HOW A TECHNICAL INNOVATION IN ANCIENT TEXTILE INDUSTRY PIONEERED A NEW WAY OF THINKING

By Ulrike Beck and Martin Jess

“As early as the 1st millennium BC, the innovative idea to cut into fabric laid the foundation for new, efficient production concepts, extensively restructured the craft and established a new distinguished discipline: the construction of patterns.”

Suggested citation:
Ulrike Beck and Martin Jess, How a technical innovation in ancient textile industry pioneered a new way of thinking. *Interface Critique* 3 (2021), pp. 151–169.
DOI: 10.11588/ic.2021.3.81306.

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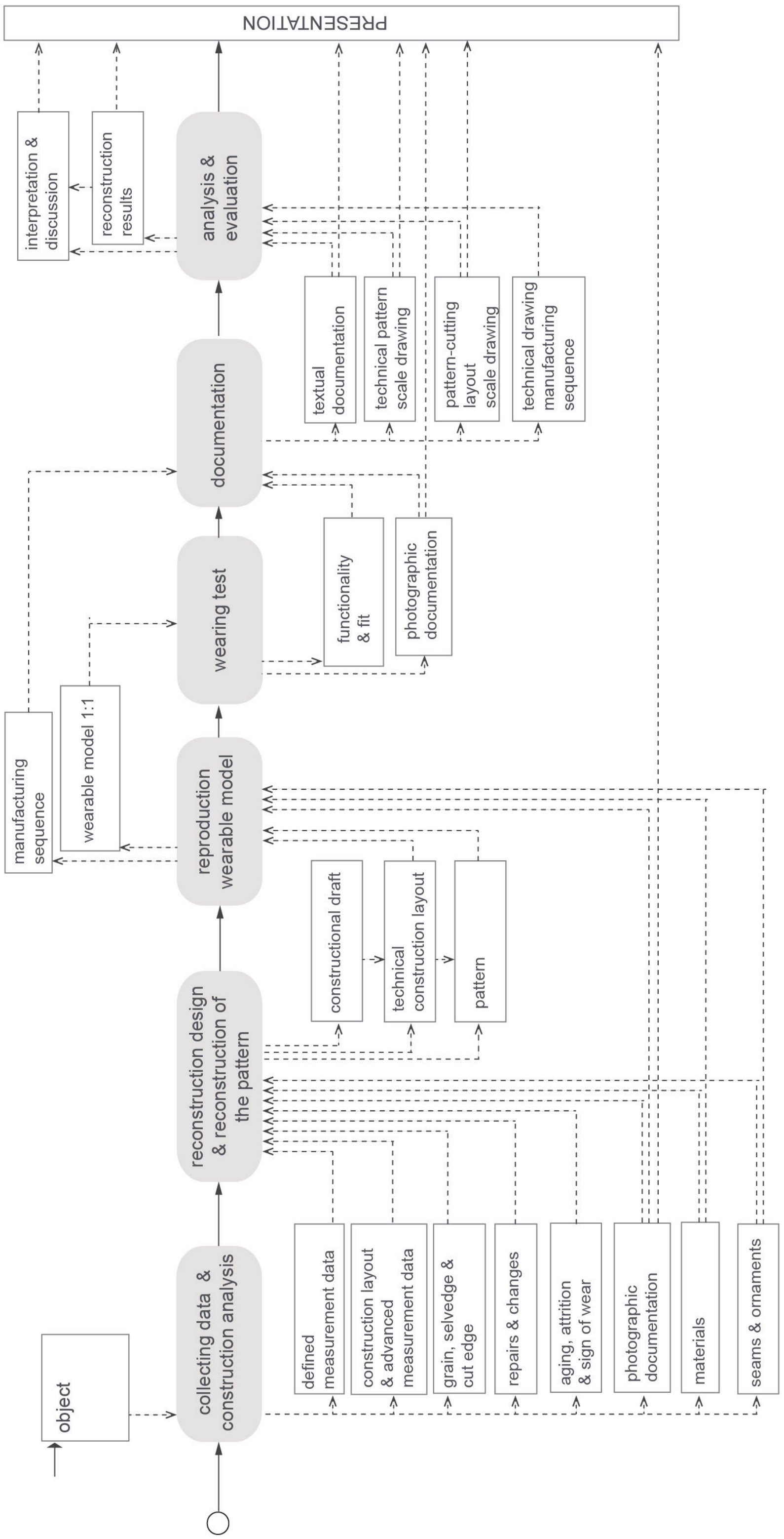

Fig. 1: Diagram of the reconstruction methodology: Overview of the different steps of the method: grey areas visualise the actions, that are executed within the methodology. The framed boxes represent the acquired knowledge and research results as well as practical achieved research findings in the form of con-struction layouts or wearing models; methodology and diagram: Ulrike Beck.

