Computational Design Methods for E-Textile

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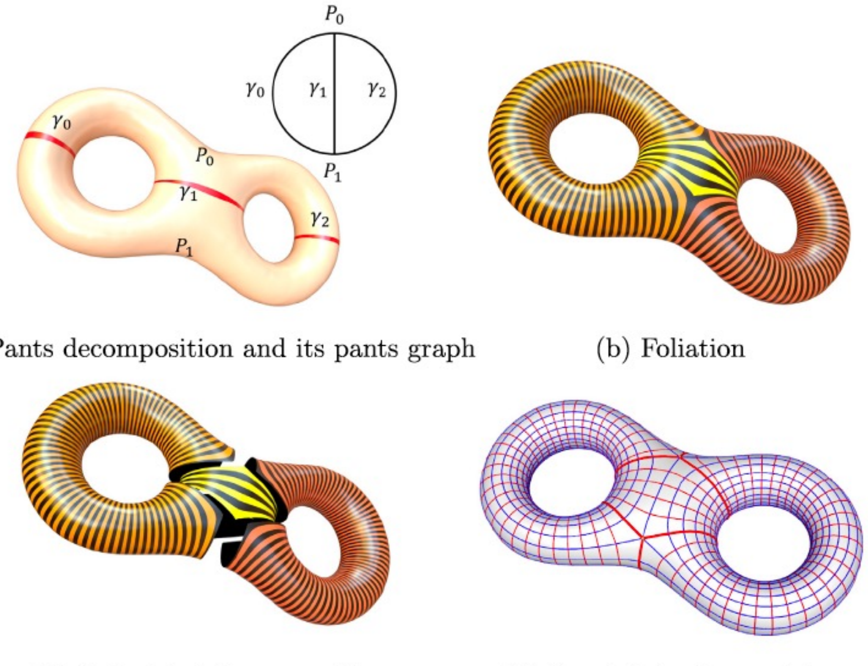
Design of conformal flexible electronics on free-form 3D surfaces

- Computational framework for conformal fabrication based on differential geometry
  - Arbitrary topology
  - Guaranteed smoothness (strip widths control accuracy in high curvature regions)
  - Minimal number of singularities and stress concentration

- Can generate woven flexible electronics designs conforming to free-form 3D shapes with 2D printed electronic circuits



(a) Pants decomposition and its pants graph

(b) Foliation

(c) Cylindrical decomposition

(d) Quadrilateral remeshing

(Yang Guo, Qian Ye et.al, CMAME 2020)

