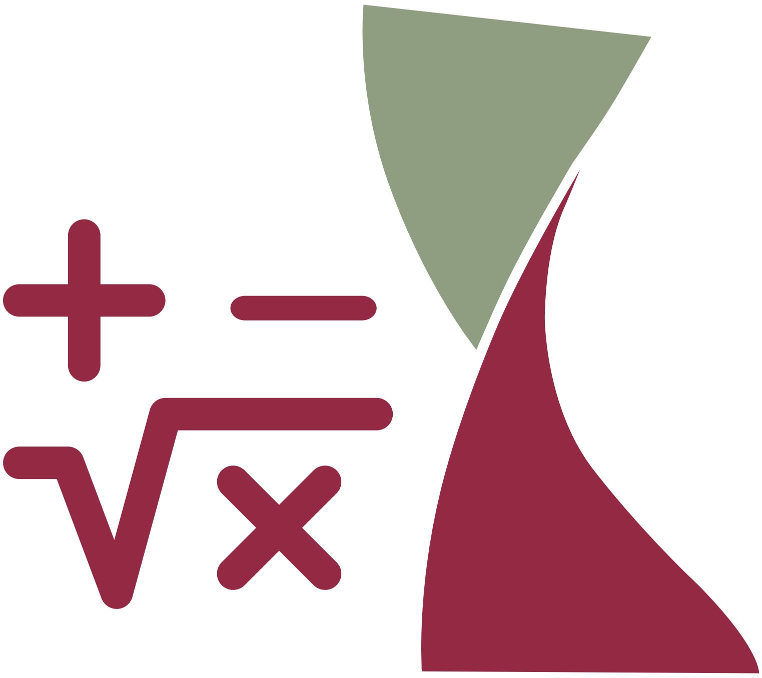
control units that regulate the process – for example, how hot the water is, how fast the fabric moves through, or how much dye is applied

### SOFTWARE

monitors and controls the process on a screen

If the system detects a deviation, the error is immediately identified, automatically corrected, and the corresponding data is recorded.

**The result is evenly dyed fabrics with reduced energy consumption and lower personnel requirements.**



# MATHEMATICS FOR ROTATION, TORSION AND STRENGTH

In textile engineering, the **mathematics of rotation, torsion, and strength** describes the mechanical properties of fibres, yarns, or fabrics that arise during spinning, twisting, stretching, or loading.

These mathematical models and formulas help to calculate, simulate, and optimize materials and processes – for example, how much a yarn can be twisted before it breaks or how much tensile force a fabric can withstand.

## HOW DOES IT WORK IN PRACTICE?

**During spinning, cotton yarn is twisted…**

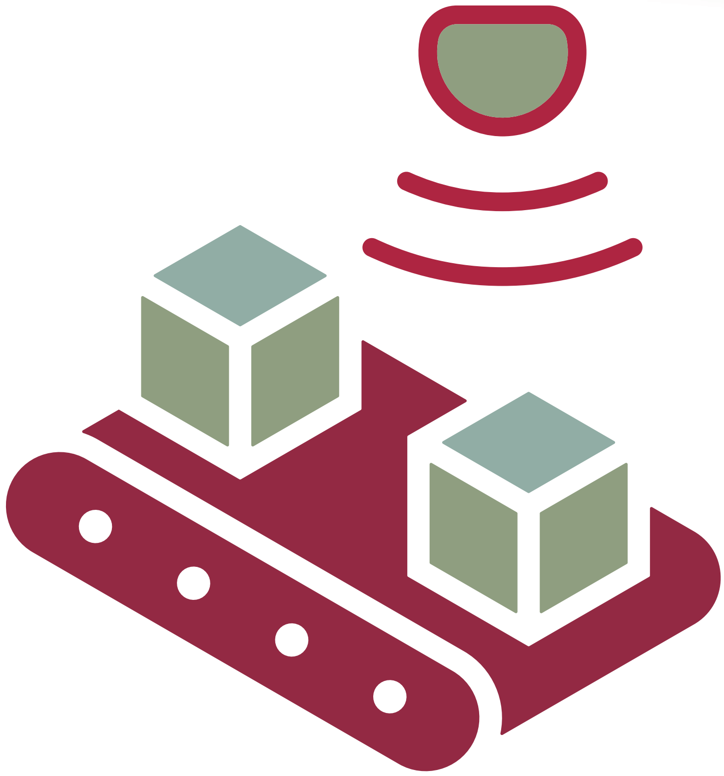
…this process, known as twisting, makes the yarn more tear-resistant and compact. The more twists per metre (e.g. 800 twists), the stronger it becomes.

However, too much twist can make the yarn stiff or brittle. The optimum twist count is therefore calculated mathematically – depending on the fibre thickness, the desired tensile strength and the intended use, such as whether the yarn is to be used for a fine shirt or a robust denim fabric.

**Without these calculations, the yarn would often be too weak, too stiff or uneven.**

## PHASE 2

### YARN PRODUCTION – SPINNING



# INLINE SENSOR TECHNOLOGY FOR QUALITY CONTROL

**Inline sensor technology** refers to the use of sensors directly within the ongoing production process to collect data in real time and continuously monitor the quality of materials or products without interrupting the process.

In the textile industry, inline sensors are used for example during spinning, weaving, dyeing, or finishing to detect defects immediately, monitor material properties, and automatically adjust or stop the process before waste is produced.

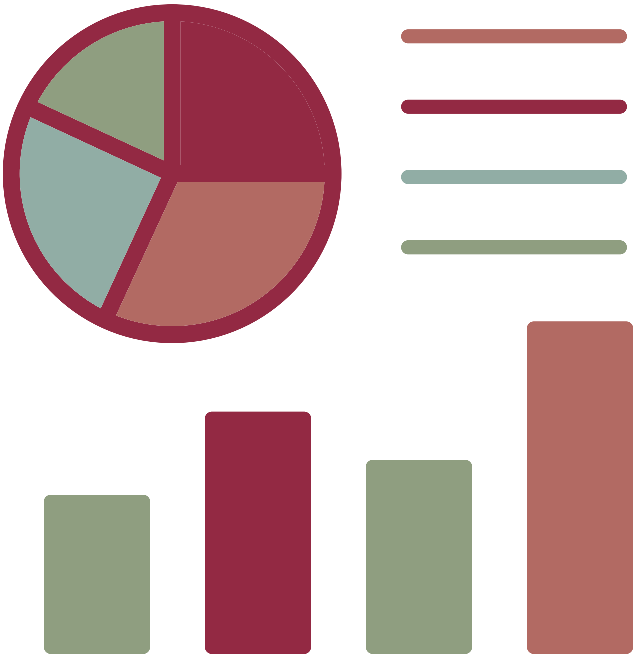
# HOW DOES IT WORK IN PRACTICE?

**While spinning a yarn, an optical sensor continuously monitors the yarn thickness and checks whether it matches the target value.**

If a significant deviation is detected, the sensor sends a signal to the control system.

The system responds automatically by adjusting the process, marking or removing the faulty material, or notifying the machine operator.

**The yarn quality remains consistent, which significantly reduces waste. At the same time, production costs decrease.**



# DATA ANALYSIS

(E.G. BREAKAGE RATES)

**Data analysis** is the process of systematically collecting, evaluating, and interpreting large amounts of production data to gain insights – for example, into sources of errors, machine performance, or material quality.

In textile engineering, this means that yarn breakages, production stops, or quality deviations are automatically recorded and analysed during ongoing operations. The goal of such digital systems is to make production more efficient, reduce costs, and sustainably improve product quality.

