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Criteria for matching fragmented archaeological textiles: a survey

Abstract

Archaeological textiles are a valuable source for understanding past cultures. However, textiles are vulnerable to decomposition and often found in a fragmentary state. Textile experts rely on their eyes and experience for manually matching similar fragments to reconstruct the original item. This requires much time and effort, as well as physical interaction with fragile artifacts. Computer-assisted virtual reconstruction has been recently proposed. Computer scientists suggested that the algorithms could mimic the criteria used by human experts. These criteria are rarely obvious or well-documented. To facilitate future interdisciplinary research efforts, a survey among archaeologists and conservators was conducted. This work explores what criteria are used by experts for matching fragments in the reconstruction process, which in turn may inspire the development of computational algorithms. Furthermore, the study evaluates the awareness among archaeologists and conservators of existing opportunities for computer-assisted reconstruction, their technological requirements and overall openness to such novel interdisciplinary solutions.

Keywords: textile, fragment, reconstruction, weave, computational, automatisation, survey

Introduction

Textiles have long played a vital role in human life (Mannering and Gleba 2012, Schneider and Weiner 1989). They have been used by humans even before the emergence of pottery and metallurgy (Barber 1991). Analysis of archaeological textile artefacts can, therefore, provide invaluable assistance in understanding past cultures. Since textiles are highly vulnerable to decomposition, they are often highly fragmented and degraded when found by archaeologists. Textiles can be produced from organic plant- or animal-based materials as well as inorganic materials (Shams 1987; Lukesova 2021; Peter 2022) that interact differently with different environmental conditions and degrade at different rates (Tímár-Balázsy and Eastop 1998). Hence, when recovered, different parts of composite textiles might be preserved to different extents.

Scattered fragments need to be matched and reassembled to recover the original textile artefact, its appearance and motifs. A vivid illustration of such a case is the Viking Age Oseberg textiles from Norway shown in fig. 1 (Vedeler 2019). The reconstruction is usually done manually by archaeologists and conservators who rely on their eyes and experience. This process resembles solving a jigsaw puzzle – a popular brain-teaser. However, unlike jigsaw puzzles, archaeological textiles are usually highly fragile and physical interaction and manipulation need to be kept to a minimum for conservation purposes. Furthermore, archaeological textiles can be damaged or faded with missing or deformed parts due to decomposition and ageing, as well as modified by post-excavation treatments. This further complicates the reconstruction, which can be very time-consuming, tedious, and exhausting for human experts as well as leaving many unanswered questions.

The emergence of machine learning and computer vision led computer scientists to propose virtual computational alternatives for the reconstruction of archaeological textiles (Gulbrandsen 2023; Gigilashvili et al. 2023a; Gigilashvili et al. 2024). Gigilashvili et al.
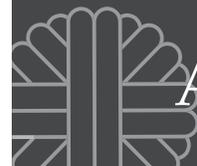
(2023b) conducted a thorough literature review of existing computational techniques for puzzle solving and archaeological artefact reconstructions. They concluded that modern machine learning models are not robust enough to offer fully automatic virtual reconstruction for archaeological textiles primarily due to the amount of missing information and the lack of proper datasets to train the models. However, the authors argue that computational techniques could offer semi-automatic solutions, where a machine could assist human experts and facilitate and expedite the reconstruction process as well as protect the objects from excessive and repetitive manipulation. Since general machine learning models do not demonstrate satisfactory performance, different authors argue (Kodrič Kesovia et al. 2021; Gigilashvili et al. 2023a; Gigilashvili et al. 2023b; Gulbrandsen 2023) that machines should mimic the approach taken by human experts. In other words, the criteria used by human experts for finding matching fragments can be an inspiration for computational algorithms. For instance, the Viking Age Oseberg textiles (Vedeler 2019) were the subject of multiple computational reconstruction attempts (Gulbrandsen 2023, Gigilashvili 2023a; Gigilashvili et al. 2024). The authors suggest that the

characterisation of the weaving technique and locally counting the threads per cm from close-up images, such as shown in fig. 2, can improve the performance of computational approaches.

The features that archaeologists and conservators measure using traditional tools and experience, and on which they rely for their judgments, can be mimicked by machines and hence, inspire advancements in computational techniques. In other words, if we automatise the measurement, analysis, and comparison of the features that are currently measured, analysed, and compared by physical observation and manual work, computers can provide valuable assistance to human experts and substantially decrease the time and effort needed for manual reconstruction of archaeological textiles.

