A Digitized Sustainable Preservation Framework for Traditional Garment-Making Techniques: A Case Study of Hong Kong Cheongsam

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Abstract Traditional garment-making techniques, as significant components of intangible cultural heritage (ICH), are increasingly threatened by globalization and industrialization, risking the loss of their transmissions. To address the limitations of existing preservation methods in systematically capturing the dynamic interactions between tailors, tools, and machines, this study proposes a digital framework for documenting and sustaining these techniques. The framework will be validated through its application in the Hong Kong Cheongsam Making Technique, showcasing its potential for broader ICH preservation efforts. The framework aims to support sustainable fashion practices and foster innovative design based on traditional garment-making techniques.

Keywords Digital preservation · Intangible cultural heritage · Sustainable fashion practice · Craftsmanship · Hong Kong Cheongsam

1 The Need for Digitizing Traditional Garment-Making Techniques

In 2003, the United Nations Educational, Scientific and Cultural Organization (UNESCO) adopted the *Convention for the Safeguarding of the Intangible Cultural Heritage*, which defines ICH as "the practices, representations, expressions, knowledge, skills—as well as the instruments, objects, artefacts, and cultural spaces associated with them—that communities, groups, and, in some cases, individuals recognize as part of their cultural heritage" [1]. Under this framework, traditional craftsmanship, which includes a wide range of traditional garment-making techniques [2], is considered a crucial carrier of cultural diversity. These techniques combine social norms, economic conditions, aesthetic pursuits, fashion and textile

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technologies, and crafting techniques, representing a key expression of the "fashion system" within a particular regional and historical context.

However, the rapid progress of globalization and industrialization, along with the disruption of crafts industry, and hence its transmission, has pushed traditional tailoring techniques into an unprecedented state of endangerment [3]. *Hong Kong Cheongsam Making Technique*, which is a representative item on the *National List of Intangible Cultural Heritage of China*, is no exception. In this context, the study and preservation of the ICH face significant challenges. For instance, there is a general lack of holistic documentation of the craftsmanship and the corresponding practices [4]. In-depth and systematic investigations of the craft are needed for establishing a primary point of reference, covering the visual and structural information, dynamic evolution of craft narratives, experiential and tacit knowledge, and their historical, cultural, and social contexts over time [5]. Moreover, a key characteristic of the ICH is notably its reliance on intricate human motions, which underscores the necessity of digital tools in recording and analyzing, and thus, its preservation [6].

To address these challenges, methods for digitizing human motion have been developed and can be broadly categorized into two types: invasive and noninvasive. These methods are distinguished by the level of visual occlusion. On the one hand, invasive methods primarily utilize motion capture technology, requiring the participants to wear sensors or markers to acquire high-precision data [7]. On the other hand, noninvasive methods are based on visual tracking technology, without requiring additional equipment, and capture motion trajectories through visual recognition and computational optimization [8]. Regardless of the approach, the resulting data comprise a sequence of coordinate frames that accurately capture and quantify changes in position and direction, serving as a foundational dataset for subsequent analysis and applications.

For example, the Tujia Brocade Handcrafts team employed Kinect and Leap Motion devices to capture limb and hand movements in traditional crafts and digitally preserved these movements through virtual reconstruction techniques [9]. Similarly, the Korean Nubi team developed a first-person perspective 3D recording framework based on head-mounted Leap Motion to enhance the Tujia Brocade method [10]. Additionally, Aoki and Miyamoto enhanced the 3D motion capture techniques for traditional Japanese Kenjutsu swordsmanship [11]. However, despite these advancements, most of these methods are confined to basic motion capture and are unable to effectively represent the intricate interactions between craftsmen, tools, and machinery, particularly in complex mechanical operation and detailed handicraft scenarios. Furthermore, although multi-sensor technology can enhance capture accuracy, challenges such as occlusion and data integration persist, impeding the accurate replication of intricate craftsmanship details [12].

2 A Proposed Digital Framework for Sustainable Preservation

The preservation of traditional garment-making techniques is confronted with two primary challenges: the digital documentation of both explicit and tacit knowledge. Explicit knowledge encompasses operational and functional information related to tangible elements, such as craftsmen, tools, and machines, as well as articulable and documentable details, ranging from textile material properties and standardized tailoring techniques to the structural configurations of various garment forms. In contrast, tacit knowledge entails the skillful use of tools, which involves complex dynamic interactions between tailors, tools, machines, and materials, as well as the subtle, experience-driven practices integral to specific techniques [13]. Tacit knowledge poses significant challenges for documentation through conventional written records and static archival approaches. Therefore, dynamic replication is crucial for ensuring holistic preservation. This chapter proposes a comprehensive digital framework for sustainable preservation, aiming to systematically record and preserve the dynamic processes of traditional garment-making techniques, while providing technical support for the inheritance and innovative design of traditional crafts.

The framework's construction is centered on standardization and virtualization as its core technical principles. First, the process flow requires standardization to ensure the integrity of the process and the clear identification of critical components [11]. Standardization comprises two key elements: (1) structuring the process flow based on the actual operational sequence, defining the logical relationships and execution steps, and (2) extracting core techniques from the workflow, distinguishing between modifiable steps and indispensable components.