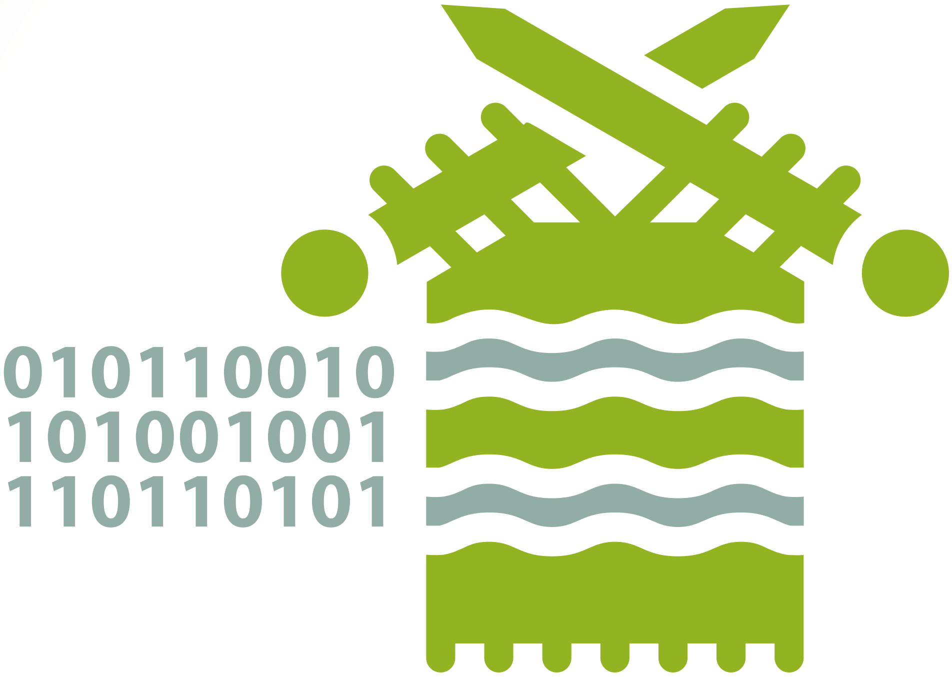
# HOW DOES IT WORK IN PRACTICE?

**In a spinning mill, sensors on the machines automatically record every yarn break.**

The data is stored in software and analysed daily, for example regarding the number of breaks per machine, time-based patterns, and noticeable differences between yarn types.

The analysis shows, for instance, that Machine 3 has about 30 percent more yarn breaks, indicating a need for maintenance. It also reveals that the breakage rate increases with high humidity, leading to a recommendation to adjust climate control.

**Downtime is reduced and product quality improves. Decisions can be made more precisely because they are based on clear data.**




# PROGRAMMING OF KNITTING MACHINES

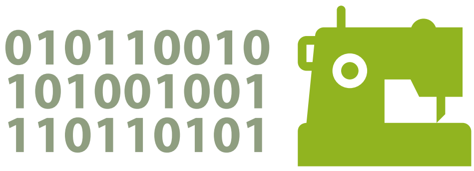
(E.G. STOLL M1+)

**The programming** of modern knitting machines involves the digital design of knitting patterns, material gradients, stitch densities, and targeted functional zones. Using specialized software like Stoll M1+, complex 2D and 3D knit models can be developed and directly transferred to the machine.

The goal is to produce customized, functional, or design-oriented knits, for example in fashion, sportswear, medical applications, or technical textiles.

## HOW DOES IT WORK IN PRACTICE?

With software like Stoll M1+, patterns or garments can be designed directly on the computer, for example a scarf with a heart motif.




The design is not knitted manually but converted into a machine program that the knitting machine automatically executes – similar to a 3D printer for textiles.

## PHASE 3

### FABRIC PRODUCTION – WEAVING, KNITTING

# SIMULATION OF FABRIC STRUCTURES

In the **simulation of fabric structures**, specialized software is used to visualize how a textile behaves – for example, how threads run, intersect, stretch, or fold.

This allows materials like linen, denim, or mesh fabric to be digitally examined on the screen before they are actually woven or sewn.

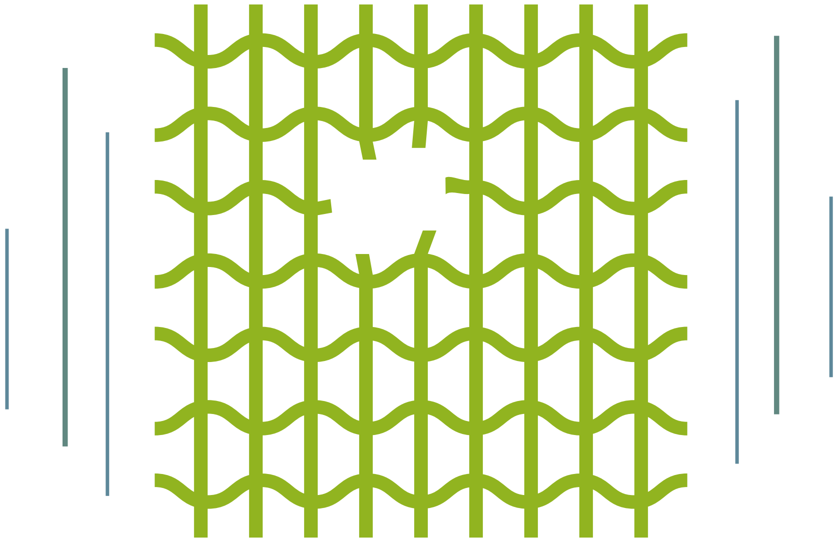
## HOW DOES IT WORK IN PRACTICE?

**When developing a gym bag, the question arises how dense a fabric needs to be to be stable yet as light as possible.**

Using a computer simulation, for example with a CAD tool or a weave structure simulator, different fabric variants are digitally represented – such as loosely woven with larger gaps or densely woven with closely packed threads.

The simulation shows how the material behaves under load, whether it tears, stretches, or remains stable, and how heavy it is with the given structure.

**Based on this, the variants can be compared and assessed to determine which is better suited for a bag meant to carry everyday loads like books or sports equipment.**



# TECHNOLOGY FOR DEFECT DETECTION

(IMAGE PROCESSING, SENSOR TECHNOLOGY)

**Defect detection** in textile engineering means that irregularities such as holes, pulls, stains, or weaving faults are automatically detected during ongoing production.

This is made possible by a combination of sensors that monitor, for example, thread tension, material thickness, or temperature, as well as camera systems with integrated image processing that visually inspect the fabric.

Specialized software continuously analyses the fabric patterns and reports deviations in real time.