Even though human experts rely on their experience, the exact criteria used for reconstruction are rarely explicitly documented and communicated. To investigate these criteria, a survey was conducted among textile archaeologists and conservators in November 2022. The survey had multiple objectives: first, to understand what criteria are used by archaeologists and conservators when they assess whether multiple fragments of archaeological textiles

Fig. 1: The Oseberg textiles contain fragments with interesting motifs from the Viking Age. However, the fragmentary state of the textiles makes it difficult to recover the stories that they are telling. This collection has previously been a case study for virtual reconstruction efforts in computer science research (Gulbrandsen 2023; Gigilashvili et al. 2023a; Gigilashvili et al. 2024) (Image: George Alexis Pantos)
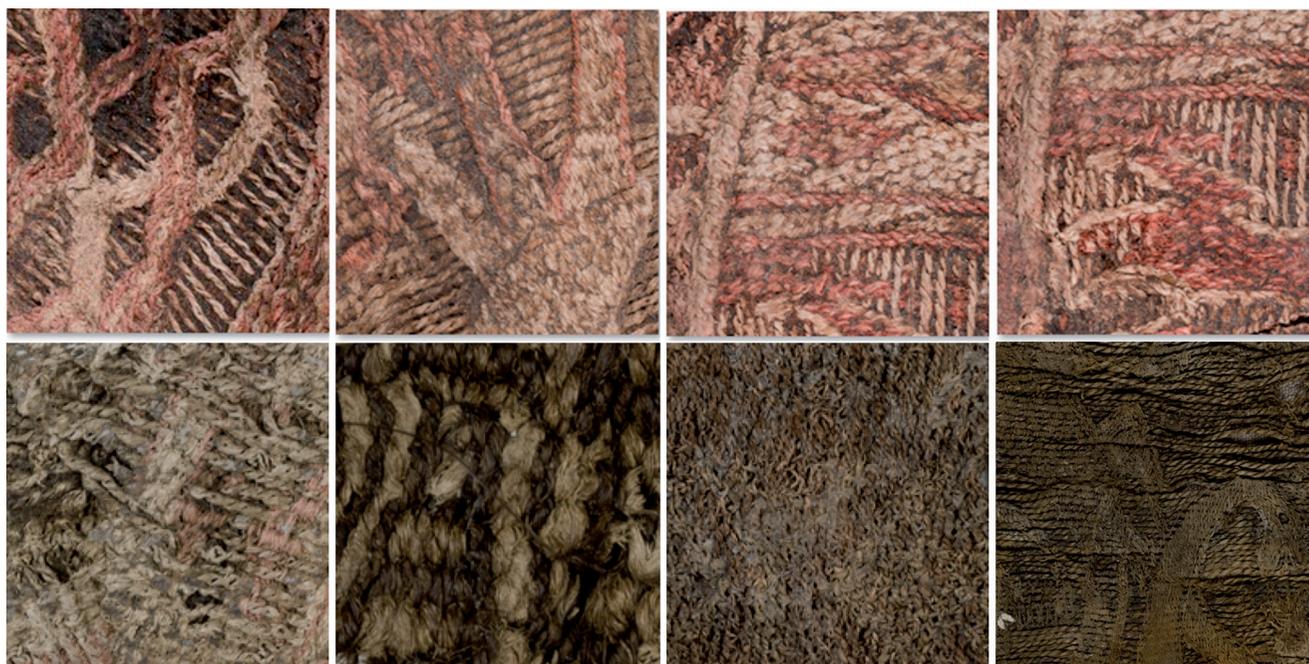
Fig. 2: Close-up of Oseberg textiles. Computational techniques can be used to automatise the measurement of technical characteristics, which can be used for further virtual reconstruction. Reproduced from Gigilashvili et al. 2023a (Image: George Alexis Pantos)

match or belong to the same original item; secondly, to investigate whether the archaeologists and conservators are aware of the existing computational solutions offered by the latest computer science developments, how much they currently rely on them, and what is the state-of-the-art; and thirdly, to evaluate their openness to relying on machine assistance and to understand where, and in what areas, computer assistance is required most.

The results of this survey will help to identify the knowledge gaps where interdisciplinary effort is essential and will foster more cross-disciplinary collaboration between archaeological textile and computer science communities in general.

The article is organised as follows: in the next section, the research methodology is presented. Afterwards, the main findings of the survey are summarised, followed by the discussion and conclusions.

Methodology
This section summarises the research methodology and describes the survey preparation and data collection process.

Preparation of the survey
The aim of the survey was to get input from the different communities that deal with archaeological textiles in different contexts. In order to maximise the clarity of the communication, the draft version of the survey was sent to 13 leading experts from archaeology, art history, and conservation. The objective of the survey was explained to them, and they were asked to provide feedback on the composition of the survey: in particular, to comment on whether the wording and formulation of the questions were clear and understandable, and whether the options in multiple-choice questions were adequate. Furthermore, they could suggest additional questions that they believed would serve the overall purpose of the survey. The draft version was revised based on the feedback of these 13 experts from different communities.