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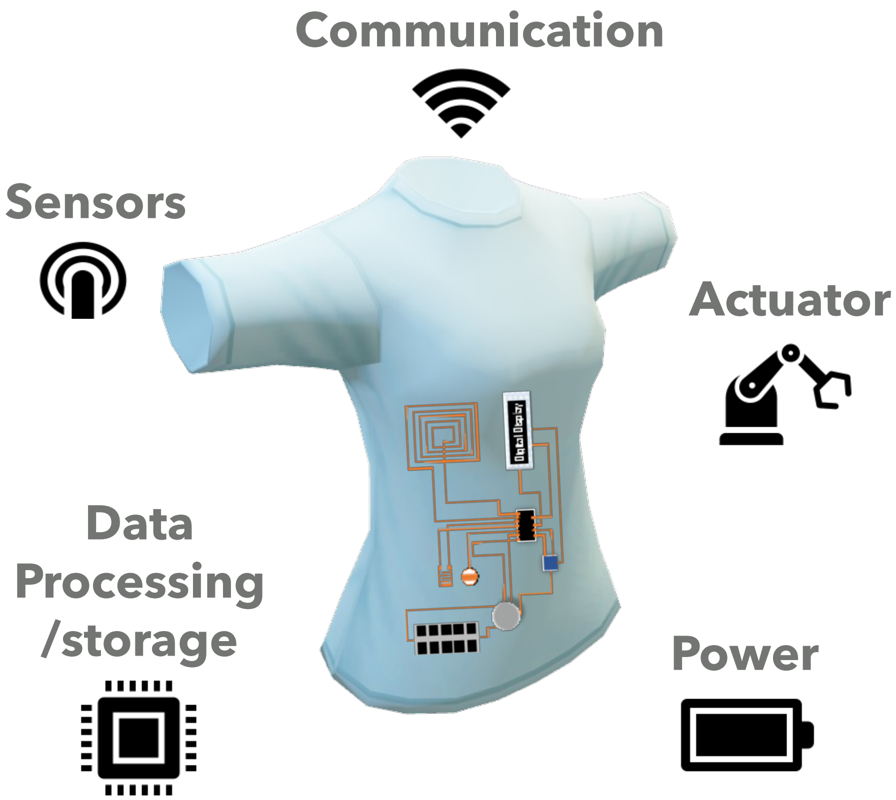
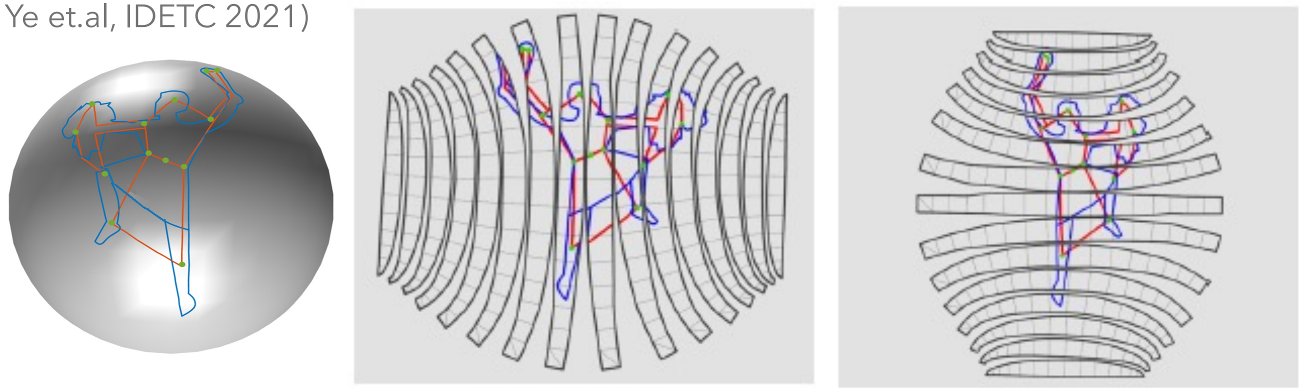
Fabrication of conformal electronics and system integration

- Integration of rigid components by conformal mapping to 3D surface and body movement

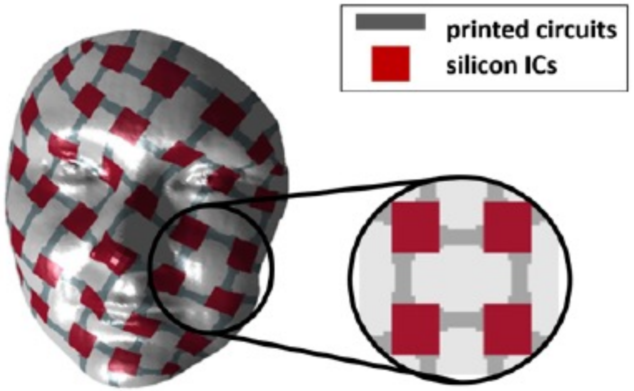


(Qian Ye et.al, IDETC 2021)