# HOW DOES IT WORK IN PRACTICE?

**During production, the running fabric is scanned by a camera.**

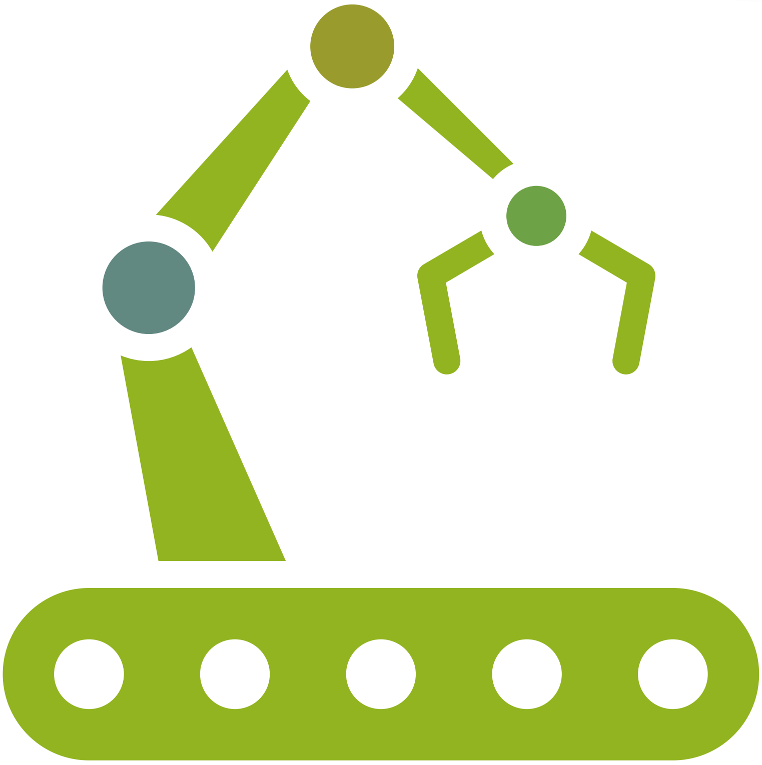
The associated software compares the captured images with the predefined pattern and detects deviations such as missing thread rows or contaminants.

When a deviation occurs, the machine can automatically respond by triggering an alarm, marking the affected fabric area, or stopping the production process.

**Errors are detected early, which helps avoid waste and quality defects. At the same time, disruptions in the production process can be addressed more quickly and precisely.**

## PHASE 3

### FABRIC PRODUCTION – WEAVING, KNITTING



# ROBOTICS & AUTOMATION

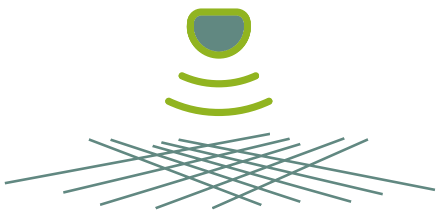
**Robotics and automation** refer to the use of automatically controlled machines and robots that independently perform precise, repetitive, or physically demanding tasks – often continuously.

In the textile industry, they are already used in many areas, for example in the automatic cutting of fabrics, packaging and sorting of clothing, or the loading of yarn spools.

# HOW DOES IT WORK IN PRACTICE?

**In automated fabric cutting, a robotic arm with a gripper precisely picks up the fabric layers.**

The cutting is then performed by a **laser cutter** or a **blade**, guided by a digital cutting pattern.



**Sensors** detect the position and tension of the material. If the system detects deviations, the software automatically adjusts the cutting process.

**This way, the fabric can be cut quickly and accurately, with less waste and a more efficient overall production process.**

# TEXTILE CHEMISTRY

## (PH VALUES, SURFACTANTS, ENZYMES)

**Textile chemistry** deals with the chemical processes and auxiliaries used in the production and finishing of textiles – for example, in washing, dyeing, bleaching, or treating fabrics.

Factors such as pH value, the use of surfactants, or the targeted application of enzymes play a central role.

They serve, among other things, to clean fibres, make colours durable, or finish textiles to be soft, absorbent, and antibacterial.

# HOW DOES IT WORK IN PRACTICE?

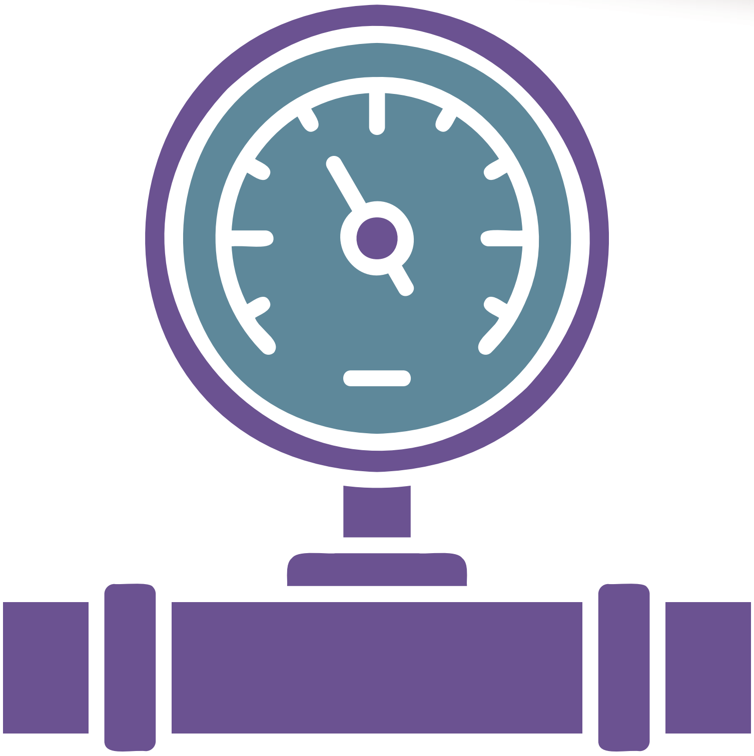
**In practice, the processing of cotton begins with a pretreatment aimed at removing impurities, improving absorbency, and preparing the fabric for subsequent dyeing.**

Surfactants dissolve fats and dirt, while enzymes break down plant residues like pectins. Additionally, the pH value is controlled, often in a slightly alkaline range, to create optimal conditions for bleaching, for example.

**The result is a clean, soft, and evenly absorbent fabric that is ideal for further finishing.**

PHASE 4

PRETREATMENT
– WASHING, BLEACHING

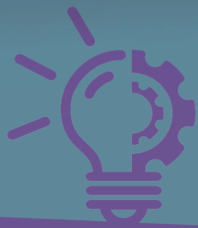


# ENVIRONMENTAL MEASUREMENT TECHNOLOGY

(WATER CONSUMPTION, WASTEWATER ANALYSIS)

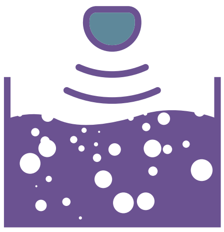
**Environmental measurement technology** includes all technical methods and measurement systems used to record, monitor, and evaluate environmental impacts during production – for example, water consumption or the pollution level of wastewater.

In the textile industry, it plays a particularly important role because significant amounts of water and chemicals are used in dyeing, washing, and finishing processes.

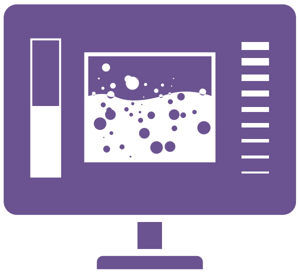


# HOW DOES IT WORK IN PRACTICE?

**During the dyeing process, water consumption is systematically recorded and analysed.**



A measuring device documents the amount of water used per batch of dyeing goods. At the same time, sensors measure the pH value and temperature of the wastewater produced.



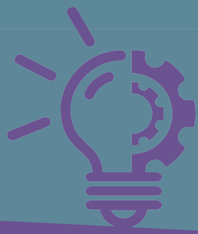
Software processes the collected data and calculates, among other things, the water consumption per kilogram of fabric. It also checks whether the measured wastewater values are within the permissible limits.

**Based on this evaluation, potential savings can be identified, enabling the operation to work more resource-efficiently and environmentally friendly.**

# REACTION ENGINEERING

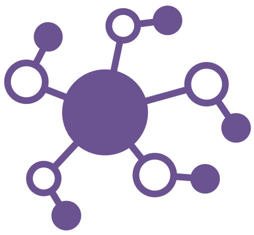
**Reaction engineering** deals with the planning, control, and optimization of chemical reactions in technical plants.

