AUTOMATED VIRTUAL DEVELOPMENT AND ANALYSIS OF STRUCTURES FOR TEXTILE WEARABLES

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ABSTRACT

This paper presents the main steps, which has to be performed for automated generation of electric circuits of textile structures for wearables. The generated 3D geometry of the textile structures is analyzed and the yarns are replaced by wires or resistances. Examples of testing the algorithm with woven and knitted structure and sewing stitch are presented. The generated circuit can be imported in specialized software and used for electric simulations.

Key Words: Conductive yarns, textile structures, simulation, automatic circuit generator

1. INTRODUCTION

The rapid development of the microprocessors during the last decades and especially the miniaturization of the electronic devices and their reduced prices increased the possibilities for their integration in textile structures significantly. Nowadays there are several companies on the market for clothing and interior textiles with integrated switches, actors and sensors. The integration of conductive yarns into textiles requires some adjustment of the textile or stitching machines, but it is no more an enormous technological problem. One of the main problems in the development of electric circuits integrated in the textiles is the requirement of interdisciplinary expertise in both textile and electronic areas. This work presents a method and its integration in a software, which allows automatic analysis of a virtual textile structures in the stage of their development with modern CAD systems. The result of this analysis is a circuit, based on the positions and interactions of the conductive yarns.

2. THEORETICAL BACKGROUND

2.1 Yarns as electrical elements

One electric circuit represents at low level a network of connected wires, resistances, capacitors, inductive elements, diodes, transistors and electric sources. The modern electronic chips integrate many of such elements into one chip. All sensors and actuators can be represented from the electric point of view as a set of these basis elements. Although the classical textile raw materials like cotton and polyester with volume resistivity $\rho_V > 10^{12} \div 10^{17} \Omega/cm$ [1] belong generally to the isolators, they can become conductors at higher moisture content. All cellulosic fibers, like cotton, viscose, modal, Lyocel and the commonly used animal fibers wool and silk adsorb moisture up to 10-15% at normal air humidity and up to 20% (cellulosic)- 30% (wool, silk) at 95% relative humidity. The wood, which is a cellulosic material too, increase the electric conductivity by $10^{10} \div 10^{13}$times with increase of the moisture [2]. These changes lead to the conclusion, that in an automated system for analysis of the topology of the electric properties of the structures, the electric resistance of the yarn, which represents wire, is not enough. The complete relation between relative humidity and the conductivity of all yarn types in the structure has to be available in some detailed or approximated form.

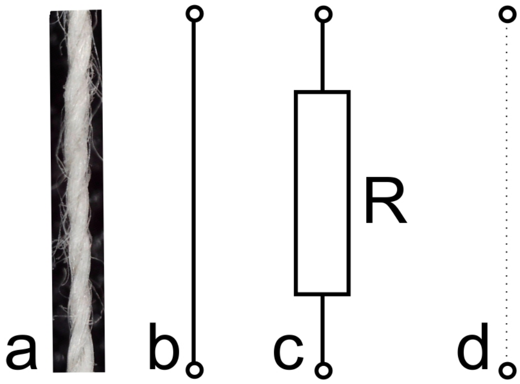

Figure 1. Textile yarn and its equivalents in the electric curcuits a) staple fiber yarn b) representation as connecting wire without resistance c) representation as wire with some resistance d) isolator – the yarn does not need to be represented in the system

Figure 1 represents three possible equivalents for representation of yarn piece into electric circuit. If the yarn has bad electric resistivity $\rho \ll 1\,\Omega \cdot m$, it is represented as a connecting wire (Fig.1b). If the resistivity is good $\rho \gg 10^{12}\,\Omega \cdot m$, it is an isolator and does not have to be represented in the circuit (Fig. 1d). If the resistivity is between these values, the yarn has to be represented as a classical resistance with its exact value (Fig. 1c). For investigation about the electric behavior of the textile with changing humidity, all these three options has to be available.

2.2 Topology of the structure

The textile structures consist of interlaced or inter-looped yarns. If two conductive yarns cross at some contact point (Fig.2a), this contact point becomes a node in the circuit (Fig.2b). The non-conductive yarns do not participate directly in the circuit. In the case of some more complex geometries the existence of non-conductive yarns among other conductive yarns is important and they cannot be ignored in the structure.