If examined in chronological order, comparable datasets of the excellently preserved textile finds from the 1st millennium BC in Xinjiang, Central Asia, tell an unusual story of the swift spread of an innovative technological idea within the clothing production in the region. It significantly changed the entire handcraft and is still essential today. It is the innovative idea to cut into fabric to manipulate its shape.[1] Even though this thought seems very natural to us at first glance – this idea is ground-breaking. Beyond laying the foundation for new, efficient production concepts and extensively restructuring the craft, its impact was felt through other parts of the culture. The concept to cut into a fabric to produce clothes is still the foundation of modern clothing production and the corresponding knowledge is mathematically implemented in today's construction systems.

Clothing fulfils practical, communicative and social functions.[2] As a cultural memory, it traces the changing eras and their social structures. Additionally, clothing plays an essential role in economic production and trading processes. It is a powerful driving force for commercial and social networking and the development of new technologies. The technology of cutting fabric to tailor clothes has prevailed over the millennia. It has adapted to industrialization, the development of chemical fibres and digitalization, and it is still absolutely essential for modern clothing production.

What principle makes this concept such an innovative and assertive strategy? Which core components enable it to integrate into modern digitalized society over millennia of fundamental social changes and restructuring?

In modern data processing, it is clearly defined: Solution strategies for complex problems must demonstrate good adaptation and allow for significant variance. In order to do this, they have to be dynamic, flexible and efficient. Could these core components represent a transferable pattern that has prevailed over the millennia? The concept of cutting fabric to tailor clothes seems to be precisely one of these phenomena. Although already developed in the 1st millennium BC, its basic principles are characterized by adaptability, flexibility and efficiency. As a new abstract thought pattern, it stands in contrast to an era of previous much more static concepts of clothing production. This ground-breaking innovation in ancient clothing production laid the technological and the intellectual foundations for today's industrialized and digitalized production processes for clothes.

1 Ulrike Beck, *Kleidung des 1. Jahrtausends v. Chr. In Xinjiang. Schnittentwicklung zwischen Funktionalität, Ästhetik und Kommunikation* (Regensburg 2018), pp. 154–222.

2 Susan North, *The Tudor Tailor* (London 2006), p. 5., Gabriele Mentges, *Kulturanthropologie des Textilen. Für eine Kulturanthropologie des Textilen* (Bamberg 2005), pp. 11–39.

Method and cast-off clothing as data archives

In order to highlight the core components of this excellent strategy, we have compared it with the model of modern solution strategies in data processing, as both clothing production and software development solve complex tasks, by converting creative ideas into a mathematical concept and applying it to a specific problem. Through this comparison, we can identify specific interdependencies and describe the different concepts and solution methods to solve complex problems. The development of different solution strategies in modern data processing is well documented. Due to the fast pace of digitalization, the concepts in data processing change and refine themselves over a short period of time.

The basis for the investigation of ancient production strategies are new insights into innovative approaches within the ancient textile industry in the 1st millennium BC in Xinjiang, China.[3] They reveal that the idea to cut into a fabric to tailor clothes was already invented at this time in Xinjiang. The consequent newly structured, faster and more dynamic manufacturing processes changed the aesthetics and the functionality of the clothes in a very short period of time. Furthermore, the new approach also significantly changed the structure of the entire craft.[4]

This ground-breaking change could be demonstrated by a new methodology which combines forensic techniques with those of reverse engineering. The method was applied to significant, and excellently preserved textile finds from the 1st millennium BC in Xinjiang, China (fig. 1).[5]

Textile finds are data archives: even after several thousand years, the ancient clothes still contain information about their design concepts and their production techniques. On top of uncovering information about the construction, aesthetics and functionality of the clothes, the unique strategies of the craftsmen at that time are still present in the stringent logic of the clothes' design and construction.

This article highlights an outstanding strategic concept and defines the core components of its longevity and exceptional adaptability.