The goal is to convert chemical substances in a controlled, safe, and as efficient way as possible – for example, in the production of dyes, synthetic fibres, or chemical auxiliaries used in textile manufacturing.

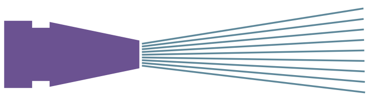


# HOW DOES IT WORK IN PRACTICE?

**In reaction engineering, two liquids, for example an alcohol and an acid, are mixed and heated together in a reactor.**



Through the resulting chemical reaction, the molecules link into long chains, forming a plastic – such as polyester.



This plastic initially has a viscous consistency, similar to honey, and is then extruded through fine nozzles. Fibers are produced in this way, which are spun into yarn in a subsequent step.

# TEMPERATURE & ENERGY OPTIMIZATION

**Temperature and energy optimization** means controlling industrial processes so that only as much energy as necessary is used – efficiently, but without compromising quality.

In textile engineering, this involves, among other things, heating during dyeing, drying, or fixing fabrics, as well as regulating machine heaters, steam generators, or exhaust systems.

The goal is to reduce energy consumption, lower costs, and at the same time ensure consistently high product quality.

# HOW DOES IT WORK IN PRACTICE?

**After the dyeing process, the still damp fabric rolls enter the dryer, where the temperature is precisely controlled.**

It must not be too high to avoid shrinking, nor too low to prevent long drying times and unnecessary energy consumption.

Sensors continuously monitor the temperature and residual moisture in the material. Based on these measurements, the system automatically adjusts the heating power and air supply.

**The result is a uniform drying process with minimal energy use.**

# PIGMENT CHEMISTRY & REACTION KINETICS

**Pigment chemistry** deals with the composition, production and application of insoluble dye particles that are applied to textiles as pigments to make colours and patterns permanently visible.

Unlike soluble dyes, pigments do not chemically bond with the fibre, but adhere physically to the surface – usually supported by a binder that ensures durability and resistance.

# HOW DOES IT WORK IN PRACTICE?

**In der Textilindustrie finden Pigmente unter anderem beim Drucken und Beschichten von Stoffen Anwendung.**

In the textile industry, pigments are used in the printing and coating of fabrics, among other things.

They are particularly suitable for bright colour effects, coarse fabrics or synthetic fibres, to which conventional dyes do not adhere sufficiently.

The fixing process, which often involves the targeted use of heat, is crucial for the durability and adhesion of the pigments and has a significant influence on wash and rub fastness.

# DIGITAL PRINTING PROCESSES

(INKJET, SUBLIMATION)

**Digital printing processes** enable textiles to be printed directly using computer-controlled printers – similar to an inkjet printer, but specially designed for fabrics.

Unlike traditional processes such as screen printing, they are significantly faster and more flexible. They are also considered more environmentally friendly, as they do not require printing stencils or large quantities of water or chemicals.

## HOW DOES IT WORK IN PRACTICE?

**A fashion company plans to design a T-shirt with a colour photo print. The motif is first designed digitally on a computer. Depending on the material, different printing processes are used:**

### INKJET PRINTING
(INKJET PROCESS)

Liquid dye inks are applied directly to the fabric. This process is particularly suitable for cotton and blended fabrics. To permanently fix the colours, post-treatment with steam or chemical fixatives is necessary.

### SUBLIMATION PRINTING

A special ink is first printed onto a carrier paper. Heating to around 180 to 200 degrees Celsius causes the ink to turn into a gas and permanently penetrate the polyester fibres. The colour is firmly bound into the fabric so that it cannot be washed out.

**The finished T-shirt impresses with its washability, high light fastness and detailed reproduction.**

# COMPUTER-ASSISTED COLOUR MEASUREMENT & MATCHING

In the textile industry, **computer-assisted colour measurement** refers to a process in which colours are objectively recorded and digitally evaluated using special measuring devices such as spectrophotometers.

In **colour matching**, software uses this measurement data to calculate the appropriate dye recipe to accurately reproduce the desired colour tone – for example, when re-dyeing, printing or reproducing a design on different materials.

# HOW DOES IT WORK IN PRACTICE?

**If a customer wants to have a T-shirt reproduced in a specific colour, she can submit a fabric sample with the desired colour.**

A **spectrophotometer** precisely captures the colour information and analyses the spectral composition. Based on this, software creates a suitable dyeing formula, for example by mixing primary colours such as blue, red and yellow in defined quantities.

This enables production to reproduce the colour shade exactly, even on different types of fabric. The desired colour shade can thus be reliably reproduced on different materials and in every production batch.

**This saves material and ensures satisfied customers.**

# SUSTAINABLE PROCESSES

## (E.G. PLASMA TREATMENT)

**Sustainable processes** in the textile industry aim to conserve resources, minimise the use of chemicals and reduce environmental impact without compromising fabric quality, and often even with noticeable improvements.

One example of this is plasma treatment. This involves treating textiles with an electrically charged gas, without the use of water or liquid chemicals. This dry technology specifically alters the surface of the fibres – for example, to make them water-repellent or absorbent, to improve the adhesion of dyes and coatings, or to achieve antibacterial properties.

# HOW DOES IT WORK IN PRACTICE?

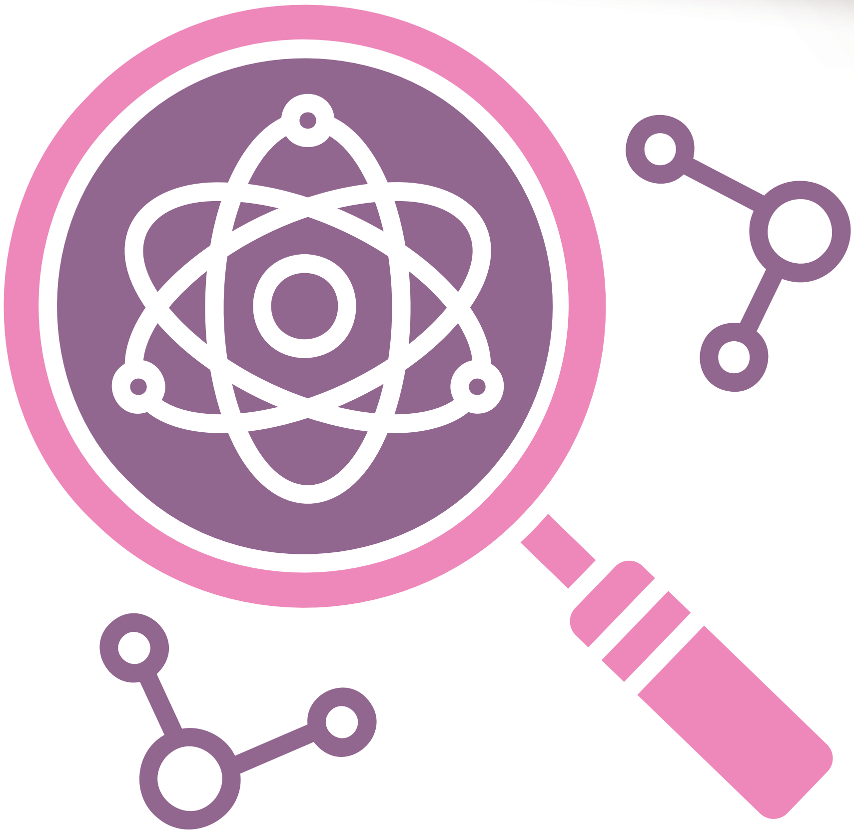
**An outdoor fabric needs to be made water-repellent, but without the use of a chemical coating bath.**

To achieve this, the material is passed through a **plasma system** in which a cold gas plasma is generated. This activates the fabric surface by specifically altering the fibre molecules at a microscopic level.