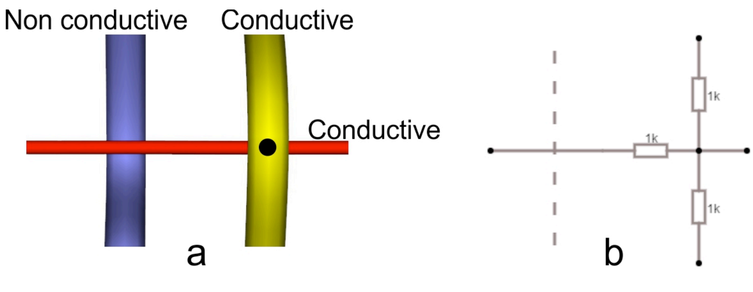

Figure 2. Crossing points between yarns with different electric conductivity. a) geometrical model b) equivalent circuit.

For the development of the circuit, each yarn in the structure has to be analyzed and its contact points with the other yarns have to be identified. The geometry of the yarn in the current case is created using the geometrical models, integrated within the TexMind Suite packages for braiding, warp and weft knitting, weaving and sewing stitches [3, 4, 5, 6, 7]. For each type of structure is developed a separated geometry generator (Fig. 3). The generated geometry can be modified ("relaxed") using different numerical methods, if this step is required and it can be visualized with the TexMind 3D Textile Viewer. The TexMind Viewer can import generated structures from other generators like WiseTex and TexGen, too. The visualized structures can be send then to the TexMind Circuit Generator (Fig.3) which evaluates the contact point between the yarns and creates equivalent electric circuit for visualization. In the current case, the data is exported in the format of the Circuit Simulator [8] of Paul Falstad.

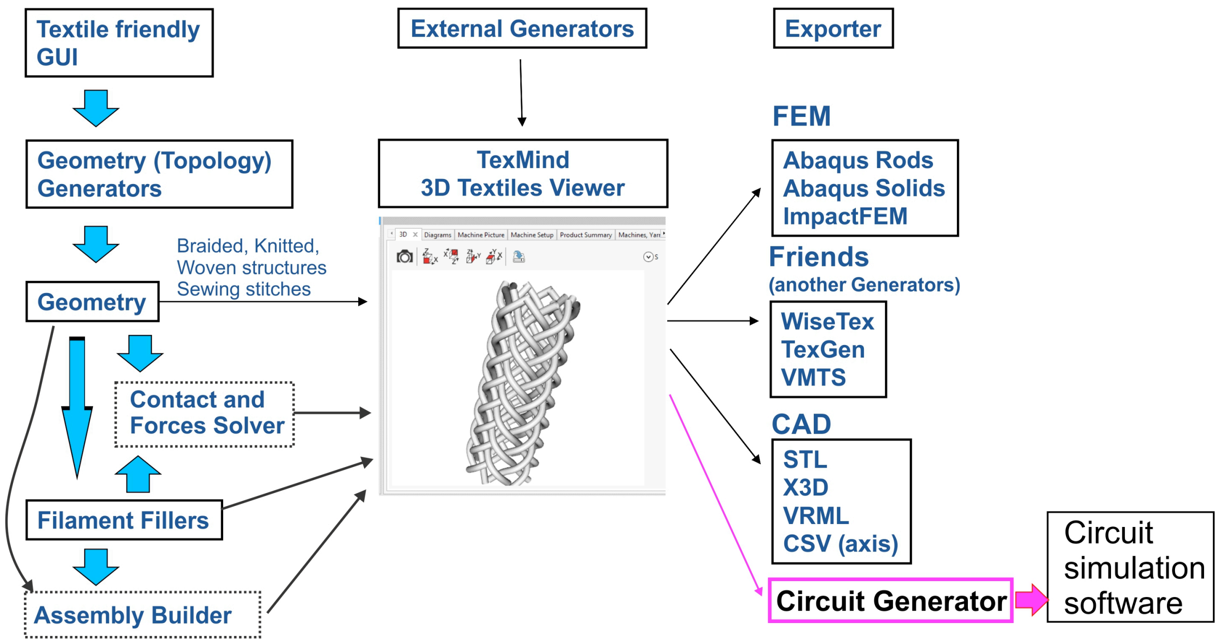

Figure 3. Structure of the software packages for automatic circuit generation.