The structure and execution of the final survey
The final version of the survey consisted of 20 questions in total that came in two parts, with 7 and 13 questions, respectively: the first part collected demographic information about the participants' background: such as age, practical training, field of expertise, years of professional experience, employment situation, and the context in which they mainly reconstructed heritage textiles. The following clarification was given before the first part: "demographic information on the respondent: the study is anonymous, and the demographic information is collected for statistical purposes only. Only the aggregate statistical data will be analysed and no individual responses that could in any way identify the individual will be ever made public."
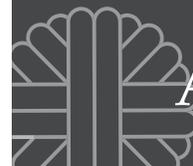
The second part of the survey consisted of 13 questions on heritage textile reconstruction and the perceived role of computational solutions. The questions came in several forms: some required free form answers, while others were multiple-choice with or without the possibility to select more than one option. The following instruction was displayed before this part: "the main part of the survey: if you are uncertain about any question, please answer to the best of your knowledge. If you want to comment further on multiple-choice questions, please, in addition to your answers, also tick 'Other' and use the space in the 'Other' option to explain."

Several questions came with additional explanations to clarify context. The exact formulation of all questions, respective explanations provided, and the multiple-choice answer options (if any) can be found in the appendix. For conciseness, below are only the questions asked in the main part (questions 8 to 20):

8) The following criteria are often used to define a historical/archaeological woven textile: Binding/weave/technique, thread count (warp/weft), spin/twist direction (warp/weft), material/fibre, and colour. What other features might you add? [free form answer]

9) How would you know whether fragments of archaeological textiles belong to the same initial item? [multiple-choice with more than one answer possible]

10) Please rank the answers/criteria that you selected in the previous question. Which one would be the most important to tell whether the fragments belong to the same item or not? Which one will be the second most important? etc. Use the space in this question to arrange/rank them by priority; 1 means the most significant and informative; 2 - second most significant and informative, and so on... [free form answer]

11) Is direct physical contact with the artefact necessary for technical analysis of archaeological textile fragments? [multiple-choice with one answer]

12) Where access to textile artefacts is limited, to what extent can a full textile analysis be carried out based on digital photographs? Please briefly explain your choice in "Other". [multiple-choice with more than one answer possible]

13) How reliable would you consider an analysis gained through digital photography? [multiple choice with one answer]

14) How much of the process of archaeological textile analysis is manual labour, i.e. done by eye and experience (physical observation and manual work) without the help of machinery? [multiple choice with one answer]

15) Please explain exactly which steps in the technical analysis of archaeological textiles involve manual labour with direct human involvement? [free form answer]

16) How many hours of work would it take you in total to describe, characterise and group 100 fragments? (see the explanation below) Please briefly explain your choice in "Other". [multiple-choice with more than one answer possible]

17) Do you usually use computer assistance, or to some extent rely on computer output? (e.g. automatic measurement of thread diameter or any other feature in a photograph, digitally puzzling fragments on a screen etc.). Please comment in "Other" if you like. [multiple choice with more one than one answer possible]

18) Currently, how much of the technical analysis of archaeological textiles and puzzle solving mentioned in question 16 can be done in an automatic manner by computational methods? [free form answer]

19) What are your computational needs? Which computational tools could, if implemented, facilitate and progress textile research? [free form answer]

20) How do you think a computer scientist could contribute to textile research: for example, how would you imagine a perfect computer assistance in virtual reconstruction/classification/puzzling developed by computer scientists? [free form answer]

Data collection
An email invitation to voluntarily participate in the survey was sent to several hundred professionals involved in EU's Cost Action #19131 – *Europe Through Textiles: network for an integrated and interdisciplinary humanities (EuroWeb)* in November 2022.

Findings
This section summarises the quantitative and qualitative results of the survey.

Respondent demography
In total, 26 experts completed the survey. On average, it took 28 minutes to complete both parts. The responses came from professionals from a broad range of backgrounds (the responses may not total 26 since respondents could choose multiple answers): the majority (18 experts) work in archaeology and conservation (5 experts), while we also had input

from textile technology, as well as art and history professionals. The majority work in academia (18) and/or cultural institutions, such as a museum (6). We had a couple of responses from industry, art and design, and governmental institutions other than academia. A total of 22 of the respondents were employed professionals, two of them were PhD students, while five were also identified as a freelancer and/or an independent researcher. The majority of the respondents belonged to the age group from 40 to 49 years, and there was input from age groups from 20 to 29 up to 60 to 69, with substantial experience in the textile field: four people with 40 to 49 years of experience, 7 with 20 to 29 years, 8 with 10 to 19 years, and the remaining 7 with less than 10 years. The majority received practical training in weaving and/or archaeology, and most of them reconstruct and interpret heritage textiles in the context of archaeology (20), costumes (9), or flat textiles and conservation (3 each). No significant differences were observed in the main part of the survey between the respondents from different demographic groups. Therefore, only the aggregated data is reported below.