A very thin, **environmentally friendly coating** can then be applied, which adheres optimally thanks to the previous activation.

Since neither water nor harmful chemicals are used, no contaminated wastewater is produced.

**The result is a functional, durable fabric that has been manufactured sustainably.**



# PLASMA TECHNOLOGY, NANOTECHNOLOGY

**Plasma technology and nanotechnology** are used in the textile industry to give fabrics special functional properties without the use of toxic chemicals or high water consumption.

For example, hydrophobic finishes can be applied to make textiles water- and dirt-repellent. Antibacterial finishes are also possible, which inhibit the growth of bacteria, particularly relevant for sports and medical textiles.

**PLASMA TECHNOLOGY, NANOTECHNOLOGY**
(HYDROPHOBIC, ANTIBACTERIAL)

# HOW DOES IT WORK IN PRACTICE?

**To manufacture a functional sports shirt ...**

... a polyester fabric is first pre-treated in a plasma process to prepare the surface for subsequent coating.

A nano-coating with integrated silver particles is then applied. This has an antibacterial effect and helps to significantly reduce sweat odour.

**This keeps the shirt fresh for longer, while the equipment is washable and manufactured in a resource-efficient manner.**

## PHASE 6

### EQUIPMENT, FINISHING

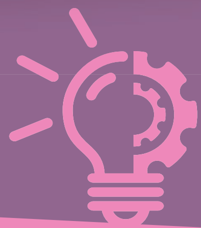
# TEXTILE FUNCTIONALISATION

(E.G. FOR SPORTS, MEDICINE)

**Textile functionalisation** refers to processes that go beyond the basic functions of textiles, such as protection and clothing, to specifically equip them with additional properties.

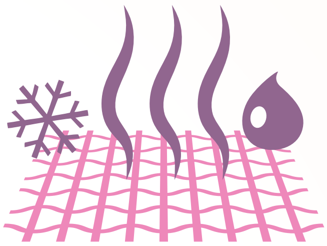
This can be achieved chemically, physically or technologically.

In sports and medical technology, for example, textiles are modified to be breathable, antibacterial or water-repellent, to wick away sweat, inhibit odours or even support wound healing. Smart textiles, which can record and transmit body data, are also created through such functionalisation processes.



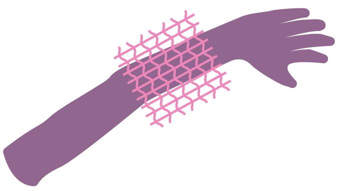
# HOW DOES IT WORK IN PRACTICE?

**Innovative finishing processes give technical textiles special functions tailored to their respective areas of application, for example in sports or medicine.**



## SPORTS TEXTILES

A modern functional shirt is finished in such a way that it improves wearing comfort and hygiene. A hydrophilic finish ensures that sweat is quickly wicked away from the skin. In addition, an antibacterial treatment prevents the formation of unpleasant odours, so that the textile stays fresh longer even with intensive use.



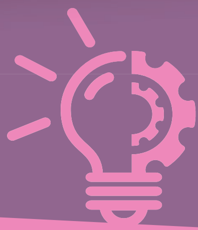
## MEDICAL TEXTILES

The primary focus of a dressing material is to protect the skin. Incorporated silver particles have an antibacterial effect and can thus prevent inflammation. At the same time, the material is breathable but does not allow germs to penetrate – a combination that is particularly suitable for wound care.

# MECHANICAL PROCESSES

(CALENDERING, SANFORISING)

**Mechanical processes** alter the surface structure or dimensional stability of textiles using pressure, friction, heat or tension – without any chemical additives. Two commonly used processes are calendering and sanforising.



## HOW DOES IT WORK IN PRACTICE?

**A common problem with new cotton T-shirts is that they shrink and crease badly after washing. This can be avoided by using specific mechanical processes in textile finishing.**

### KALANDRIEREN

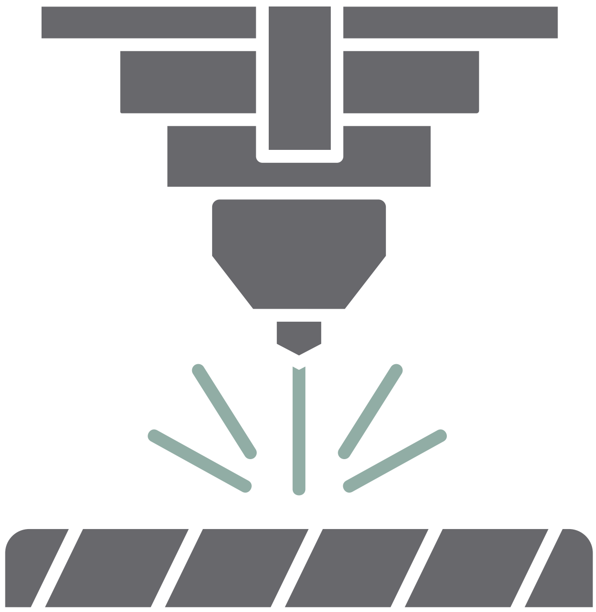
In calendering, the fabric is passed through smooth, heated rollers. This creates a smoother, denser and sometimes shiny surface, which improves the look and feel of blouses and lining fabrics in particular.

### SANFORISING

Sanforising is a mechanical pre-finishing process that is used especially for cotton fabrics. The textile is deliberately stretched and compressed to pre-shrink it. This means that shirts, trousers and home textiles hardly shrink at all when washed.

**PHASE 7**

**FINISHING
– CUTTING, SEWING**



# AUTOMATED CROPPING

(E.G. USING ARTIFICIAL INTELLIGENCE)

In automated cutting, computer-controlled machines – using knives, lasers or water jets, for example – perform precise cutting of fabrics, often directly based on digital patterns.

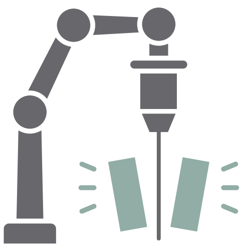
Modern systems increasingly rely on artificial intelligence to optimally place cut pieces on the material, thereby minimising waste. At the same time, defects in the fabric, such as stains or creases, can be automatically detected and taken into account.

The adaptation of cutting patterns to different sizes, models or fabric types is also becoming increasingly intelligent and efficient.

# HOW DOES IT WORK IN PRACTICE?

**Digital planning can significantly reduce fabric consumption in T-shirt production**

The individual pattern pieces, such as sleeves, torso and collar, are first arranged virtually in the system. AI then calculates the optimal cutting pattern to minimise material waste.

