Robotic Needle Felting

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Robotic Needle Felting explores the development of an additive manufacturing technique for nonwoven textiles. Nonwoven textiles, such as felt, can be natural materials (wool), synthetic polymers (polyester), or blends of the two. These textiles have numerous performative aspects for architectural applications including excellent acoustic absorption, thermal insulation, and tactile characteristics. The nonwoven textiles can be manipulated by a process called needle felting - whereby barbed needles, when punching through layers of material, entangle the fibers together making it a uniform material. This process binds the material together seamlessly without the addition of sewn thread or toxic adhesives, making this technique a more environmentally friendly process.

Needle felting can range in scale from handcraft techniques with a single needle to large scale web processing. Integration into a robotic process not only enables precision and speed in manufacturing but also extends needle felting as a three-dimensional process, especially for surfaces with complex geometries and allowing for local differentiation of stiffness and other properties across a homogenous solid. Through a customized digital workflow, formal and material properties can be varied at local level within a component. By developing a fully integrated design to production methodology for influencing these properties, this research opens a wide range of potentials for nonwoven textiles in architectural applications.

The project involves three areas of development; the tooling for robotic felting, the digital workflow that enables the formal and material properties to be specified computationally and embedded into the machine code, and prototypes of architectural elements such as acoustic panels and furniture demonstrating different techniques and processes. Additive manufacturing (AM), commonly known as 3D printing, has revolutionized the design to production workflow in a wide range of disciplines. While AM processes have been developed for a wide range of materials, from ceramics to plastics to metals, there have been very few investigations into their applications for textiles. Given the unique capacity of felt to be seamlessly “added” into a cohesive solid, it presents a unique opportunity to investigate the potentials of an AM approach with nonwoven textile as composite material. In some cases, a nonwoven thermoplastic textile was used together with other natural felt materials to both create varied ribbed textures and to enhance overall stiffness by heat setting after felting.

The prototypes explored four techniques resulting in different surface textures and form: quilting, shiplap, shingle, and thermo-activated composite. For these techniques, different layers of material could be felted together or onto a foam substrate as an integrated process. Additionally, an automatic tape feed facilitated both shiplap and shingle techniques with unique patterns and varying overlap. Through the research, design, and fabrication of acoustic panels and furniture using the techniques developed, the computational design process negotiates the precision and nuances of robotic felting with the specific material behaviors of nonwoven textiles. Geometric limitations are also incorporated, which respond to the tool’s movement and the types of material being felted.
Robotic Needle Felting explores the development of an additive manufacturing technique for nonwoven textiles. Nonwoven textiles, such as felt, can be natural materials (wool), synthetic polymers (polyester), or blends of the two. These textiles have numerous performance aspects for architectural applications including; excellent acoustic absorption, thermal insulation, and textile characteristics. The nonwoven textile can be manipulated by a process called needle felting, whereby barbed needles, when puncturing through layers of materials, entangle the fibers together, making it a uniform material. This process binds the material together seamlessly, without the addition of any thread or inset adhesives, making this technique a more environmentally friendly process.

Needle felting can range in scale from handcraft techniques with a single needle to large-scale processing. Integration into a robotic process not only enables precision and sized in manufacturing but also commutes needle felting on a three-dimensional process, especially for surfaces with complex geometries and allowing for local differentiation of stiffness and other properties to provide a homogenously solid. Through a customized digital workflow and material properties can be varied at local level within a component. By developing a fully integrated design to production methodology for influencing these properties, this research opens a wide range of possibilities for nonwoven textiles in architectural applications.

The project involved three areas of development: the tooling for robotic felting, the digital workflow that enables the manipulations and material properties to be specified computationally and embedded into the machine code, and prototypes of architectural elements such as acoustic panels and furniture demonstrating different techniques and processes. Additive manufacturing (AM), commonly known as 3D printing, has revolutionized the design to production workflow in a wide range of disciplines. While AM processes have been developed for a wide range of materials, from ceramics to plastics to metals, there have been very few investigations into their applications for textiles. Given the porous nature of felt, it was necessary to develop a unique opportunity to investigate the potential of AM approaches combined with nonwoven textiles as concrete material. In some cases, a nonwoven thermoplastic textile was used together with other natural felt materials to both create uses and ribbed textures and to enhance overall stiffness by heat setting after felting.

The prototypes explored four techniques resulting in different surface textures and form qualities: drop casting, shape change, and thermo-activated composites. For these techniques, different layers of material could be fused together or used from substrate as an integrated process. Additionally, an automatic tape feed facilitated both airbag and shape techniques with unique patterns and varying overlaps. Through the research, design, and fabrication of acoustic panels and furniture using the techniques developed, the computational design process integrates the precision and nuances of robotic felting with the specific material behavior of nonwoven textiles. Design limitations are also incorporated, which respond to the tool’s movement and the type of material being felted.

1. Drop-quilted texture acoustic panels.
2. Section drawing of end effector for robot, showing automatic pneumatic feed and cut, motorized components, and heater head with needle. (Left) top to bottom: Triangle and twisted felting needle types, surface below after punching showing fibers being placed through the material, and close-up of felted material showing winding of fibers.
3. Shaped technique with 1 1/2” wide, 1/16” thick F10 natural felt.
4. Simple technique with 1 1/2” wide, 1/8” thick F0 natural felt.
5. View of each batch from left to right, samples of composite felting (top), 36” x 10” acoustic panels, side footage of various robotic felted process, and foreground, bench with local surface.
7. Automatic feed, cut, and revetment of wood felt areas. Curvature and reliefs are varied continuously along the surface.
8. Approximately 27’ x 27’ x complex surface panel with 1/2” thick grey F0 industrial felt single nested.