The criteria for textile analysis
One of the fundamental objectives of the survey was to identify the features that the experts use to characterise historical or archaeological textiles and to determine whether the fragments belong to the same initial item. In addition to the criteria proposed in the first question of the second part, multiple respondents (at least three) identified several important criteria independently from one another. These criteria are conservation state and mineralisation, context of discovery (where the fragments were found), decorations, style and presence of selvedge (the longitudinal edge of a woven textile following the warp direction) or lack thereof, thread diameter, fibre diameter and length. Question 9 provides clearer quantitative insight into this question. The results are illustrated in fig. 3. As the figure shows, the criteria selected by the largest number of experts are weave technique (24), fibre material (22), thread count and yarn/thread twist/spin (20 each), type of pattern/motif (17), and selvedge (15). Six respondents proposed additional criteria, which can be grouped into two types: context of discovery (location where it was found and chronology) and colour or dyes.
Finally, the respondents were given an opportunity to rank the criteria by importance. As this is a free form ranking, two types of metrics are reported to measure the importance of a given criterion: how many respondents mentioned a given criterion in their ranking; and what was the average rank. The
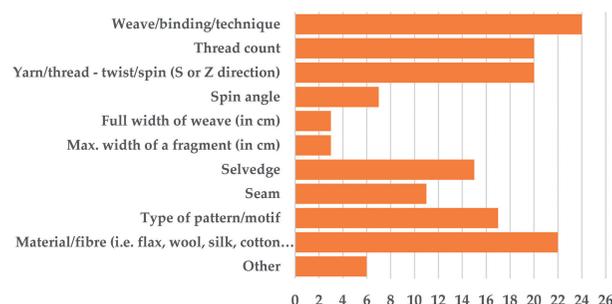

Fig. 3: The results of a survey. The graph shows the number of respondents who rely on a given feature to know whether two textile fragments belong to the same initial item (Image: Davit Gigilashvili)

results for those features that were mentioned by at least 6 respondents are given in table 1. The results of the ranking are consistent with that of the previous questions: technique and the textile material are considered the most significant criteria, while yarn/thread twist/spin, type of pattern/motif, thread count, selvedge, and seam are also pointed out by many. Several respondents mentioned that all criteria are important, while one mentioned that all criteria must be equal to conclude that the fragments belong to the same item. Two respondents pointed out that the importance of criteria depends on the fragments and specifically, on their state of preservation, as some of those may or may not be detectable from the fragment (e.g. motifs may or may not be visible). The motif itself as a criterion can be vague, as one respondent commented that a similar motif in dimensions and spatial features is highly unlikely to belong to different items, while the same is not true for typological similarities in motifs. The same respondent pointed

Feature	Times Mentioned	Average Rank
Weave/binding/technique	20	2.00
Material/fibre (i.e. flax, wool, silk, cotton etc.)	19	2.16
Yarn/thread - twist/spin (S or Z direction)	12	2.83
Type of pattern/motif	13	2.92
Selvedge	8	3.50
Thread count	15	3.53
Seam	6	4.83

Table 1: The features mentioned by at least 6 respondents in a free form ranking. The second column shows how many respondents included a given feature in their ranking, while the third column shows their average rank (Table: Davit Gigilashvili)

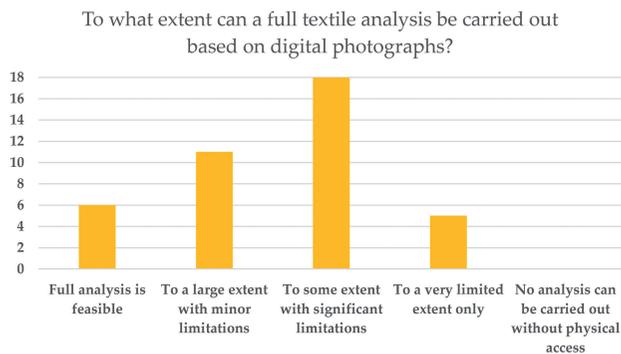To what extent can a full textile analysis be carried out based on digital photographs?

Fig. 4: The graph shows to what extent can a full textile analysis be carried out based on digital photographs, according to the respondents (Image: Davit Gigilashvili)

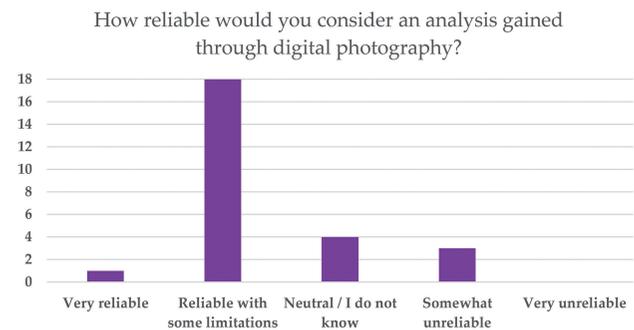How reliable would you consider an analysis gained through digital photography?

Fig. 5: The graph shows how reliable this analysis is considered when using photographs for textile analysis. Although some limitations are seen by the majority of the observers, their opinions are more on the positive side (Image: Davit Gigilashvili)

out that the importance of weave also depends on the context, as exclusive pieces are more likely to be assembled from different craftsmen and techniques, while pieces of daily use tend to be made by a single person and have one type of technique.