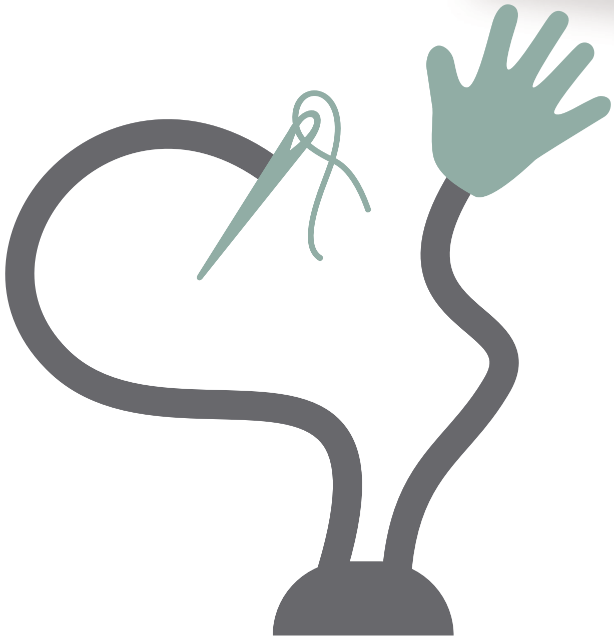


The cutting machine handles the entire process automatically – precisely, quickly and without the use of paper templates.

**This results in an efficient production process with virtually no material waste and consistent quality from piece to piece.**

PHASE 7

FINISHING
– CUTTING, SEWING



# ROBOTICS FOR SEWING PROCESSES

(E.G. SOFT ROBOTICS)

Robots are increasingly being used in the clothing industry to automate tasks such as sewing, moving or precisely guiding fabrics. Until now, these activities have been almost exclusively reserved for human manual labour, as textiles are soft, stretchy and difficult to control.

An innovative approach is known as **soft robotics** – a field in which flexible, yielding robot arms or gripping systems are used. These adapt sensitively to delicate materials without distorting or damaging them, thus enabling textiles to be processed gently and efficiently at the same time.

# HOW DOES IT WORK IN PRACTICE?

**Today, T-shirts can be sewn together using automated systems.**

A flexible robot arm carefully picks up the fabric pieces, such as a sleeve. High-resolution cameras are used to determine the exact position of the seam line. The robot guides the material under the sewing machine with millimetre precision and without creases.

This results in a fully automated sewing process in which the T-shirt is assembled step by step.

**The process ensures consistent quality, even for small quantities or customised garments.**

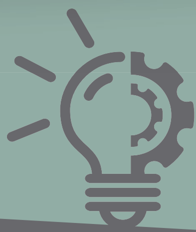
## PHASE 7

### FINISHING
### – CUTTING, SEWING

# SENSORY QUALITY CONTROL

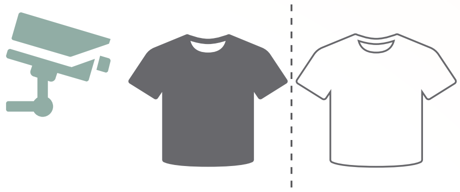
**Sensory quality control** describes the use of technical sensors for the automated detection of defects and deviations in textiles and garments – either during production or afterwards. Cameras and pressure, tension or colour sensors perform tasks that were previously mostly carried out by manual visual inspections.

Among other things, these systems can detect seam defects, creases or holes, measure dimensional deviations and deformations, and reliably check colour consistency and fabric quality.

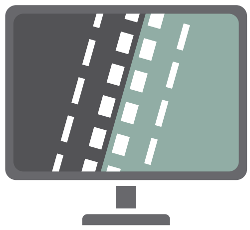


# HOW DOES IT WORK IN PRACTICE?

**After sewing, each T-shirt is automatically checked on a conveyor belt.**

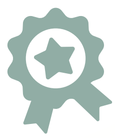


A camera system scans the finished garment and compares it with the specifications.

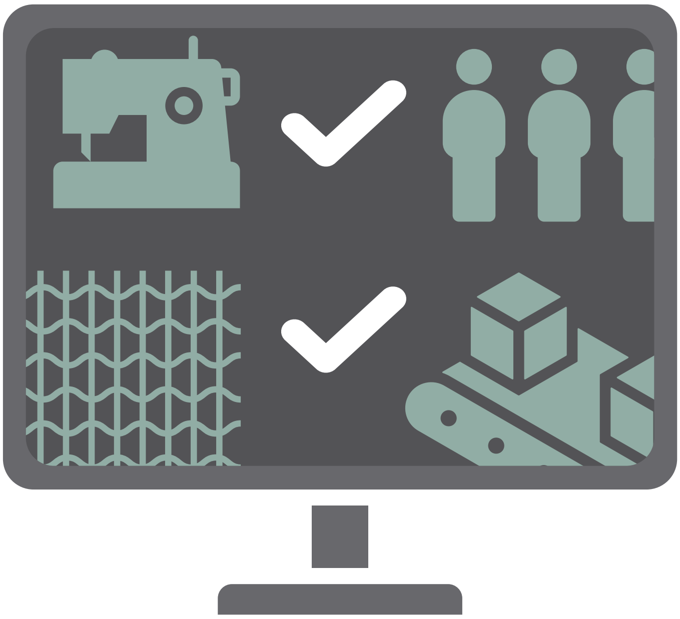


The software detects whether the seams are straight, whether there are any holes, creases or stains, and whether the size and shape correspond to the pattern.

If any deviations are detected, the defective item is automatically marked or sorted out.



**This ensures consistent quality, reduces the effort required for manual checks and minimises waste.**



# WORK PREPARATION USING SOFTWARE

(E.G. ENTERPRISE RESOURCE PLANNING)

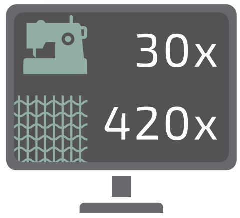
In the textile and clothing industry, work preparation ensures that materials, machines, personnel and processes are optimally coordinated before production begins.

With the help of **modern software**, such as an ERP (Enterprise Resource Planning) system, this process can be digitally planned, coordinated and monitored in real time.

This enables efficient, timely and resource-saving production.

# HOW DOES IT WORK IN PRACTICE?

**A fashion company plans to manufacture 500 blouses...**

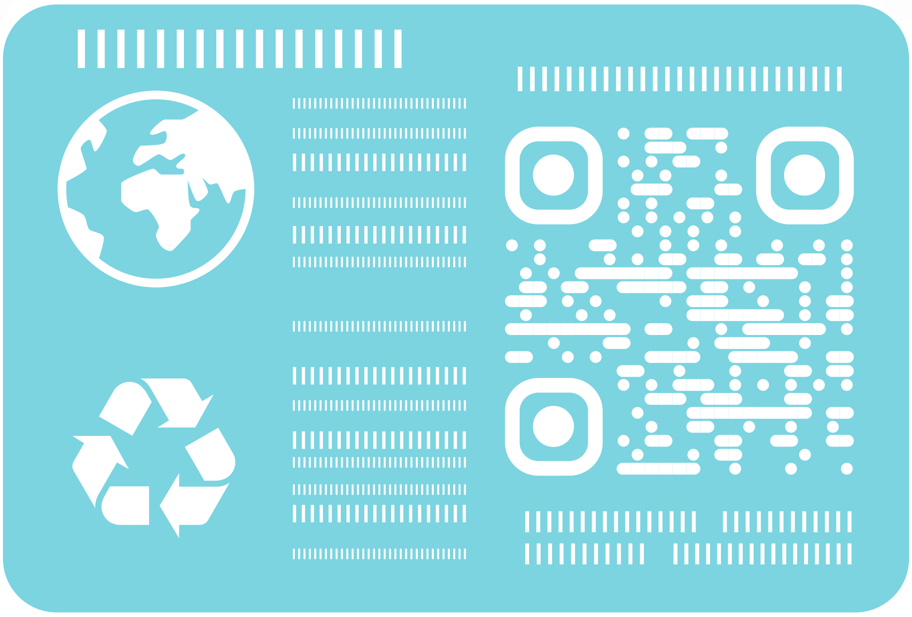



Special software calculates in advance how much material – such as fabric and buttons – will be needed, which machines and work steps are required, and how the production schedule should be organised.

