The *Soft Systems Design Kit*

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Sensitive and intelligent fabrics have shown promise in constructing flexible and stretchable human-computer interfaces, soft sensors and transceivers, and wearable assistive devices. In these systems, the fabric itself plays a crucial role in the functionality of the device, such as transducing electrical signals or providing structural support. The mechanical and electrical performance of these fabrics rely on factors determined by many disciplines, such as textile design, engineering, and manufacturing. When creating a fabric component, it is often difficult for disciplines to communicate their needs and constraints towards functionality in a way that is understood by the others. Furthermore, it is difficult to predict the overall physical and electrical behavior of the fabrics and ensure performance without extensive iterative design and testing cycles.

The *Soft Systems Design Kit* (SSDK) is proposed as a set of tools, workflows, and guidelines to assist textile development throughout the design and manufacturing process. The structure of the SSDK is based on that of *process development kits* (PDKs), which are fundamental tools used in the semiconductor industry to guide development of integrated circuit devices. PDKs offer circuit designers simulation tools and layout guidance to forecast a circuit's performance and verify its manufacturability. These toolchains have been created and refined over several decades and enable a predictable, consistent development process without extensive use of sampling and prototyping. We propose to apply these toolchains to functional textile devices.

The SSDK focuses on facilitating collaboration and communication between users with domain-specific expertise to guide the broad development of textile-based devices throughout ideation, construction, and testing. The SSDK addresses the practical needs of each discipline by providing entry points for textile design and construction, lists of materials and properties, standardized testing methods, and data acquisition, processing, and intelligent modeling strategies. This information is organized as a schema in a uniform and consistent structure that can be applied generally across a range of e-textiles systems. This schema is created and evaluated through analyzing the development cycles of our existing e-textiles devices to determine what key factors in the design contribute to device performance. Based on these findings and drawing from the *IPC 2581B* standard for circuit board design data, we have developed a preliminary hierarchical structure (Figure 1) to contain these parameters, thus providing an extensible framework to organize and communicate device designs.

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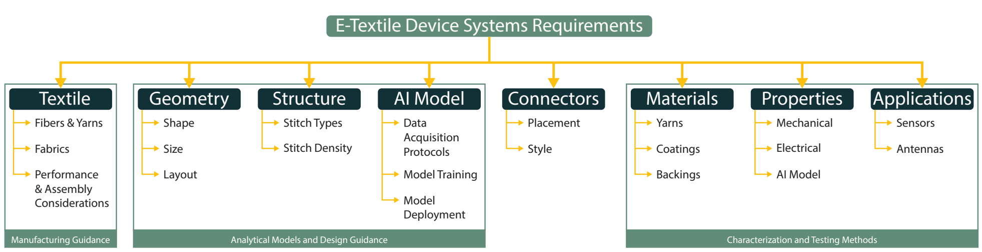

Fig. 1. Diagram of the SSDK hierarchy. The components of the SSDK schema are organized to provide entry points to determine appropriate materials selection, textile manufacturing techniques, fabric device modeling and integration with supplementary electronics devices, electrical connections between soft and hard components, and testing and characterization methodologies.

In addition, the SSDK provides users with simulation and modeling tools to forecast the performance of pre-production fabric circuit designs to better guide initial development. An example abridged workflow is illustrated in Figure 2 which details the design and characterization of a textile capacitive touch sensor. These simulation tools connect the anticipated high-level behavior of a fabric device with the low-level circuit produced from a textile's material composition and physical construction. Furthermore, visual circuit modeling techniques created for the SSDK allow textile designers and engineers to communicate physical design and performance requirements in a way that is generalizable to a wide class of textile construction methods. Lastly, the SSDK provides guidance towards data acquisition, data processing, and machine learning techniques to provide end-user applications with high-level, actionable data.

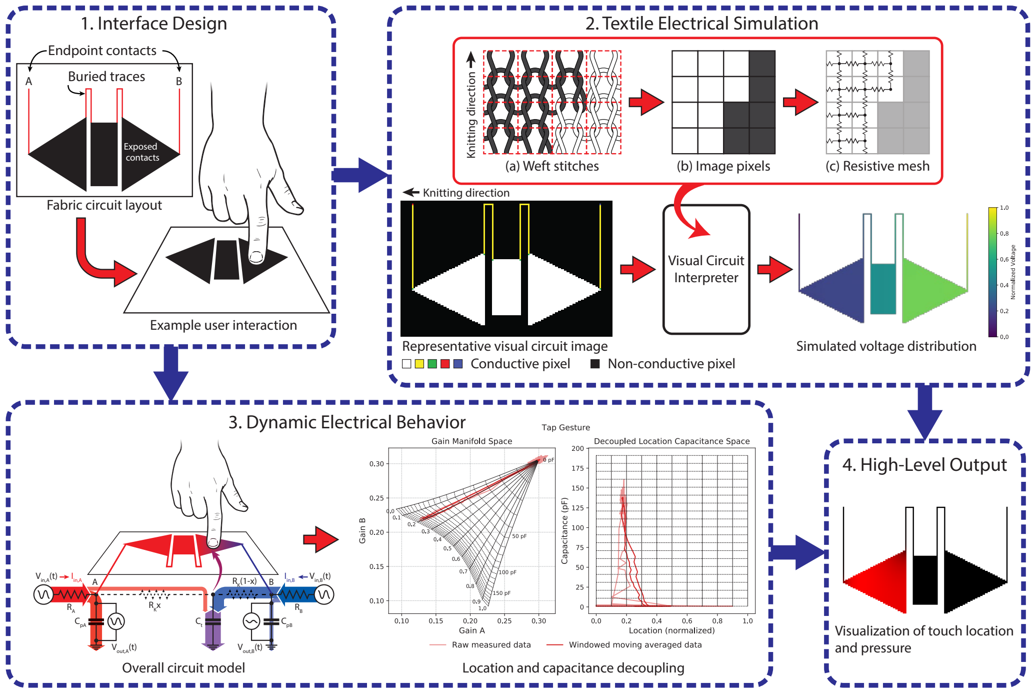

Fig. 2. Example of an abridged SSDK workflow to model, simulate, and evaluate the electrical behavior and sensing performance of a textile capacitive touch sensor. (1) The overall textile interface is formulated and modes of user touch interaction are identified. (2) A representative visual circuit model is produced and parsed to create a resistive mesh circuit. The voltage distribution and current flow are simulated and visualized using the image. (3) The high-level dynamic electrical behavior of the system is modeled and used to decouple touch location and pressure from measured voltage waveforms. (4) The simulated voltage distribution is used in conjunction with decoupled touch data to visualize touch location and pressure.

CCS Concepts: • **Human-centered computing**; • **Hardware** → *Sensors and actuators*; **Sensor applications and deployments**; *Sensor devices and platforms*; *Tactile and hand-based interfaces*; • **Computing methodologies** → *Machine learning*;

Additional Key Words and Phrases: e-textiles, toolkits, wearables, functional fabrics

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