Photographs as a substitute for physical interaction
Another question is whether the experts consider professional high-quality museum photographs to be adequate substitutes for physical interaction. 17 respondents said that direct physical contact with the artefact is necessary for technical analysis of archaeological textile fragments, while nine said that it is not. Fig. 4 summarises to what extent an analysis can be conducted on digital photographs, according to our respondents, and fig. 5 shows how reliable it is found to be. Although the majority of them see some limitations in using photographs instead of direct interaction, the plots are skewed and photography is seen as more positive and reliable than negative and unreliable. The respondents could explain their responses, where they listed the limitations that they see in using photographs. These limitations can be classified into three groups: impossible to carry out chemical (for example, dyes, fibre materials) analyses from the photographs; image quality and insufficient spatial resolution (for example, fibres need to be analysed with a microscope, not a photograph); and access to the photographs (difficulty to obtain permission to photograph objects due to museum policies).

Current state-of-the-art
The third question that was investigated with this survey is how much of the analysis is currently done manually and how much time and effort it takes. Fig. 6 shows that most of the textile analysis is still being done manually by humans without automated machinery.

The estimated number of hours for analysing 100 fragments varied considerably, as shown in fig. 7. The respondents explained that this varies from case to case and depends on several important factors: such as the state of preservation, type of fragments, how many fragments are missing, and how much of the context is known. However, the overwhelming majority said that it would take more than one day of work. They were also asked to specify what kind of work requires manual labour. They responded that they extensively rely on machinery for magnification (microscopes); however, the measurements and analysis (counting threads, looking for selvedges, identifying twist and spin directions, describing decors, and puzzling) are done manually. Furthermore, some respondents refer to manual inspection as a method to check the flexibility of the fabric, identify the fabric material, and observe the fragments from different viewpoints. Sample preparation and documentation (cleaning, documenting the context, photographing) are also done manually. Several respondents explicitly mentioned the Dino-Lite microscope and its proprietary software. Dino-Lite microscopes are part of a series of small digital USB tools that are popular for their cost-efficiency and practicality in terms of size and weight. They do not offer any functions for automated measurements. However, manual measurements of magnified images are possible. Digital microscopes can operate as simple optical microscopes with built-in LED light source and without eyepieces where an image is observed on a monitor (Lukesova 2022).

The need for interdisciplinary effort
Finally, the objective of the survey was to identify the knowledge gaps with potential room for interdisciplinary collaboration between textile and computing communities. Ten respondents answered that they do not use any kind of computer assistance.

How much of the process of archaeological textile analysis is a manual labor?
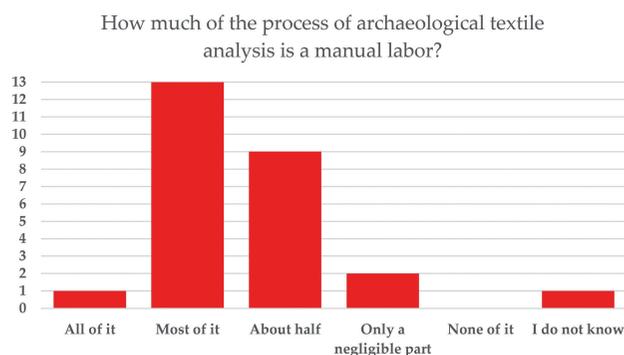
Fig. 6: The graph shows how much of the textile analysis needs manual labour, i.e. done by eye and experience rather than by automated machinery, according to the respondents (Image: Davit Gigilashvili)

Out of those who said that they did use computer assistance, only four explained their choice. Two of them mentioned that they use a computer to digitally puzzle the pieces by moving the fragments on the screen manually; and two mentioned Dino-Lite for thread description and basic measurements. Half of the respondents do not know how much can be achieved by computer assistance due to limited experience; nine seem positive and believe that some measurements, such as thread counting and weaving pattern identification, as well as puzzle solving, could be achieved with a computer, while four are sceptical either due to the complexity of the task or negative experience in the past. The computational needs that could facilitate and progress textile research are divided into three major groups: automating measurements (thread counting, thread diameter and length measurement, weave analysis, spin angle estimation, selvedge/hem detection, and decor detection) and generating statistics based on these measures; visualisation (automatic sketching, drawing planes of weave, zooming capabilities, ability

How many hours of work would it take you in total to describe, characterise and group 100 fragments?
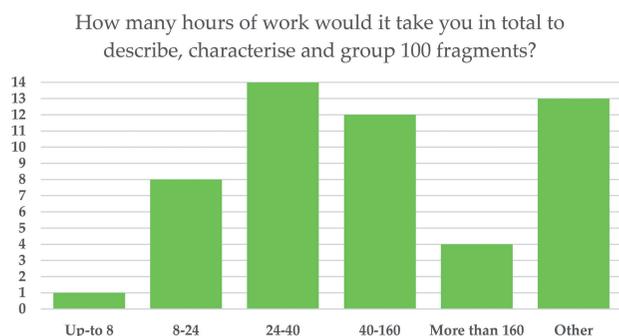
Fig. 7: The graph shows the estimated number of hours needed for analysing 100 fragments according to the respondents (Image: Davit Gigilashvili)

to move the fragments around, adjustable opacity, stereoscopy); and reconstruction (puzzle solving, 3D shape reconstruction, photogrammetry, clustering based on material and weave). A total of 23 out of 26 respondents are positive about collaboration with computer scientists and believe that solutions for the above-mentioned computational needs will be beneficial, while the remaining three are uncertain and could not answer the question.