3 Beck, *Kleidung des 1. Jahrtausends v. Chr. In Xinjiang*, pp. 62–222.

4 Ibid., pp. 154–222.

5 Ibid., pp. 26–60.

An ancient development achievement: The idea to cut into a fabric and its ground-breaking consequences

At the beginning of the First Millennium BC in Xinjiang, the pieces for a pair of woollen trousers are handcrafted directly on a loom: Therefore, right from the beginning, both trouser legs and the crotch piece are woven into the right shape and size and then sewn together.[6]

In that time in Xinjiang, garments were directly woven on the loom.[7] For this purpose, each separate construction part of a garment was already shaped during the weaving process.[8] This time-consuming approach required significant planning and foresight. While weaving the fabric, all desired details had to be included properly, to ensure that they would sit in the right place in the finished garment.[9] Therefore, the different phases of the production process – the weaving, the construction and the sewing – were completely interconnected disciplines and could not be processed independently.[10] The entire manufacturing process was very likely realised by one person, or in very close cooperation.

With this technique, the clothes could be decorated with complex ornaments or patterns that were directly woven into specific positions of the garment. However, the method had two major disadvantages: To weave clothes on a loom, the entire concept and planning of the garments had to be done right at the beginning of the manufacturing process. Only when the planning was completed, the actual production process could start. Therefore, possible construction mistakes in the working process were only visible and verifiable on the finished garment, weeks or even months later.[11]

For technological reasons, the form weaving offered only a few possibilities for the three-dimensional construction of the clothes because the loom as a tool is best suited to producing two-dimensional textile surfaces rather than to construct three-dimensional garments.[12] Thus, the

6 Ulrike Beck et.al, The invention of trousers and its likely affiliation with horseback riding and mobility. *Quaternary International* 348 (2014), pp. 224–235; Beck, *Kleidung des 1. Jahrtausends v. Chr. in Xinjiang*, pp. 62–75.

7 Beck et.al, The invention of trousers and its likely affiliation with horseback riding and mobility; Beck, *Kleidung des 1. Jahrtausends v. Chr. In Xinjiang*, pp. 62–75, 78–88, 154–222.

8 Beck et.al, The invention of trousers and its likely affiliation with horseback riding and mobility, pp. 224–235; Beck, *Kleidung des 1. Jahrtausends v. Chr. in Xinjiang*, pp. 62–75, 78–88, 154–222.

9 Ibid., pp. 154–263.

10 Beck et.al, The invention of trousers and its likely affiliation with horseback riding and mobility pp. 224–235; Beck, *Kleidung des 1. Jahrtausends v. Chr. in Xinjiang*, pp. 62–75, 78–88, 154–222.

11 Ibid., pp. 214–215.

12 Ibid., pp. 156–159.

Fig. 2: Reconstructed woolen garments from Yanghai: Reconstruction and wearing test of a pair of woollen trousers (2003SYIM21:19) and a woolen poncho (2003SYIM21:4/1) from Yanghai, manufactured around 1000 BC in Xin-jiang. Both garments consist of only a few basic geometric shapes, that were directly shaped on the loom. Left and middle: wearing test with the reconstructed models; right: construction layout of the garments; reconstruction and technical drawing: Ulrike Beck, photographs: Martin Jess, model: Juan Felipe.

clothes that were produced in this manner consisted of only a few basic geometric shapes (fig. 2).[13] The aesthetic of these garments was primarily created through exquisite patterns and ornaments.[14]

However, this demanding and time-consuming production technique was replaced smartly and unexpectedly: the exquisitely hand-crafted fabrics were cut.

13 Ibid., pp. 78–88, 156–159.

14 Ibid.

A new idea

The idea to cut into a handcrafted fabric is exceptionally innovative. It intends to destroy an exquisite, handmade product in order to manufacture it into something new. This idea to manipulate the shape of a fabric by cutting it into a new pattern would revolutionize the craft.

To implement this idea, new techniques were needed to stabilize the cutting edges of the delicate fabrics and stop the threads from unravelling. These trimming tech-

Fig. 3: A reconstructed woolen tunic from Wupu: Reconstruction and wearing test of a woolen tunic (86HWM-NN-1) from Wupu, manu-fac-tured around 500 BC in Xinjiang. The tunic was made of one single, six metres long fab-ric. To construct the garment, the fabric was cut only three times. Left and middle: wearing test with the reconstructed model; right: construction layout of the garment; reconstruction and technical drawing: Ulrike Beck, photographs: Martin Jess, model: Frederike Doffin.

niques were developed and propagated in Xinjiang in a short period of time. In the second half of the 1st Millennium BC, these trimming techniques were already implemented in a wide range of different variations depending on the quality of the textiles.[15] This concept probably evolved from earlier repairing techniques for small holes and tears in the fabrics.[16] However, this knowledge was now implemented to drive forth a new manufacturing concept.