2. PRACTICAL EXAMPLES

Figure 4a demonstrates 3D model of woven narrow tape from shuttle weaving machine. In the case that all yarns are conductive and no isolated, the automatically generated equivalent circuit with the wires and their contact points are visualized in Fig. 4b. In case of increasing of the resistance of the single yarns, but when they still remain conductive, each area between two contact points has to be represented with separated resistance (Fig. 4c). Figure 5 demonstrates a circuit for the same structure, but in the case of placing of two nonconductive warp yarns between the others. The software can be optimized to represent the three yarn pieces as a single one and not as three connected resistances, but this is a pure visualization issue and has no influence of the circuit simulation process. Figure 6 represents a generated circuit for a single yarn of a weft knitted structure. The areas with more contact points are separated to small pieces in order to allow correct representation of the contact regions with the other yarns. The contacts areas between the yarns and within the same yarn (self contact) require a special attention. Figure 7a demonstrate sewing stitch geometry, generated with the TexMind Stitcher and topology based algorithm described in [7]. For the case of conductive yarns, represented as wires, the equivalent circuit presented in Fig. 7b. Actually, the upper and bottom areas of the stitches often have contact and the two yarns within the stitch opening react as one wire (Fig.7d). If the circuit is generated automatically without adjustment of the mesh size of the single yarns and using fine data after the yarn contact identification, the result is more complicated (Fig.7c). In this case a numerous of single resistances for the yarn pieces and the contacts between them are generated, but few of them build parallel lines.

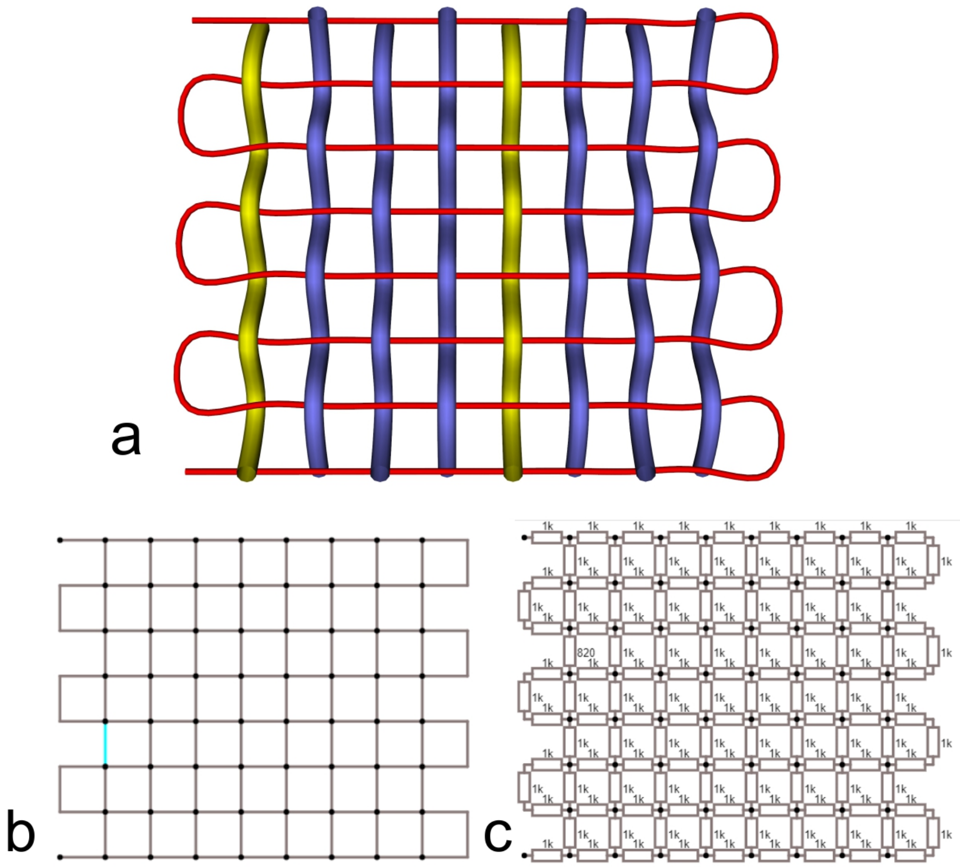

Figure 4. Simulated woven structure and its automatically generated cicruits a) 3D geometrical model based on the TexMind Weaver b) circuit for the case of conductive yarns c) circuit for yarns with non negligible resistance

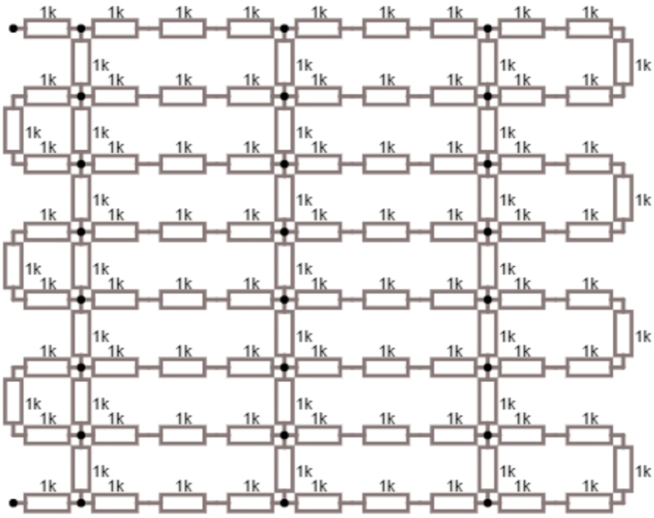

Figure 5. Circuit of the structure from Figure 4 for the case where after one conductive warp yarn two non conductive warp yarns are placed.