Discussion

The survey conducted among archaeologists and conservators revealed several interesting trends. This section discusses the main takeaways from respondents' feedback and proposes a framework for future reconstructions.

It is apparent from the responses that analysis and characterisation of textiles to date relies primarily on the eye and experience of the experts, while the use of machinery is limited to magnification and visualisation tools with little or no automation. The majority of the experts see the need for computational solutions and are open to interdisciplinary collaboration. The survey revealed the primary features or criteria that the experts use for grouping fragmented textiles together and for identifying which fragments should belong to the same original item. Weave/binding technique, fibre material, type of motifs (if visible), thread count, yarn/thread twist/spin, selvedge type, and seam have been named among the most significant factors, along with the discovery context and chronology. Measurement and description of these features currently need long and tedious manual labour; hence, automatisation of this process by specially tailored computer algorithms can save multiple days or even weeks of work and protect vulnerable archaeological fragments from excessive manipulation if high-resolution professional photographs are available. The authors argue that taking such photographs contributes to good documentation of archaeological finds and is less harmful than subsequent and repetitive manipulation. These results had interesting implications for the open reconstruction problem of the above-mentioned Oseberg textiles. Gigilashvili et al. (2024) tested several computational techniques to identify matching fragments from the Oseberg textiles and cluster them by similarity. They asked textile experts to do the similar task manually and compared their responses with the automatic solutions. Interestingly, the experts used nearly identical criteria to those reported by the respondents of this survey (thread count, type of motifs, spin/twist etc.). This illustrates that the accuracy of the computational solutions is benchmarked against
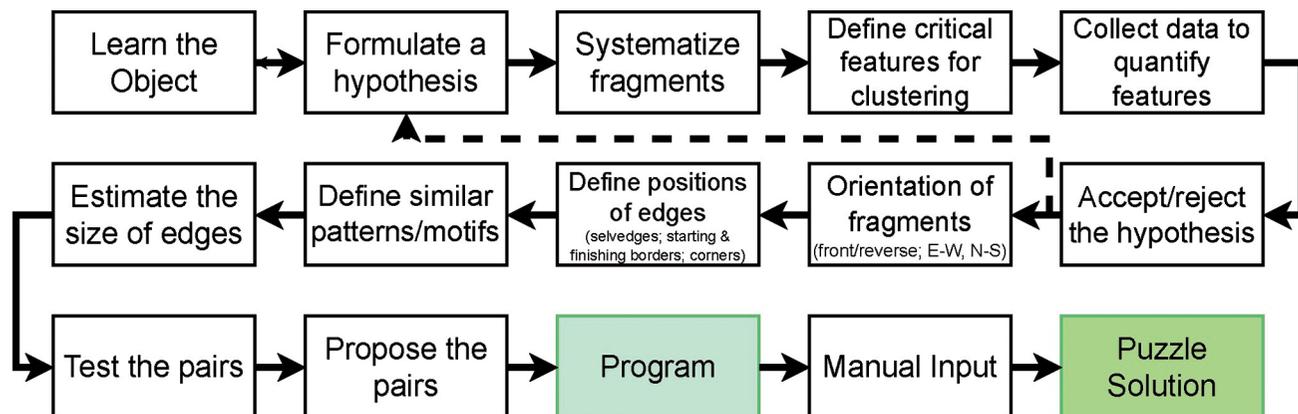
Fig. 8: The proposed semi-automatic workflow based on the literature review and survey of the experts, which can be followed in the puzzle solving process (Image: Davit Gigilashvili and Hana Lukesova)

the pseudo ground truth defined by the criteria that were reported in this article. Zain Fadillah et al. (2024) recently published the preliminary results of automatic thread counting for the Oseberg textiles. Their results showed an algorithm that enabled automated thread counting of warp in an area where weft was missing. Further work on the automation of thread counting can lead to promising results since it can be faster than manual measurements. Furthermore, the authors conducted clustering using the automatically extracted warp and weft thread counts alone, and the results for twelve out of 27 fragments were aligned with the experts' opinions. The development of automatic solutions for the additional criteria, such as weave analysis, spin estimation and motif recognition, will increase clustering accuracy and greatly benefit the reconstruction of Oseberg and other heritage textiles.

Nevertheless, the experts see several significant limitations in using photographs against physical interaction, such as: impossibility of chemical dyestuff and material analysis, as well as lack of motion and 3D structural information. As a workaround, a recent literature review (Gigilashvili et al. 2023b) proposes using more sophisticated imaging techniques, such as hyperspectral imaging (HSI) and reflectance transformation imaging (RTI), which could provide additional information on material composition and surface characteristics, respectively.