Around 500 BC in Xinjiang, an ankle-length tunic is produced from fine dark brown wool and decorated with deep blue wool twines on its seams and hems. It is made of one single, six metres long fabric. For the construction of the tunic, the fabric is cut only three times. The pattern pieces were trimmed and sewed.[17] This method is a whole new way to manufacture clothes (fig. 3).

By that time, the separate pieces of a garment were already cut out of larg-

15 Ibid., pp. 163–167.

16 Ibid., pp. 165–167.

17 Ibid., pp. 166–167.

er fabrics. This new approach separates the weaving from the three-dimensional construction of the clothes. As a result, shape-neutral fabrics can be produced independently and later processed as needed.[18] Because of that, a piece of fabric is not just one defined part in a planned garment anymore. Instead, a fabric has potentially many different functions and can be processed as needed.

Division of labour, specialization and trade

The new strategy to separate the weaving of the fabrics from the three-dimensional construction of the garments lays the foundation for division of labour and specialization in the craft. Textile craftsmen were now able to focus on one of the two areas within the clothing production and to develop and refine their skills. Various specialists in the craft promote cooperation in the production process and open up space for differently oriented production sites. Thus, trading with intermediate products such as delicate fabrics and different-coloured yarns becomes beneficial.

It is improbable that the prior manufactured garment pieces, which were shaped on the loom, have already been traded, such as a single trouser leg of a specific size, shape and colour. Garment pieces that are directly shaped on the loom are so explicitly produced for their one single purpose, that it is preferable to manufacture and finish them on one production site.

In contrast, the trade with various exquisitely crafted fabrics and woollen yarns between different production sites seems very worthwhile with this new strategy. It increases the variety of the materials, patterns and shades of the garments. In addition, trade leads to an exchange of knowledge. One of the most important trade routes worldwide leads through Xinjiang, Eastern Central Asia: the Silk Road. It was an important economic hub for the exchange of materials, knowledge and technologies across Europe and Asia. Evidence for trade with intermediate products and a lively exchange of knowledge which took place in Xinjiang is clearly shown by the materials and techniques found in the textile finds from the second half of the 1st millennium BC.[19]

A new dynamic and fast strategy

In addition to the specialisation and the division of labour, the new strategy of

18 Ibid., pp. 167–170.

19 Ibid., pp. 169–170; Regula Schorta, A group of Central Asien wollen textiles in the Abegg-Stiftung collection in: *Riggisberger Berichte 10. Fabulous creatures from the desert sands*, eds. Dominik Keller and Regula Schorta (Riggisberg 2001), pp. 79–114; Wang Bo, Xiao Xiaoyong, A General Introduction to the Ancient Tombs at Shampula, Xinjiang, China, in: ibid., pp. 77-78; Emma C. Bunker, The Cementery at Shanpula Xinjiang. Simple Burials, Complex Textiles, in: ibid., pp. 15-46.

clothing production also has an entirely different advantage: It accelerates the design and construction process from the idea to the finished product in a ground-breaking way. Because the construction and the cutting of the garments are now realised on the already finished fabrics, the concepts and designs can be verified and adapted much faster as a consequence. Whereas weeks or months passed by weaving the fabrics into a specific form, now the same procedure takes only a fraction of the time by cutting a finished fabric. A design idea can be implemented within just one day, discrepancies can be verified during the process, and troubleshooting is much easier. If a pattern behaves differently than expected, it can also be adjusted afterwards or simply cut again.

As a consequence of the new strategy, the concept of a garment can now be implemented, tested and optimized more quickly. The design process is, therefore, significantly more dynamic and adaptable. A construction idea can now be further refined and improved while it is still being implemented.

Together, these new components in the production process pioneer a new distinguished discipline: the construction of patterns.

The construction of patterns – from decorator to architect

In the 1st Century AD in Xinjiang, an extraordinary ensemble of silk garments was constructed. It consists of a delicate blouse and a long silk wrap skirt.[20] *The construction of the blouse is a masterpiece. The narrow cuffs and the high standing collar are finely lined and artfully composed of a mosaic of narrow silk ribbons. The blouse shows an exquisite balance and fit when worn (fig. 4).*[21]

At that time, the garments already show an extraordinary degree of abstraction in their construction. The technology of cutting fabrics and constructing patterns has already developed enormously in only a short period of time.[22] The dynamic process and the verifiability of the new construction concepts enable a significantly better adaptation of the clothes to the human anatomy and motor function. As a consequence, the conceptual examination of the human anatomy is clearly reflected in the construction of the clothes. Thus, the functionality and the fit of the