Building upon standardized categorization, the framework employs digital modeling technologies to develop virtual components, including "virtual tailors," "virtual tools," and "virtual machinery." These components function as core modules of the virtual platform, aimed at replicating the dynamic interactive processes inherent in traditional garment-making workflows. In the digital documentation of tacit knowledge, motion capture technology and depth cameras are essential. Specifically, based on standardized procedures, the craftsman's hand movements, tool operations, and machine dynamics are captured frame by frame. Complex processes are divided into 1-to-2-second segments for data storage [14]. By employing multimodal data collection, motion capture, mechanical force sensors, and tool interaction data are combined to produce a multifaceted data stream, which is then digitized and transferred to the virtual platform.

Subsequently, the virtual platform employs a modular design to establish a complete technical chain, spanning from data acquisition to dynamic replication. Firstly, the data acquisition module, based on Leap Motion and depth cameras, records the three-dimensional trajectories of the tailor's hand movements with a motion capture accuracy of up to 0.001 meters [15]. Secondly, parametric modeling techniques are utilized to construct interactive models of virtual tailors and tools, integrating multimodal data for real-time dynamic visualization. This technical chain ensures the

comprehensive transformation of traditional garment-making techniques from physical entities to explicit knowledge. Through the platform's six degrees of freedom (6-DoF) observation interface, users can analyze the dynamic coupling between tailor gestures and fabric deformation in real time. Additionally, the platform provides force feedback on hand movements and detailed operational analysis, allowing users to develop a comprehensive understanding of the intricate methods involved in complex craftsmanship.

3 The Case of Hong Kong Cheongsam-Making Technique

The framework will be validated through its application in the *Hong Kong Cheongsam Making Technique*. Hong Kong cheongsam encompasses a range of diverse dress forms of Chinese men's and women's attire. Its structural origins can be traced back to the ancient Chinese robe known as the *Right-opening Straight-hem Robe* for men [16]. During the Republic of China era (1912–1949), cheongsam gradually became a symbol of women's pursuit of modernization and social liberation, and it was introduced to Hong Kong from Shanghai in the 1920s [17]. Against the backdrop of the highly Westernized and hybrid cultural ecology, the attire incorporated Western three-dimensional tailoring techniques, resulting in the unique and iconic Hong Kong-style cheongsam. In 2014 and 2017, the *Hong Kong Cheongsam Making Technique* was successively inscribed on the *Intangible Cultural Heritage Inventory of Hong Kong* and the *Representative List of the Intangible Cultural Heritage of Hong Kong*. Furthermore, in 2021, it was officially included in the fifth batch of the *National Representative List of Intangible Cultural Heritage of China* [18].

As a garment-making technique that integrates Chinese and Western cultural elements, exhibits technical complexity, and carries profound cultural symbolism, *Hong Kong Cheongsam Making Technique* serves as an ideal case study for conducting a pilot experimental trial of the proposed framework. The construction of its digital preservation platform will be based on the key dress forms of three pivotal periods: the 1920s, 1940s, and 1960s in accordance with their structures and cutting methods. The platform will comprise five core modules: a tool and machine library, a process library, an interaction library, a design material library, and a pattern library [19]. Designed with dynamic replication and data-driven approaches, as illustrated in Fig. 1, the platform aims to systematically document the material foundations and tacit knowledge of *Hong Kong Cheongsam Making Technique* through technological means, thereby supporting its preservation, education, and innovation.

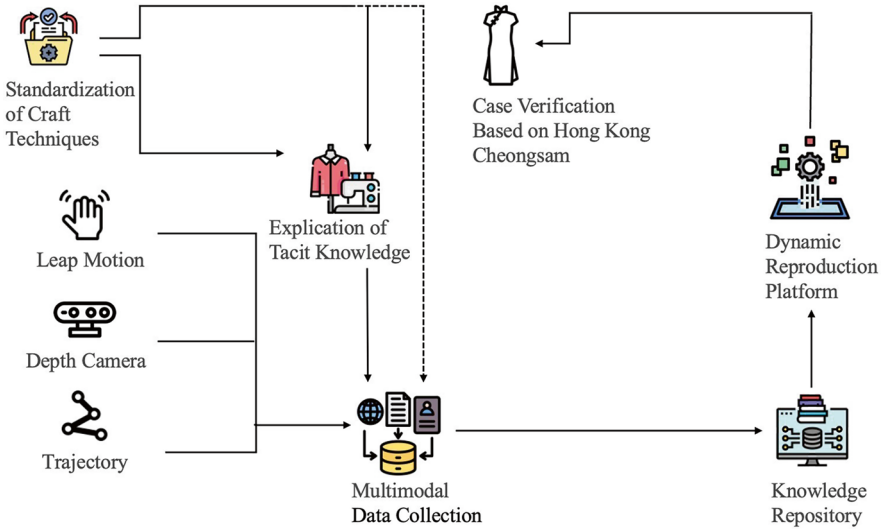

Fig. 1 The research structure and methodology

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