Finally, considering the knowledge status on computational solutions from the literature (Gigilashvili et al. 2023b) and the results of the survey that was conducted with archaeologists and conservators and reported in this article, the authors propose the following workflow for computer-assisted arrangement of flat archaeological woven textile puzzles as shown in fig. 8.

At the first stage, a human expert needs to *learn the object*, inspect it, and *formulate a hypothesis* about its belonging and place in the puzzle. Afterwards, they need to *systematize the fragments* based on the formulated hypotheses, i.e. identify the groups that are likely to belong to the same original item, as well as those that contain little to no useful information due to extreme degree of degradation. Afterwards, they should *define critical features for clustering* similar fragments. The features will be used to identify which fragments belong to the same cluster. After they define the set of features they want to measure, they *actually collect data to quantify features*. For example, if they define thread count (number of threads per cm) as a critical feature that has to be used in clustering and matching, at the data collection stage, they should actually count the number of threads per cm in warp and weft directions for each fragment. Data collection can involve manual measurements, automated computational solutions, or a mixture of both. The measured features are fed to the clustering algorithm, and the machine clusters fragments based on these features. The clustering results are compared against the hypotheses that were formulated at an earlier stage, and the experts either *accept or reject particular hypotheses*. Depending on the result, they may need to re-think and re-formulate the hypotheses (fig. 8), or if enough quantitative evidence is available, they can proceed to the next step.

They virtually separate the fragments that belong to the same original item from the rest and start *orienting these fragments* in space. At this stage, they can identify how the fragments are oriented in space based on motifs, warp and weft directions, and other factors such as front and reverse side.

The next step toward solving the puzzle is to define positions of edges – in other words, to identify

fragments that are likely to be the edges (starting and finishing borders, selvedges, corners) and place them respectively to have an outline of the puzzle. This approach is also commonly taken when solving regular jigsaw puzzles. Afterwards, they can start identification of neighbouring fragments and start pairing them. For this, experts need to define similar motifs – for example, if two fragments contain parts of a red horse, they are likely to be part of the same horse and thus, to be adjacent fragments in the final arrangement. At this stage, they should estimate the minimal size of edges to estimate the overall size of the original and outline the space where the rest of the pairs should be placed to ensure that the proposed pairs fall within the edges. Next, they test different orientations and fitting options to test whether the pairs are actually adjacent. Whether or not they fit (based on outline, colour, motifs, technique etc.), the human expert makes a decision and proposes the pairs. This information can be used for developing a novel computer programme or can be simply used as an input to the software that is already available, such as *Gulbrandsen's Artifact Assembly* (Gulbrandsen 2023), where the puzzle will be finalised based on manual input, where the human expert re-arranges the pairs in a trial-and-error manner and validates the result.

Conclusion
This work reports the results of a survey that was conducted with 26 archaeologists and textile conservators. While the cutting-edge computational techniques enable solutions to many complex problems, to date, automatic archaeological textile reconstruction remains beyond reach. Archaeological textiles are currently reconstructed manually. The parameters that are used by humans for identifying matching pieces, such as thread count or yarn twist and spin, can be measured automatically by machines in the future and taken as input to the clustering algorithms to identify similar fragments in a semi-automatic manner. The survey revealed that the awareness of new horizons that computer science and machine learning have to offer is relatively low in archaeology and conservation communities. However, the community points out the need for computer-assisted solutions and expresses openness to them, which paves the way for the rigorous interdisciplinary research effort in the future.

Acknowledgements

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Appendix: The questionnaire used in the survey

Demographic Information on the Respondent
The study is anonymous, and the demographic information is collected for statistics purposes only. Only the aggregate statistical data will be analysed and no individual responses that could in any way identify the individual will be ever made public.

1. How long have you been active in the textile field?
- Less than 10 years
- 10-19 years
- 20-29 years
- 30-39 years
- 40-49 years
- 50+ years

2. In which context did you get your practical training?
- Textile design
- Textile art
- Weaving
- Embroidery
- Sewing
- Other (please, specify if possible)

3. What is your age?
- 18-19
- 20-29
- 30-39
- 40-49
- 50-59
- 60-69
- 70-79
- 80+

4. What is your working situation?
- Student (Bc, MgA)
- Student (PhD)
- Employed professional
- Freelancer
- Independent researcher
- Retired
- Other (please specify)

5. What is your field?
- Archaeology
- Art History
- Conservation
- Other (please specify)

6. Where are you working?
- Academia
- Cultural institution (as museum)
- Industry
- Art & Design
- Other (please specify):

7. In which context do you mainly reconstruct heritage textiles?
- Costumes
- Flat textiles
- Archaeology
- Conservation
- Art History
- Other (please specify)

The main part of the survey
If you are uncertain about any question, please answer to the best of your knowledge. If you want to comment further on multiple-choice questions, please, in addition to your answers, also tick "Other" and use the space in the "Other" option to explain.

