Ori-mandu: Korean Dumpling into Whatever Shape You Want

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Abstract
Food 3D printing is getting the spotlight by offering the opportunity to customize food appearances, textures, and flavors that are troublesome to make by hand. Additive manufacturing machines extrude ingredients into a certain shape, however, they cannot be applied to all types of food, such as *mandu* (Korean dumpling). In this pictorial, we extend the research on digital gastronomy by using digital fabrication to create custom tools that assist the process of cooking. We present the iterative process of designing the "*Ori-mandu*" system, and how Ori-mandu enables users to fabricate dumplings in whatever shape they want.

Authors Keywords
Digital Gastronomy; food fabrication; dumpling;

ACM Classification Keywords
H.5.m [Information interfaces and presentation (e.g., HCI)]: Miscellaneous

Introduction
The integration of computation and digital fabrication with cooking allows cooks to individually address the users' needs and desires [7]. 3D Food printers open up the possibility of manufacturing food with customization in shape, color, flavor and even textures that are hard to make by hand. Additionally, digital gastronomy makes the cooking experience exciting and easy, even for inexperienced cooks or children.

Additive manufacturing techniques, used in traditional 3D printers, can also be applied to food, especially for sugar, jelly, gum, pancakes, or chocolate.

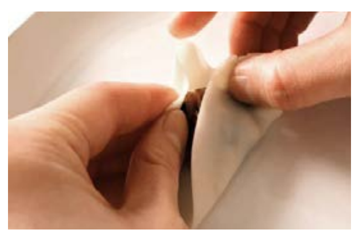
Recently, several projects have introduced digital fabrication in the kitchen. The most common type is extruding a paste into an arbitrary shape [2,8,10,11], like Foodini [8], which uses fresh food paste as its ingredient, or PancakeBot [10], which extrudes the dough directly onto a cooking plate located at the bottom. Also, existing fabrication machines are used for foods. For example, laser cutting machines are used to selectively cook the fat of bacon[4].

However, these techniques are not applicable for the types of food that require multiple steps with different ingredients. Korean dumpling, or *mandu*, is an example that has such a complicated cooking process. The cook needs to cut the dough into a certain shape, insert the filling, fold it into a delicate form, and finally seal the edges.

In this pictorial, we propose a novel and hybrid process in which we fabricate custom tools that assist the process of cooking [9]. To assist in the mandu-making process, we present a stamp and jig system. Computer-aided design (CAD) software generates these tools based on the user's parameters, then the user cuts the dough with the stamp and folds the dumpling using the jig. The user can make mandu into various geometric shapes quickly without any special skills. In the following pages, we documented our process of designing *Ori-mandu*.

Cutting.
Prepare the dough into shape.

Filling.
Place the filling on the dough.



Folding.
Fold the dough

Sealing.
Seal and decorate with a fork.

Cooking.
Fry or steam prepared dumplings.

Being the machine

How do we cut the dough?

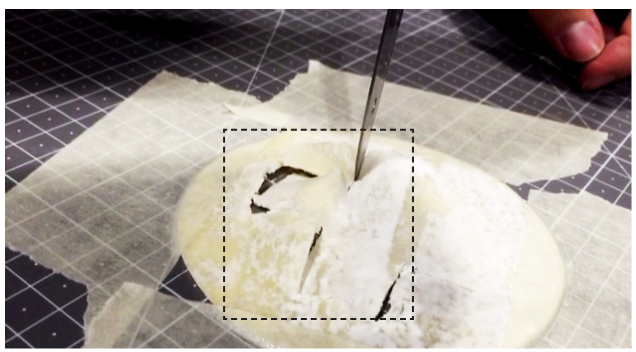
Our first intent was to understand the materials and to explore the proper techniques for making mandu. We were inspired by the method used in *Being the Machine* [3], which invites people to act as the fabrication machine, and identified the role of the machine in hybrid cooking [9].

The main ingredient of mandu, the flour dough, has a unique set of material qualities (soft, high viscosity, sticky). Therefore, we needed to try different techniques for cutting the dough into the proper shape, and decided to explore the operation of CNC machines as a viable method. As the dough for the dumpling can be easily obtained from the market frozen, we skipped the dough making process.

Here, we tried two different cutting types: being a moving knife and being a rolling knife.