20 Beck, *Kleidung des 1. Jahrtausends v. Chr. in Xinjiang*, pp. 184–188, 195–198.

21 Ibid., pp. 184–188.

22 Ibid., pp. 170–177.

Fig. 4: A reconstructed silk ensemble from Niya: Reconstruction and wearing test of a silk blouse (95MN1M5-23) and a silk wrap skirt (95MN1M5-18) from Niya, manufactured in the 1st Century AD in Xinjiang. Both garments were cut and constructed of different silk fabrics and illustrate an extraordinary degree of abstraction in their design. They are both produced on the basis of the ‚dynamic construction principles' that were implemented into the production process in Xinjiang at that time; above: wearing test with the reconstructed models; below: construction layout of the garments; reconstruction and technical drawing: Ulrike Beck, photographs: Martin Jess, model: Deva Schubert.

garments achieve a new quality.[23]

With form weaving the aesthetic of the clothes was achieved through colourful patterns and ornaments. Now the new construction concepts themselves emerge as a distinct form of expression.

The silk wrap skirt, which was worn with the blouse embodies such a new idea: The translucent silk fabric artfully cascades around the body. With every step, the skirt moves like a fine mist. The seams draw subtle lines into the fabric,

23 Ibid., pp. 177–188.

like delicate leaf veins in the overlapping silk pedals (fig. 4).[24]

The design of the skirt is outstanding: It is sculptural and created for motion.[25]

This is the last advanced step, that was needed: It is the idea to utilise the strictly logical construction of the garments as an independent, sculptural form of expression. It is the idea to design for motion and the interaction with the moving body.

This is the beginning of constructing clothes as an advanced art form, as we know and use it today in our modern clothing production.

"The soul of the dress is the body."[26]

A modern development achievement: Agile software development – the peak of a rapid evolution

Since the beginning of the computer program production, three concise process models have emerged. Their development can be traced from the 1950s.

At that time, the course of flight paths was still calculated manually in a NASA department, requiring many people and man-hours.[27] *Thus, new computer programs were developed for a more efficient and faster process and to minimize the error rate in the calculations.*

Over time, these programs became more and more complex, so that writing the source code can no longer be implemented without careful planning.

For this reason, the first two-phase model in programming was developed. Alan Turing put it aptly as: "Make a plan and break the problem down. Do the programming of the new subroutines and program the main routine."[28] This model is divided into the analysis phase and the subsequent programming. In the first phase, a concept is created and structured for the problem to be solved. In the following programming phase, the specific instructions in the form of arithmetic commands are implemented exactly according to the plan.

In this model, one person usually conducts the entire process, from planning to writing the specific arithmetic commands. The 2-phase software development model with the direct sequence of analysis and programming is functional for manageable and clearly defined problems.

24 Ibid., pp. 195–198.

25 Ibid., pp. 195–198.

26 Jean Cocteau, *Beauty and the Beast: Diary of a Film* (New York 1972).

27 Jim Hodges, She Was a Computer When Computers Wore Skirts, *NASA History*, August 26, 2008; https://www.nasa.gov/centers/langley/news/researchernews/rn_kjohnson.html, access: November 18, 2020.

28 Alan M. Turing, *Programmer's Handbook for Manchester Electronic Computer Mark II* (Cambridge, undated); http://www.alanturing.net/turing_archive/archive/m/ m01/M01-001.html, access: November 18, 2020.

Specialization in software development

From the 1970s onwards, digital data processing opened up to be used in a broader social context. Until then, the problems and applications for computer programs had been narrowly defined. With the rapidly increasing use of computers, the requirements for software development are changing. Programs are getting more extensive and the problems to be solved are more and more complex. It is no longer feasible to have the software implemented by just one person. The 2-phase model is now reaching its limits.

Therefore, new strategies are being developed that allow the distribution of tasks and specialization of software developers. In order to use the knowledge of various specialists in a structured manner, the software manufacturing process is divided into several phases. A subject area and a specialist are assigned to each phase. Each topic is processed in its corresponding phase and the results are passed on to the next specialist.

From the 1960s on, this model developed more and more phases.[29] In the 1970s, Thayer wrote an abstract description of this development method and labelled it as 'waterfall model'.[30] The advantage of this model is that different specialists work on corresponding steps of a computer program. Each phase is self-contained and can be planned separately. All specialists can focus on their phase and work on it independently.

In the 1980s, the invention of microprocessors paved the way for a new wave of technological innovations. However, these new developments also caused a software crisis that leads to the next evolutionary stage in software development.