All relevant information is automatically transmitted to the warehouse, production and purchasing departments.

Thanks to this preparatory planning, production can start smoothly and without delay.

**This reduces errors and idle times and ensures significantly better planning.**



# PRODUCT PASSPORT & QR CODES FOR TRACEABILITY

A **product passport** is a digital record that contains all relevant information about a garment or textile product, including details on material composition, origin, care, repair options and recycling options.

Access is usually via a **QR code**, which is attached to the label, in the care instructions or on a sewn-in chip.

The code can be read with a smartphone or scanner to directly access the digital product file.

# HOW DOES IT WORK IN PRACTICE?

**A sports shirt has a QR code on the label that provides a wide range of information when scanned.**

Consumers can find out about the origin of the materials, such as whether recycled polyester was used, as well as details about the production location and carbon footprint.

Care instructions, repair options and information about the take-back system are also stored.

The QR code also offers advantages in production: the garment can be automatically recorded, sorted and tracked throughout the entire process.

**This creates digital transparency along the entire value chain.**

PHASE 8

RETAIL

# DATA ANALYSIS

## (CONSUMER BEHAVIOUR, RETURNS)

**Data analysis** refers to the systematic evaluation of large amounts of data in order to gain insightful knowledge about customer behaviour, sales trends and reasons for returns.

In the textile industry, this information comes from sources such as online shops, cash register systems, returns and surveys.

It helps to identify purchasing patterns – such as particularly popular colours, sizes or styles – and to better understand high return rates, for example due to fit problems or dissatisfaction with the material. On this basis, product development, warehousing and sustainable strategies can be optimised in a targeted manner.

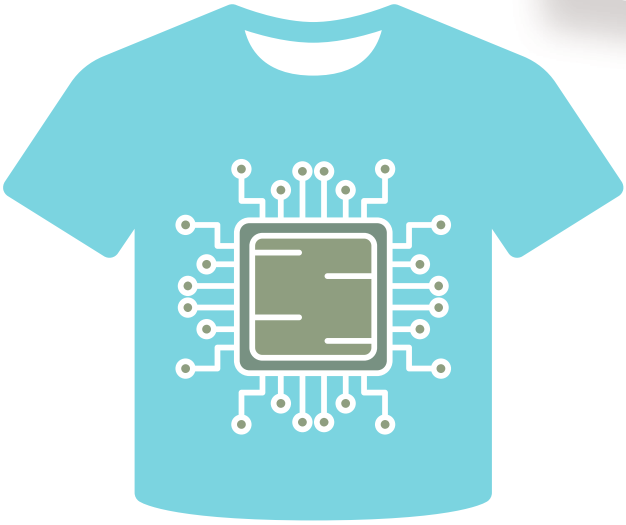
# HOW DOES IT WORK IN PRACTICE?

**A fashion company analyses returns from its online shop to identify potential weaknesses in its product range.**

For example, it finds that dresses in size M are frequently ordered but returned in around 40 percent of cases. A more detailed analysis reveals that many customers say the dress is too tight around the shoulders.

Based on this feedback, the design team can make specific adjustments to the cut.

**This leads to fewer returns, more satisfied customers and a lower environmental impact.**



# SMART TEXTILES / WEARABLES

**Smart textiles** are fabrics equipped with electronic components, sensors or functional materials. They can respond to external stimuli, collect data or actively perform certain functions.

This makes them the basis for so-called wearables – portable electronic systems such as clothing or accessories that connect digital technologies directly to the body. This interface between fashion, technology and health opens up numerous fields of application in the textile industry.

In the sports and fitness sector, smart textiles enable the measurement of pulse, respiration or movement. In medicine, they are used to detect falls or continuously monitor bodily functions such as temperature or blood sugar.

They are also used in workwear, for example for warning systems, location tracking or automatic temperature regulation. In the lifestyle and fashion sector, integrated LEDs or touch-sensitive materials are opening up new design and interactive possibilities.

# HOW DOES IT WORK IN PRACTICE?

**Conductive fibres and sensors are integrated into a fitness shirt, which record important body data such as heart rate and breathing rate during training...**

...This information is transmitted via Bluetooth to an app on a smartphone, which evaluates the values in real time.

This allows the system to provide information on the current level of exertion and the optimal training intensity.

**The result is intelligent clothing that actively responds to the body and provides individualised training support.**

# E-COMMERCE ALGORITHMS & CONFIGURATORS

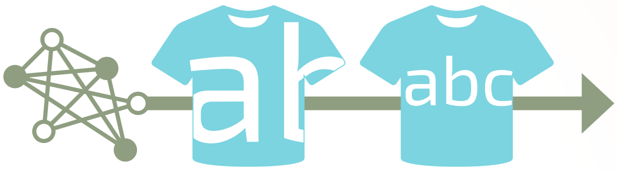
In online retail, fashion and textile companies are increasingly relying on **algorithms** and **product configurators** to make the shopping experience personalised, efficient and user-friendly.

**Algorithms** analyse user behaviour and provide personalised recommendations – such as suitable items, sizes or colour variations. They help to simplify product selection and increase customer satisfaction. **Configurators** also make it possible to design products according to your own ideas.

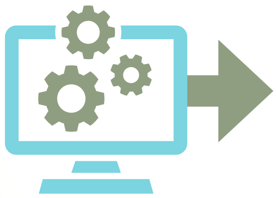
A T-shirt can be designed entirely according to your own ideas, for example with a customised print, your desired cut and the right fabric.

## HOW DOES IT WORK IN PRACTICE?

**In an online shop, customers can customise their T-shirts – the cut, colour, text and graphics can be conveniently selected with a click.**




An algorithm automatically checks whether the font size matches the selected design, whether the desired product is in stock and which size is likely to fit well.



After the order process, all information is sent directly to production, for example to the printing machine.

**The result is a customised product that is digitally planned and efficiently implemented.**

# FIBRE ANALYSIS & MATERIAL SEPARATION

(E.G. NEAR-INFRARED SPECTROSCOPY)

**Fibre analysis** is used to determine the exact composition of textiles, for example whether a fabric is made of cotton, polyester or a mixture of different fibres.

Modern methods such as near-infrared spectroscopy (NIR) enable fast, contactless and non-destructive identification of materials.

This is particularly relevant for quality control in production, for sorting old textiles in the recycling process and for automated **material separation** within a functioning circular economy.

# HOW DOES IT WORK IN PRACTICE?

**Modern NIR technology (near-infrared spectroscopy) is used in textile recycling.**

A used garment is placed on a conveyor belt, where a spectrometer analyses the material composition of the surface – for example, cotton with a polyester content of 30 percent.

Based on this measurement, a robot arm automatically sorts the textile into the appropriate recycling channel.

**This allows mono and mixed fibres to be separated and recycled in a targeted manner. This improves the quality of recycling, reduces waste and enables more efficient use of resources.**

PHASE 9

RECYCLING & CIRCULAR ECONOMY

# CHEMICAL RECYCLING

## (E.G. POLYESTER DEPOLYMERISATION)

In **chemical recycling**, synthetic textile fibres such as polyester are not simply melted down, as is the case with mechanical recycling, but chemically broken down into their original components.