8. Question: The following criteria are often used to define a historical/archaeological woven textile: Binding/weave, thread count (warp/weft), spin/twist direction (warp/weft), material/fibre, and colour. What other features might you add?

9. Question: How would you know whether fragments of archaeological textiles belong to the same initial item?

Explanation: Imagine the following context: multiple fragments have been found at different parts of a single grave. How do you distinguish which ones belong to the same initial item (i.e. have been part of the same while) and which ones come from different items? Please select and/or list at least 5 criteria that you consider most important. The criteria/features can be as below (select from the list of specify in Others, in total 5 or more answers needed).
- Weave/binding/technique
- Thread count
- Yarn/thread - twist/spin (S or Z direction)
- Spin angle
- Full width of weave (in cm)
- Max. width of a fragment (in cm)
- Selvedge
- Seam
- Type of pattern/motif
- Material/fibre (i.e. flax, wool, silk, cotton etc.)
- Others (please specify):

10. Question: Please rank the answers/criteria that you selected in the previous question. Which one would be the most important to tell whether the fragments belong to the same item or not? Which one will be the second most important? etc. Use the space in this question to arrange/rank them by priority; 1 means the most significant and informative; 2 - second most significant and informative, and so on...

11. Question: Is direct physical contact with the artefact necessary for technical analysis of archaeological textile fragments?
- Yes
- No

12. Question: Where access to textile artefacts is limited, to what extent can a full textile analysis be carried out based on digital photographs? Please briefly explain your choice in "Other".

Explanation: We ask this because replacing physical fragment with digital images can have several important benefits: firstly, limiting contact avoids potential damage to highly fragile artefacts; second, direct physical examination can require costly and time-consuming travel, while digital images are readily accessible to a far broader community across the globe; third, a computer processes and analyses

digital images in complex ways, which, to some extent, simplify manual labour.
- Full analysis is feasible
- To a large extent with minor limitations
- To some extent with significant limitations
- To a very limited extent only
- No analysis can be carried out without physical access
- Other (please explain your choice)

13. Question: How reliable would you consider an analysis gained through digital photography?
- Very reliable
- Reliable with some limitations
- Neutral / I do not know
- Somewhat unreliable
- Very unreliable

14. Question: How much of the process of archaeological textile analysis is a manual labour, i. e. done by eye and experience (physical observation and manual work) without the help of machinery?
- All of it
- Most of it
- About the half of all the work
- Only a negligible part
- None of it
- I do not know

15. Question: Please explain, exactly which steps in technical analysis of archaeological textiles involve manual labour with direct human involvement?

16. Question: How many hours of work would it take you in total to describe, characterise and group 100 fragments? (see the explanation below) Please briefly explain your choice in "Other".

Explanation: Imagine the following scenario: you have tens of archaeological textile fragments, and your task is to identify: a) which fragments are likely to belong to the same item; b) recover how they have been arranged spatially. So in simple terms, you have pieces of a several puzzles, which you have first grouped by their origin in order to then solve the puzzle and recover the original item as much as possible (many pieces are missing though). How fast can you do this?
- Up-to 8 hours
- 8-24 hours
- 24-40 hours
- 40-160 hours
- More than 160 hours
- Other (please explain your choice)

17. Question: Do you usually use computer assistance, or to some extent rely on computer output? (e.g. automatic measurement of thread diameter or any other feature in a photograph, digitally puzzling fragments on a screen etc.) Please comment in "Other" if you like.

Explanation: When you do technical analysis of archaeological textiles similar to the puzzle-solving scenario in Question 16: How much of the job to solve the problem is currently done by a computer? Exactly what parts are performed by a computer (if any)?
• Yes
• No
• Other

18. Question: Currently, how much of the technical analysis of archaeological textiles and puzzle solving mentioned in Question 16 can be done in an automatic manner by computational methods?

Explanation: Regardless of what you answered to Question 17, i.e. whether you use computer assistance or not, to the best of your knowledge, how much of the process can be performed by a computer? Are you familiar or have you heard of any computer-based solutions (whether or not you have used them yourself)?

19. Question: What are your computational needs? Which computational tools could, if implemented, facilitate and progress textile research?

Explanation: No matter whether the solution exists or not, imagine the process described in Question 16. What elements of the job do you think would be improved if performed by a computer instead of a human, and in which of those would computer involvement have the biggest impact?

20. Question: How do you think a computer scientist could contribute to textile research: for example, how would you imagine a perfect computer assistance in virtual reconstruction/classification/puzzling developed by computer scientists?

Explanation: Anything related to the analysis and interpretation of the archaeological textiles that has not been mentioned above and you think would be interesting and valuable to collaborate on with the computer science community. Any suggestions for a computer scientist. For instance, image you get a nearly perfect computer program that helps you with the task described in Question 16. Could you describe this program? How does it operate? What features does it have? How does it help you?