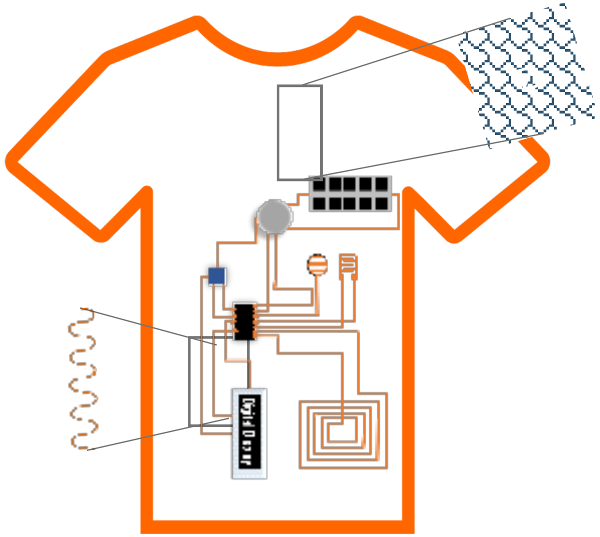
(a) Weft strips (b) Warp strips

- Woven 3D surfaces take advantage of conventional 2D electronic printing

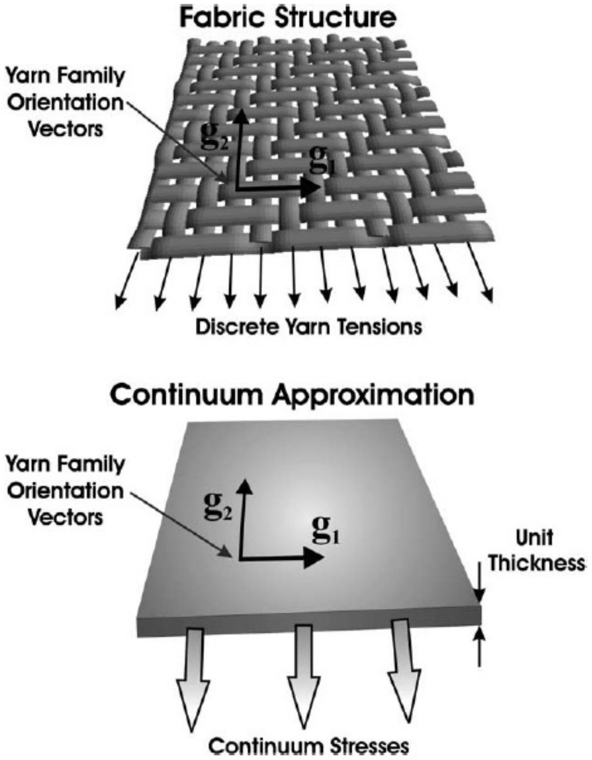


Multiscale mechanical behavior of woven fabrics

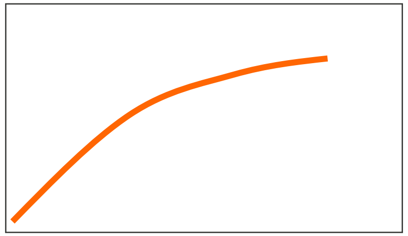
- Durability studies of fibers and connection based on multiscale continuum mechanic models
- Sensitivity and reliability of multifunctional fibers in relation to body motion



E-textile: a multi-material and multi-scale system



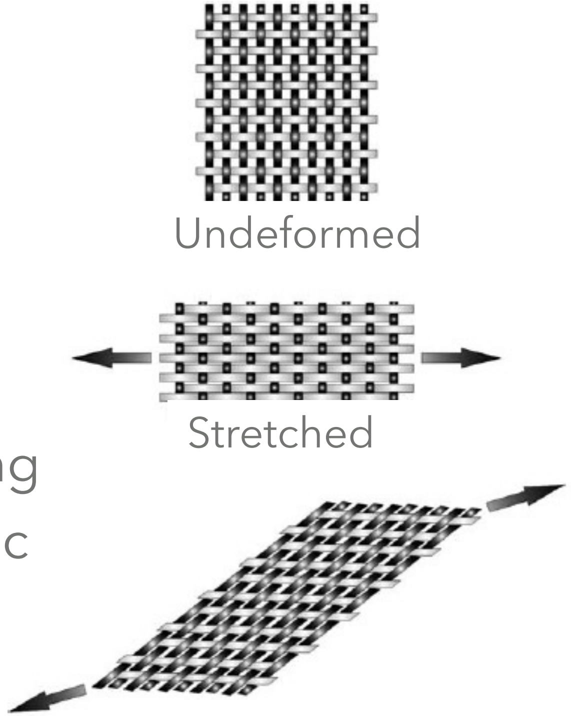
[IJSS 42 (2005) 3867-3896]



Stress-strain curve of a single yarn

- Rigorous upscaling from fiber to fabric

(ISN collaboration, DARPA-CompMods)