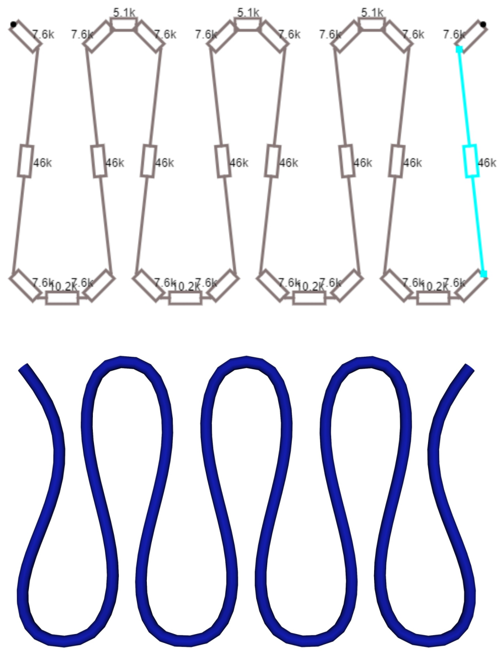

Figure 6. 3D Model of one row of weft knitted structure and its equivalent electric circuit

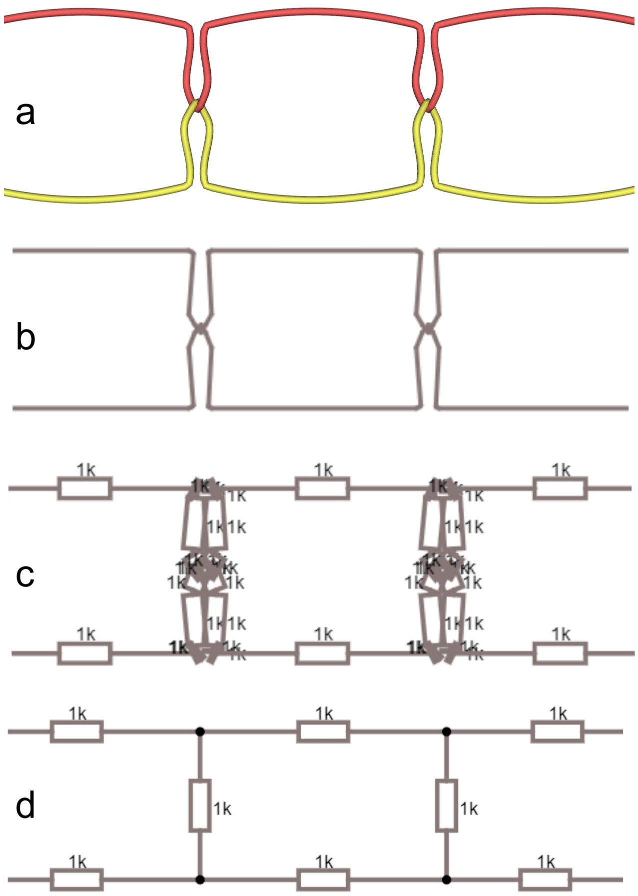

Figure 7. Sewing stitch and its circuits. a) 3D geometrical model b) electric equivalent in case of conductive yarns, c) automatically created equivalent circuit based on the contact information d) manually adjusted circuit, based on the automatically created one

2. CONCLUSIONS

This paper presents the main principle of automatic generation of electric circuits directly from the geometry data of the textile structures. The algorithms are tested as an extension of the existing geometrical models for the different structures. For the main cases, the automatically generated circuit can be directly used for simulation and analysis, after electric source and additional non-textile elements are included. The contact areas with sewing stitches and especially the areas with self-contact lead to generation of large number of small resistances, which make the circuit difficult to understand. Such areas are improved manually currently and the automatization of this intelligent check is under development. With or without manual correction, the initially automatically generated circuit still speeds up significantly the development of textile structures with conductive materials for textile wearables.

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