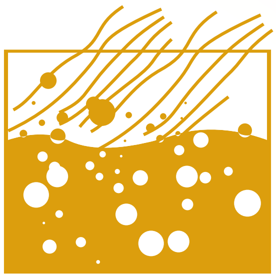
This process is known as depolymerisation, whereby the plastic polymer is broken down into its individual chemical components.

These purified raw materials can be used to produce high-quality polyester again, in a quality that corresponds to that of new goods.

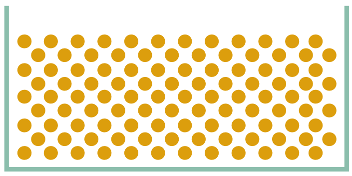
**CHEMICAL RECYCLING** (E.G. POLYESTER DEPOLYMERISATION)

# HOW DOES IT WORK IN PRACTICE?

**A T-shirt made from 100 percent polyester (PET) can be completely chemically recycled.**



In the recycling process, the material is depolymerised in a reactor, for example through glycolysis, in which the polyester is broken down into its constituent parts, such as terephthalic acid and ethylene glycol, with the aid of glycol.

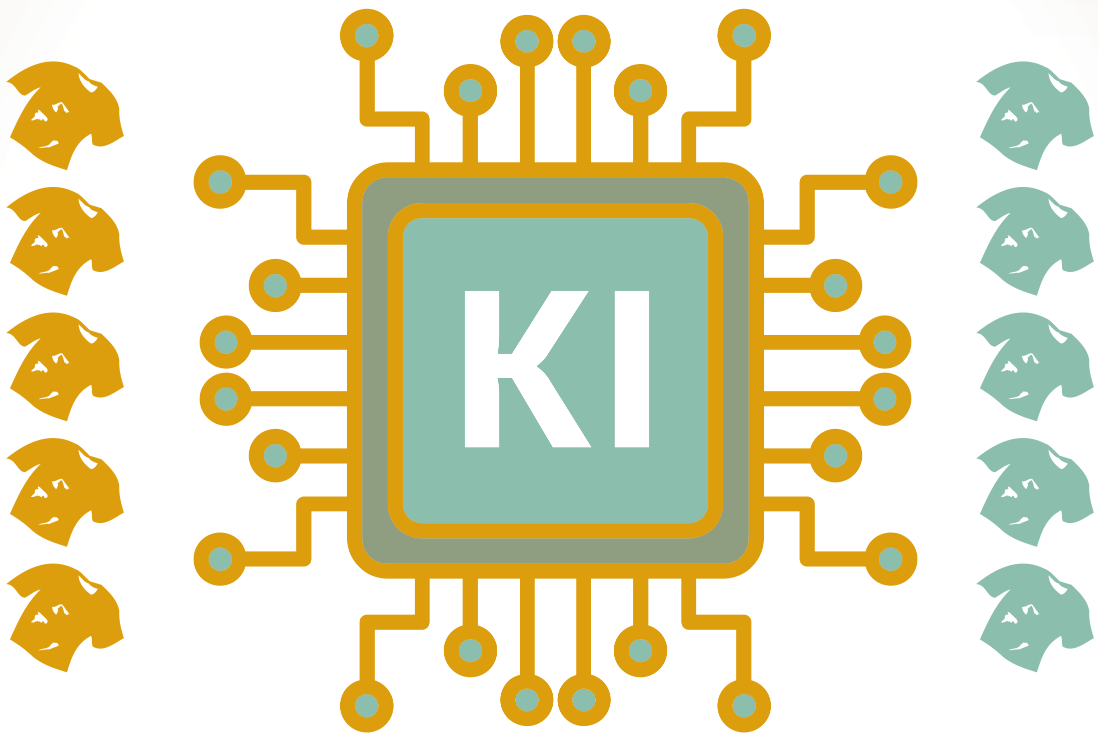


These pure raw materials can then be processed into new polyester granulate, which is used to produce high-quality yarn for textiles – without any loss of quality.

**In this way, a used garment is turned into a new fibre, closing the loop and enabling sustainable recycling.**

PHASE 9

RECYCLING &
CIRCULAR ECONOMY

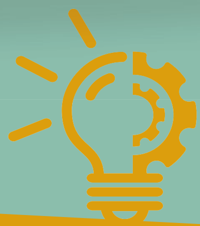



# ARTIFICIAL INTELLIGENCE FOR SORTING

The use of **artificial intelligence for sorting** means that adaptive computer systems are used to automatically recognise, distinguish and classify textiles – for example, by colour, material, condition or product type.

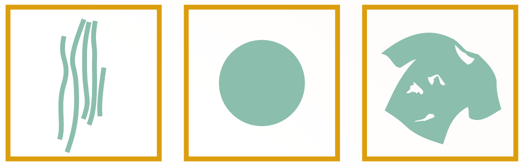
Instead of manual inspection, cameras, sensors and intelligent algorithms analyse large quantities of textiles in real time. This is particularly relevant for efficient recycling processes and automated warehouse logistics.

ARTIFICIAL INTELLIGENCE FOR SORTING



# HOW DOES IT WORK IN PRACTICE?

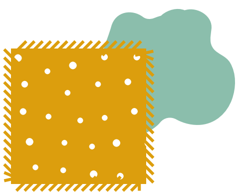
**In a recycling plant, large quantities of used clothing are emptied from containers and sorted automatically.**



With the help of AI-supported systems, each piece of textile is analysed – for example, according to material composition, colour and condition.

A well-preserved garment made of pure cotton in blue can thus be directly designated for the second-hand sector.

A shirt made of a polyester-cotton blend, on the other hand, is sent for chemical separation to recover the fibres.



Heavily damaged or soiled items are recycled as cleaning rags or for the production of insulation material, depending on their condition.

**This makes textile sorting more efficient, more precise and more resource-efficient.**

PHASE 9

RECYCLING &
CIRCULAR ECONOMY

# LIFE CYCLE ASSESSMENT & DATA MODELLING

**Life cycle assessment** (LCA) is a scientific method for evaluating the environmental impact of a product throughout its entire life cycle – from raw material extraction to disposal, i.e. 'from cradle to grave'.

**Data modelling** plays a central role in this process. It mathematically and digitally maps complex material and energy flows in order to compare different scenarios. For example, it can be used to investigate whether recycled polyester has a better environmental balance than cotton, or how much $CO_2$ is produced when manufacturing a T-shirt in Asia compared to Europe.

# HOW DOES IT WORK IN PRACTICE?

**To create a life cycle assessment for a cotton T-shirt, various data points are collected throughout its entire life cycle.**

These include water consumption in cotton cultivation, energy requirements for spinning, weaving and dyeing, and transport distances, for example from the production site in China to Germany.

Consumer use – in particular washing and care – is also included in the survey.

All this information is fed into a digital model that calculates the ecological footprint, $CO_2$ emissions and water consumption.

**This provides companies with a sound basis for specifically using more environmentally friendly materials or more efficient processes.**

# CAREER GUIDANCE: STEM IS IN VOGUE

Promoting sustainability in the textile and fashion industry through STEM careers.

## PROJECT NUMBER

2024-1-DE02-KA210-VET-000247981

## PROJECT PARTNERS

**CorEdu**, Germany

**Eurocultura**, Italy

**GoSpark**, Slovenia

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# STEM COMPETENCIES

## ALONG THE TEXTILE VALUE CHAIN

What Role Do Mathematics, Computer Science, Natural Sciences and Technology Play in the Fashion Industry?