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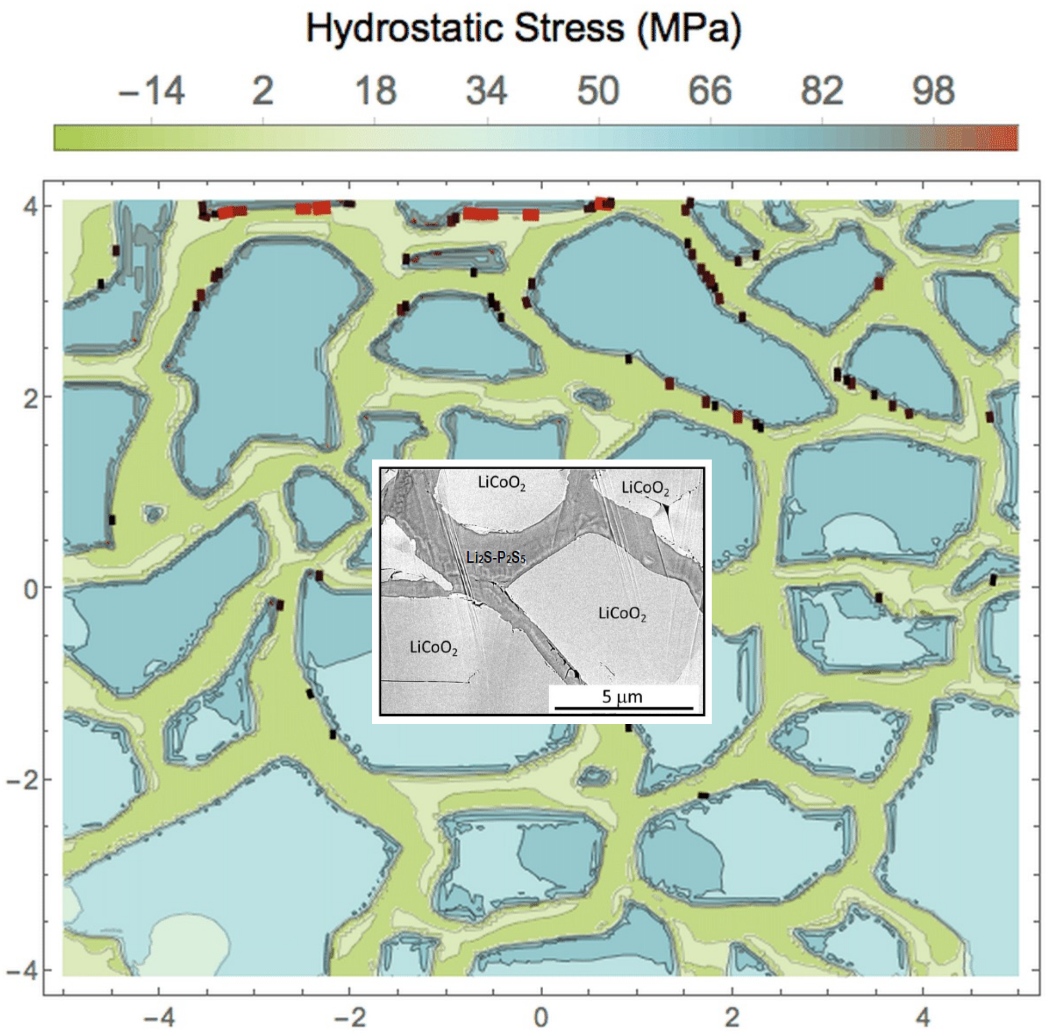
Mesoscale battery design, mechanical degradation

- High energy density solid-state batteries

- Coupling between electrochemistry and mechanics
  - Mechanical compatibility of materials
  - Study of multifunctional materials



[Bucci et al., JPS 441, 2019; Bucci et al., PhysRev Mat 2, 2018; Bucci et al., J Mat ChemA 5, 2017; Bucci et al., JES 164(12), 2017; Bucci et al., JES 164(4), 2017; Bucci et al., ActaMat 62, 2016]