At the beginning of the 1970s, computer inquiries were still centrally processed by mainframes in an organization's data centre. By the end of the 1970s, personal computers were already indispensable on desks in banks and offices. As early as the 1980s, computers found their way into the living room of private households and in the mid-2000s, they finally arrived in our pockets.

Due to the continuing fast advancement and distribution of hardware, the requirements for software are changing enormously. Scientific studies have identified the problem:[31] Every program has to manage an enormous number of different requirements so that it is impossible to calculate them from the start. Instead, they become apparent only during the process. The challenge for this software development stage is to manage this newly occurring problem strategically.

29 Winston W. Royce, Managing the Development of Large Software Systems. *Proceedings, IEEE WESCON* (August 1970), pp. 1–9.

30 Thomas E. Bell and T. A. Thayer, Software requirements: Are they really a problem? *Proceedings of the 2nd International Conference on Software Engineering* (San Francisco 1976), pp. 61–68.

31 Herbert Weber, Die Software-Krise und ihre Macher. (Springer-Verlag, 1992).

An interdisciplinary team is needed

From the mid-1990s onwards, a new strategy developed: It was based on the idea to place flexibility and speed at the centre of the cooperation between specialists. The agile software development method was born.[32]

The problem of the waterfall model is the one-way communication, similar to an assembly-line. A topic is processed in one phase and the results are transferred to the next specialist. If new insights and related changes arise during the work process, they can only be factored in during the current and all subsequent phases. However, all results of the phases that had already been completed are not changed. As a consequence, necessary changes during the process could not be transferred to the entire structure of the program but only to the current and upcoming phases. This could lead to enormous problems in programming.

In contrast, in agile programming each step is divided into smaller and manageable topics. Also, in this method, the phases from analysis to programming are structured sequentially, but only for the respective small topics.[33] When one cycle is completed, the next part of the software is processed in the same way in a new cycle. The enormous advantage of this method is that new insights and feedback from the first cycle can be integrated into the second cycle right from the start. This approach creates an excellent feedback loop: Each phase benefits from the feedback from all other phases and specialists. Software development is an interdisciplinary teamwork.

The priority of this approach is the quick feedback among the various specialists. Beyond that, the realization of intermediate products enables additional external feedback during the development process. The finished parts of the software can already be verified by the user and the feedback can be incorporated into further development.

Consequently, the agile software development method is a fast, adaptable, and dynamic strategy. The coordinated and interdisciplinary collaboration between the different specialists is a fundamental step forward in the fast-moving field of software development.

Pattern recognition – the strategies in comparison

Both clothing production and software development solve complex tasks by converting creative ideas into a mathe-

32 Tom Peters, *Thriving on Chaos. Handbook for a Management Revolution* (New York 1987).

33 Ken Schwaber, Scrum Development Process, in: *OOPSLA Business Object Design and Implementation Workshop*, eds. J. Sutherland et al. (London 1997).

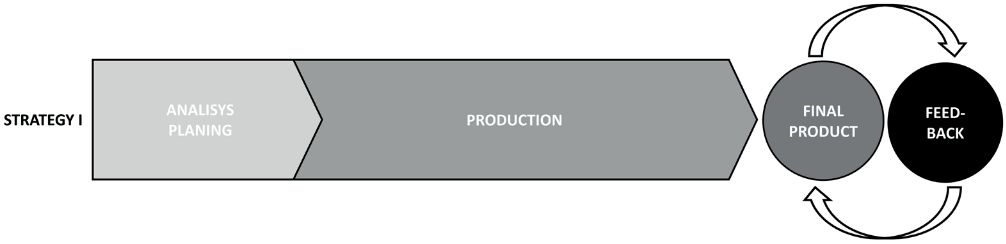

Fig. 5: Diagram of Strategy I: One 'all-rounder' proceeds linearly: One 'all-rounder' analyses, plans and develops the product and proceeds linearly in sub-steps. Analysis and planning are at the beginning of the production process and the defined concept is strictly implemented. Therefore, significant adjustments can only be im-plemented in a new product; diagram: Ulrike Beck and Martin Jess.

matical concept and applying it to a specific problem. Even though they belong to different historical contexts and use different technologies, they both show strikingly similar solution strategies which seem to relate to one transferable pattern. In order to define their core components, we demonstrate how their concepts evolved until they reached an adaptable and dynamic strategy.

