Jeeeun Kim- *Research Statement*

"3D printing will revolutionize the way we make almost everything (Barack Obama, 2013)" Recent advances in digital fabrication (DF) technology allowed everyday designers to enter a new realm of manufacturing. Having observed growing excitements over 3D printing and DF, the hope presumes that users already have sufficient skills in creating complex models. It implies designers own sufficient domain knowledge to understand underlying principles. Although this assumption has lead to the great advances in consumer grade fabrication machines (FM), such advances in hardware do not **support users' desire to solve everyday issues and to augment the everyday objects they live with.** Current DF algorithms do not provide successful channels through which users and FM to communicate through the process in the same dimension. By failing to provide an accessible handle and to engage humans throughout the entire process, current DF has lost bridges to allow users to redesign and update their initial thinking via emerging design decisions. As humans naturally do in conventional handcraft, compromising partial outcomes and integrating new materials into the middle of process promise gradual augmentations of existing things.

My research aims to **augment the world where people live, interact, and own at hands by hybrid-fabrication**. It will be possible through the fluid exchange of information between humans and FM throughout the entire fabrication process. To do so, **machines need to be intelligent to perceive humans' conceptual thinking presented via design action**, and translate it into parameters for computation. Traditional handicraft integrates this pipeline from ideation to final outcome as a holistic creative process. The craftsperson fuses design decisions, materials, and new discoveries from the process with partial outcomes. Current DF processes lack the abilities to project physical constraints onto virtual models and engage with humans' design action through the entire pipeline. I **define formalism and renovate design approaches that bridge mismatches between a person's mind and physical products in computer-aided fabrication.** The formalism interpolates chasms between humans' initial design conception and the virtual model to express it as digitized information. Further, my work fills gaps that occur during a physical production by FM using virtual models sit in design tools. My design approach restores human's lost control over the entire DF pipeline by allowing machines to listen to him at anytime. It empowers people to bring real objects as initial inputs, gradually aggregate emerging designs, by participating in the entire fabrication procedure.

DF should lower the hurdle for a user to have sufficient domain knowledge. A non-expert user should be free from any implicit prerequisite to have sufficient knowledge. The requirements users are required to have include, computer graphics to understand how a 3D model is manipulated in a particular data structures, mechanical engineering to consider constraints (*i.e.* clearance, center of mass), or material engineering to understand property of elements (*i.e.* viscosity, elasticity, adherency) etc. These factors are best handled by FM's precise and rapid computations, once users have more freedom to embody their design thinking in an design action to be delivered to machines for processing.

DF can raise the ceiling of viable applications, in terms of material, scale, and the place. Current fabrication systems limit the type of applications, mainly in one material at a time, within a desktop size, created indoors. Restraining DF into uni-material in the lab setting saved cost and reduced the risks. Unfortunately, human creativity is curbed by such limitations that repel human nature-- utilizing a variety of materials, employing a wide range of tools, and exploring functions at anywhere they want to deploy. By removing limitations, the expected artifacts could break the shell that confining the size of the product.

Previous Research: Augment Existing Things to Improve the Personal DF Experience

In the physical world, nearly everything is built on something existing; Augmentation is the process of building a proxy medium to connect a virtual model and a physical product. Novel innovations in DF need to consider the current environment, infrastructures, and constraints. **Augmentation fills the gap between the physical world and the digital model,** addressing challenges using existing solutions from everyday life. It translates additional information and functions from one dimension to the other, adding new values to users' possessions. They want to address everyday issues from existing things by DF, adapting their design to the target objects, augmenting them with their own creative design.

Moveable 3D Tactile Pictures (CHI'15) My first exploration in augmentation starts with **transcribing and augmenting 2D visuals into 3D printed tactile pictures** for children. Experimenting with a wide range of aspects that affect the tactility and moveable parts in picture books, I prototyped a set of mobility primitives that help remix augment of 3D objects. This will be accomplished with a parametric 3D modeling platform that I developed, to facilitate the process.
Flat physical interface (CHI '17) I also augment **a flat physical appliance with tactile overlays to address common accessibility problems**. The system allows a blind user to take a photo of appliances, and use computer vision to retrieve the actual size and shape of the control panel. The image is then sent to crowdsourcing platform to label spatial and textual information. Our user study showed that a blind user can independently 3D prints the overlay and attaches tactile buttons onto the original control panel.
Everyday Objects with Uncertainty (UIST'16, DIS '17) The main challenge in augmenting the real world originates from its uncertainties**.** Every individual has different constraints arising their unique objects, and faces various needs from distinct settings. Despite the precision and speed of computational tools, they do not project real specifications onto an adaptation target. I developed a tool that **addresses uncertainties from measurements in users' adaptation, allowing users to solve everyday issues.**

Current Research- Define an algorithm that gives fabrication system an intelligence

Human-FM Interaction (in submission): From previous research, I have learned that human and FM must exchange their work-in-progress in the same dimension, in real-time. A machine needs a **function that projects human's design action translated into parameters for machine computation**. This allows designers to generate on-the-fly adaptations that emerges from the initial design thinking, incrementally injecting changed design choices and new discoveries into the process. I identified a formalism that abstracts human's physical handcraft practice and physical inputs as symbolisms, interpreting them as input into a FM's operation. By encapsulating physical dynamics and human behavior, machines can understand a human's interaction as computational input, processing real-time intervention, maintaining 'collaboration' in the entire fabrication pipeline. It is the first attempt to augment FM's capabilities by giving machines the intelligence to discuss virtual model and physical action in the same dimension.

Future Research- Extend the frontier by removing limitations in material, scale, and place

Augmenting-Fabrication in Scale: At present, the primary purpose of advances in FM is to reduce the size of machines used by industrial high-end manufacturer, which create difficulties in fabricating large-scale objects. **Users desire to build objects in scale, fusing common materials.** Fabrication technology can aid this process, by connectors that themselves embody algorithms and instructions, which guide the assembly of raw material with it. The precise computation of FM will generate the best form, direction of bridging materials, required force, *etc.,* that all embedded in its design. They will be abled to fabricate large-scale construction that is aesthetically appealing, functional, and mechanically stable.
Scaffold-driven Sustainable Fabrication: In the future, changes in environments and infrastructures will transform our perception from the original form factor of existing objects in shape and function. I hope to extend fabrication to **create design proxies for fabrication with organic materials.** Existing raw materials will be gradually attached to the proxy, which stays during the assembly process as a scaffold. A computational algorithm will generate the proxy structure with ad-hoc material attachments in mind, reducing any negative impacts when the scaffold later decomposition, leaving only natural materials.
On-site Augmented Fabrication: The algorithm I develop lays out the fundamentals for incorporating physical objects and design actions as inputs into the machine, not simply the shape of the object, but also considering its properties. My future work is to build DF systems to enable the utilization of on-site materials, in order to build on-the-fly ad-hoc designs beyond the existing foundations. Future DF should **adapt physical dynamics from in-the-wild environments, and compose a new design within the natural scheme**.