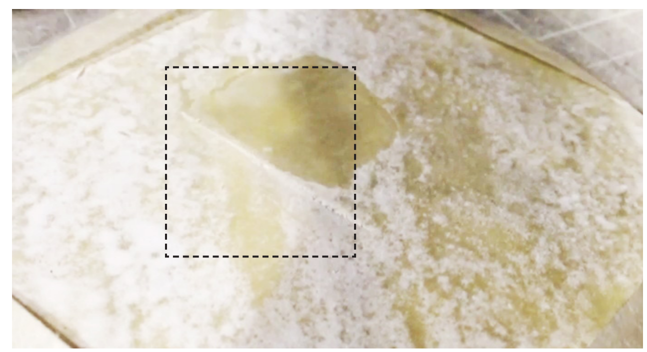
Being a Moving Knife

Firstly, we became a knife that moves in the X and Y coordinates. We attached the edge of the dough to the cutting board, as the dough was not sticky enough to stay fixed in position. However, the dough started moving again half way through the cutting process. The traditional operation of CNC machines seems inappropriate for cutting dough.



Being a Rolling Knife

In the second iteration, we became a knife that rolls along the cutting board, in order to press the dough while cutting. We modified an aluminum can into a rolling knife by cutting out the middle of the can into a blade. The results were satisfactory but the process was inefficient in terms of the time it took to cut a the dough.



▶ After testing out each technique, we realized that building a machine for cutting the dough would be inefficient as it requires a large amount of time and effort compared to the outcome it achieves. In order to cut the dough quickly and accurately, we decided to fabricate a stamp-like tool that cuts the dough into custom shapes. Inspired by the blueprints used in origami, the stamp imprints both the folding line and cutting line onto the dough as guides.

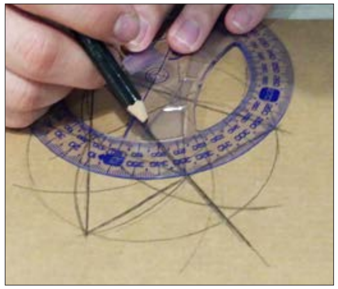
Low-fi Prototyping

How do we fold & seal the dough?

The next difficulty lies in folding the mandu into a pre-configured shape. Traditionally, assembling the dough into a nice shape required special skills or know-how. As a result, there has been a high barrier for making mandu at home.

To address this issue, we pursued the idea of fabricating a jig that can be used as a guide while folding the mandu. There needed to be a tool that keeps the shape of the mandu while folding, and helps seal the edges easily.

We explored possible shapes or designs with cardboard, and tried making mandu with our prototypes. This helped us understand the crucial aspects of the jig: the importance of extra space (wings) on the edges for sealing and the ability to apply pressure evenly on the wings. Also it showed us what to consider for the digital design: 1) how to fabricate hinges with a 3D printer, 2) how to set the angles necessary for assembly, and 3) how it corresponds with the stamp design.



Journey of Cooking with Ori-mandu

Whilst originally we thought of a machine that cuts dough, we switched to the 'fabrication of tools that fabricate mandu.' This makes the process easier and lowers the barrier for cooking. The entire journey consists of three steps: designing the tools, 3D printing the tools, and making the mandu by using the tools.

1. Customize the Tools

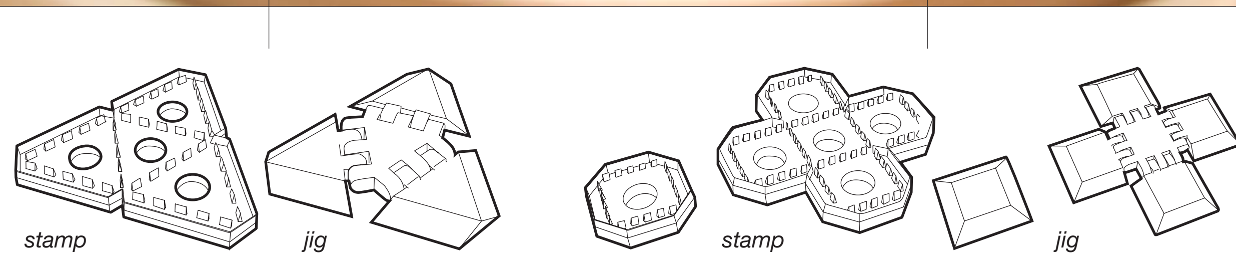
The first step is to customize the Ori-mandu tools into the shape you want. We made a parametric design (tetrahedron and cube) that automatically generates the model based on the parameter inputs.

2. 3D Print the Tools

When the users are satisfied with their custom design, they can fabricate the stamp and jig with any type of 3D printer.