"Homo sapiens is about pattern recognition […]."[34]

Strategy I: One 'all-rounder' proceeds linearly

- Concept: Both development cycles begin with the concept of one 'all-rounder' who at first analyses and plans his approach and then develops the final product. In the clothing production, this concept is implemented through the ancient strategy of form weaving, where the clothes are directly produced on the loom. The same structural procedure can be observed in the 2-phase model during the early data processing. In both cases, the production process relies on the linear 2-phase principle. Analysis and planning of the design are executed and completed at the beginning of the process. In the following production phase, the defined concept is strictly implemented (fig. 5).
- Core components – all-rounder, sub-steps, singular analysis: One all-rounder analyses, plans and develops the product. He proceeds linearly in sub-steps. Analysis and planning occur only at the beginning of the production process.
- Limitations: Due to the single analysis at the beginning of the process, it is hardly possible to react to new insights that occur in the practical implementation. Therefore, significant adjustments can only be implemented in a new product. As soon as the problems become extensive, the all-rounder strategy reaches its limits: It is very complicated for one person to analyse and plan the entire structure and all the details at the same time and in depth.
- This issue necessitates the devel-

34 William Gibson, *Pattern Recognition* (New York 2003).

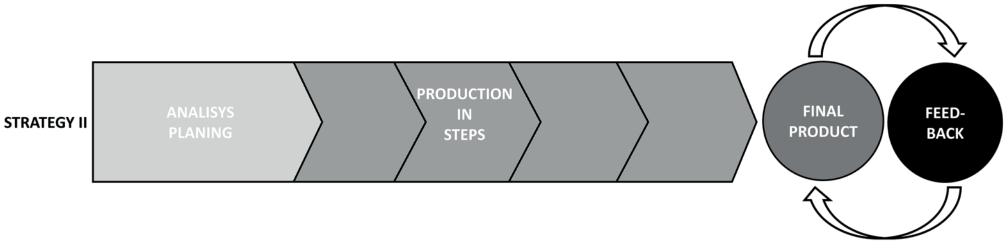

Fig. 6: Diagram of Strategy II: Specialists work on sub-steps: Specialists work on sub-steps, they proceed linearly through phases. Analysis and planning are at the beginning of the production process. Once completed, the developed concept is forwarded to the next phase. Thus, the specialists communicate only in one direction, which inhibits quick and dynamic reaction to new insights; diagram: Ulrike Beck and Martin Jess.

opment of a new strategy. In clothing production, a new technological idea causes the advancement: The idea to manipulate the shape of a fabric by cutting it into a new pattern. In data processing, the rapidly growing complexity of the requirements leads to a change.

Strategy II: Specialists work on sub-steps

- Concept: With this new strategy, the work is divided between different specialists. The division of labour is adapted to the sequence of sub-steps. Each specialist is assigned to one sub-step or phase in the entire development process. The sequence of all sub-steps results in the overall structure (fig. 6). Each specialist can focus on their corresponding phase. An example for this approach is the 'waterfall model'.
- Core components – specialization, sub-steps, singular analysis: Specialists work on sub-steps for the product. They proceed linearly through phases. Analysis and planning are still at the beginning of the production process.
- Limitations: The limitation of this strategy is due to its structure: Despite the division of labour and the specialization, it is still linear and static. Analysis and planning are performed at the beginning of the manufacturing process. Once completed, the developed concept is forwarded to the next phase. Thus, the specialists communicate only in one direction. Unfortunately, this type of communication inhibits quick and dynamic reaction to new insights. Thus, the approach is effective but not efficient. The waterfall model shows that specialization alone does not necessarily lead to the desired success. Instead, and more importantly, it is the manner how the work is divided and how the specialists are able to cooperate with each other.

Strategy III: Specialists solve sub-problems

- Concept: This strategy identifies sub-problems. These are executed and resolved by specialists. The solution of the sub-problems leads to the solution of the overall problem. The specialists

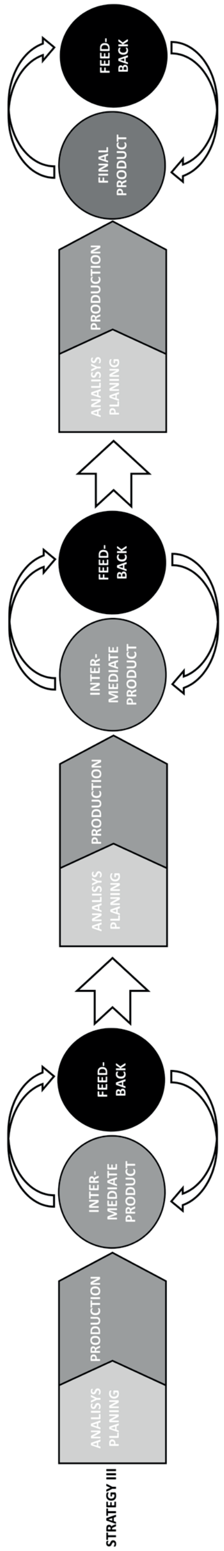

Fig. 7: Diagram of Strategy III: Specialists solve sub-problems for the final product. Analysis and planning for each sub-section provide the foundation for an efficient feedback mechanism. These core components are fundamental for a dynamic, flexible and efficient production process; diagram: Ulrike Beck and Martin Jess.