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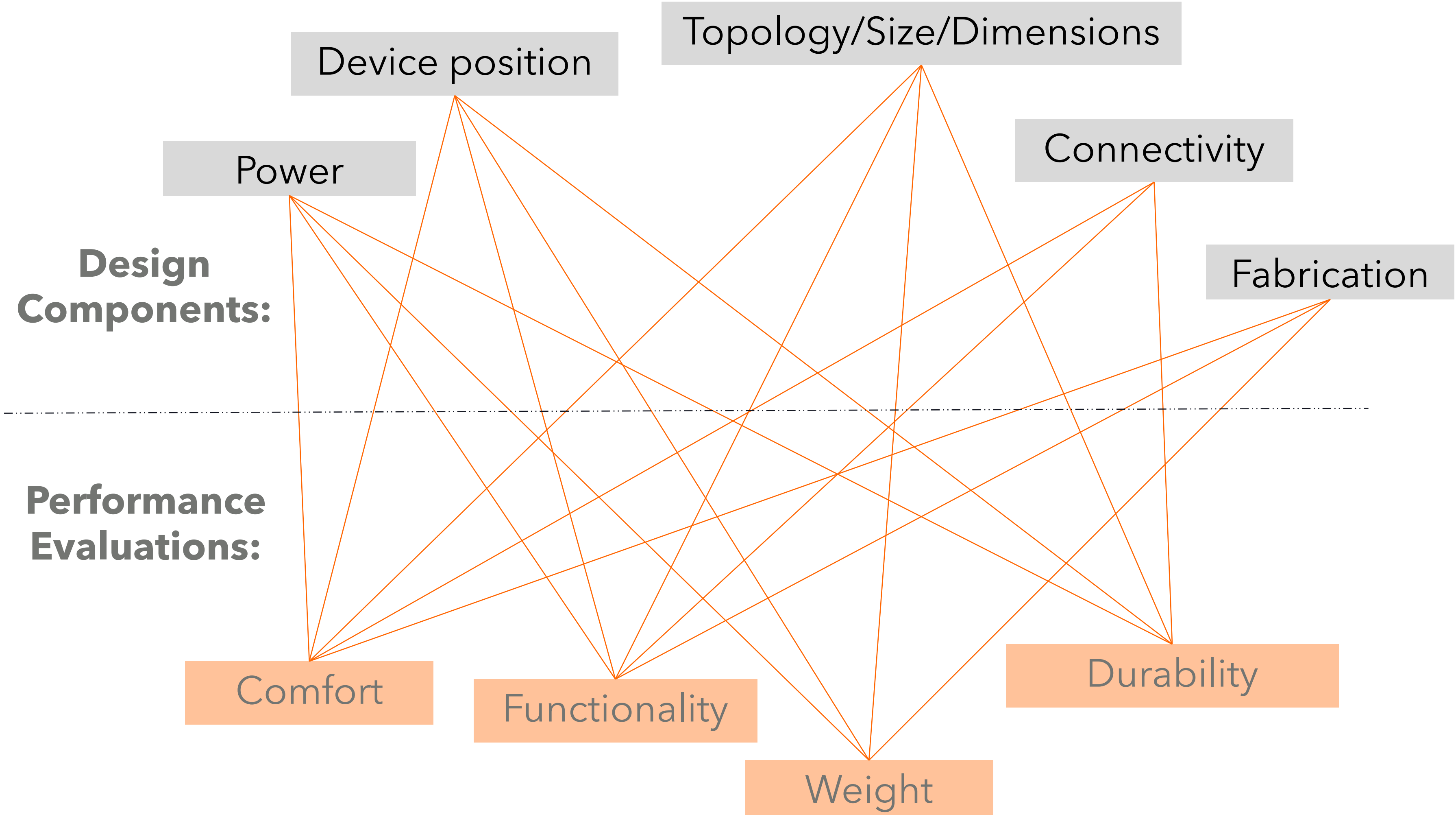
Design tools for the integration of materials and functionalities



Theoretical and computational tools:

- Design of 3D woven structures
- Mechanical response form fiber to fabric to garment
- Multifunctional material modeling
- Topology optimization guided by AI

Theoretical and computational tools in support of SMART e-PANTS:

- **Assembly**: design of 3D woven structures for integration of electronic components by conformal mapping to 3D surface (arbitrary geometries, guaranteed smoothness)
- **Comfort and durability:** analyses of the mechanical response from fiber to fabric to garment-system by rigorous upscaling
- **Sensitivity and reliability:** modeling of multifunctional fibers, solid-state batteries, and piezoelectric materials under large deformations
- **System design:** topology optimization guided by AI

PARC's hardware capabilities

- **Materials/ chemical synthesis**: Synthesis of novel chemical material in-house, as well as processing capabilities of commercially acquired materials
- **Fiber fabrication:** developed different process methods to fabricate fibers, and fiber like structure with dimensions ranging from 100nm – 1um. Different process methods include electrospinning, melt extrusion, melt-electrospinning, solution extrusion, pultrusion, coaxial fiber synthesis etc.
- **Device fabrication:** nano/micro fabrication capability.
- **Device integration and testing:** PARC has wide range of equipment as well as people-expertise to test different electronic devices. We have fabricated and tested piezoelectric devices, opto-electronic devices, energy generation and storage devices as well as integration capabilities to develop full-fledged electrical circuit.
- **Deformable electronics**: PARC hardware research lab has been working on flexible and stretchable electronics and has in-house capabilities of detailed electro-mechanical testing of the devices.

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THANK YOU

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