can develop strategies for their corresponding sub-steps and dynamically integrate the results into the overall concept (fig. 7). Both, the concept to cut into fabric to produce clothes and the agile software development follow this fundamental principle. Both processes are explicitly structured to produce verifiable intermediate products by solving sub-steps. These products efficiently allow an analysis and a dynamic adjustment already during the production process. In case of the clothing production, this would be the finished fabrics that can be processed further as required. These intermediate products enable an excellent feedback mechanism where new insights during the manufacturing process can be integrated dynamically. Analysis and planning stand no longer exclusively at the beginning of a production process. Instead, both steps can be performed in each sub-step during the entire process.

- Core components – specialization, sub-problems, feedback mechanism: Specialists solve sub-problems for the final product. Analysis and planning for each sub-section provide the foundation for an efficient feedback mechanism.
- Advantages: The interdependence of these core components is fundamental for a dynamic, flexible and efficient production process. It allows good adaptation and can cope with significant variance, which are the foundations of successful complex problem solving.

Both the concept to cut into fabric and the agile software development utilise the same core components and follow the same fundamental pattern. An excellent example of this innovative strategy developed several thousand years ago is illustrated by the 'dynamic construction principles'.[35] In the second half of the 1st millennium BC, those were already implemented in the clothing production in Xinjiang.[36] Based on the planned garment and its appearance, fit and size, its construction was dynamically adapted to the measurements and material properties of the available fabrics.[37] This extraordinary combination of analysis and adaptation during the manufacturing process enabled the craftsmen in Xinjiang to produce at the same time excellently constructed, functional and even opulent clothing with a remarkable material-saving approach (fig. 4).[38] This was an exceptional achievement combining high clothing standards with an absolutely resource-friendly production.

Conclusion

In modern data processing, the following premise is clearly defined: Strategies for complex problems must allow good adaptation and deal with significant variance. In order to do this, they have to be dynamic, flexible and efficient. A comparison of both strategies, to cut into fabric to tailor clothes and agile software development, demonstrates that the ancient clothing production concept in Xinjiang utilises the same core components and strategic pattern that is used in modern concepts today.

By integrating specialization, sub-problem solving, and excellent feedback mechanisms into the clothing production process, this innovative ancient concept transformed into a ground-breaking assertive strategy within the clothing production over several thousand years.

The core components of this strategy are crucial for a dynamic, flexible and efficient approach. They allow an excellent adaptation and integration of new insights into the production process as well as a broad variability to cover a wide range of requirements. Their interdependency is fundamental to solve complex problems efficiently.

As early as the 1st millennium BC, the innovative idea to cut into fabric laid the foundation for new, efficient production concepts, extensively restructured the craft and established a new distinguished discipline: the construction of patterns. Furthermore, its impact was felt through other parts of the culture. In the course of its further development, it pioneered the concept to duplicate construction patterns and established the crucial step from custom-made garments to serial production. Today, its corresponding knowledge is mathematically implemented in modern construction systems.

35 Beck, *Kleidung des 1. Jahrtausends v. Chr. In Xinjiang*, pp. 198–204.

36 Ibid., pp. 198-211.

37 Ibid., pp. 198-204.

38 Ibid., pp. 198-211.

The technology of cutting fabric to tailor clothes has prevailed over the millennia. It has adapted to industrialization, the development of chemical fibres and digitalization, and it is still absolutely essential for modern clothing production. It demonstrates an outstanding strategic pattern, which we consistently apply in different contexts to solve complex problems efficiently. The technology's ground-breaking resilience is our tool to meet new challenges creatively.

Acknowledgements:
This study is a contribution to the „InnoTexGes" research project. It would not have been possible without the exceptional support by the Federal Ministry of Education and Research (Grant 01UL1917X). We express our heartfelt gratitude to Gesche Joost, Professor of Design Research at the Berlin University of the Arts, for providing us with kind support and the necessary infrastructure for the research.

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