3. Make mandu with Tools

When all the ingredients are ready, they can start cutting the dough with the stamp, and fold and seal it by using the jig as a guide.



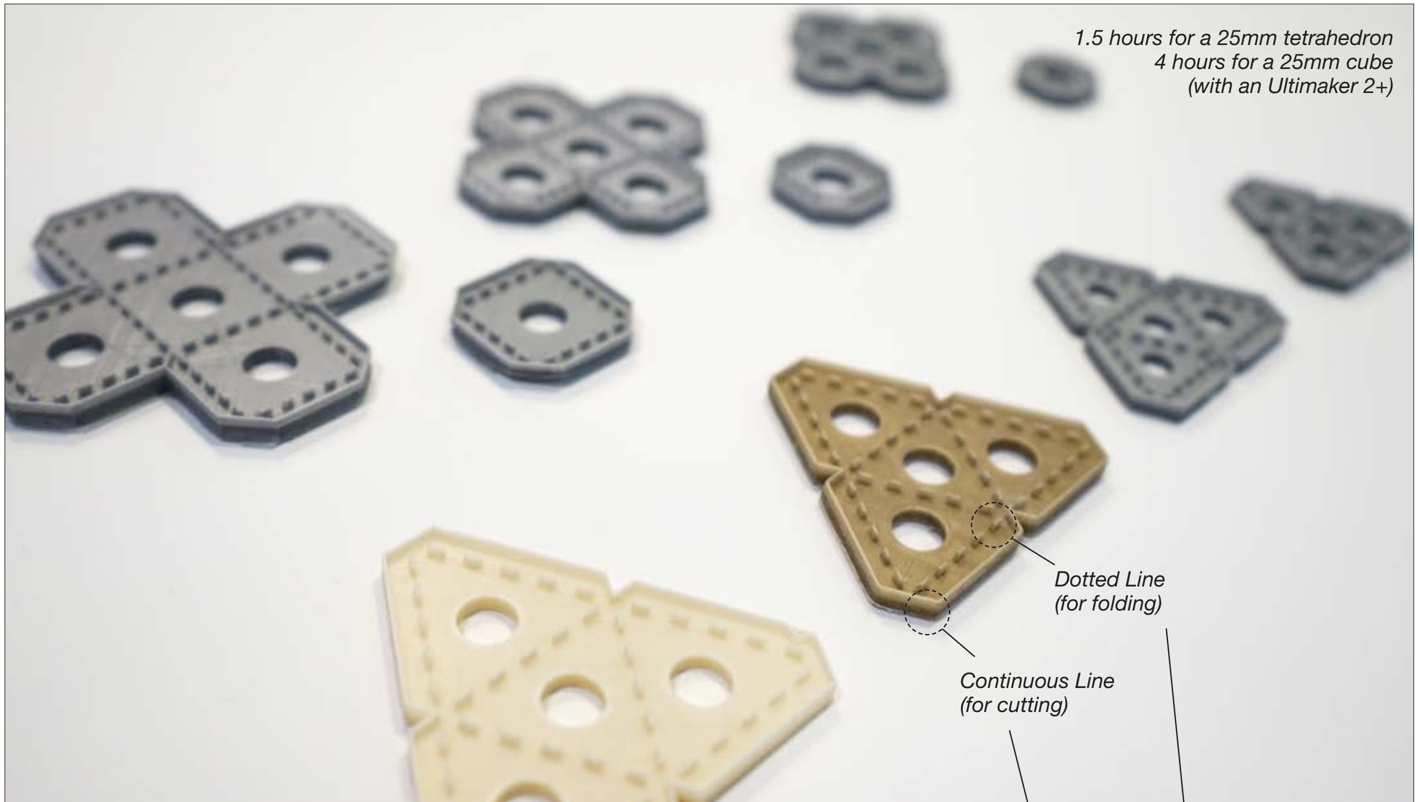
Ori-mandu Stamp

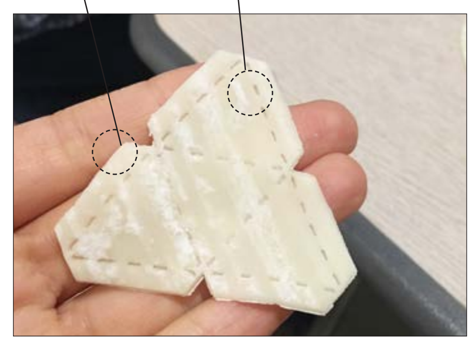
The design of the stamp was inspired by the process of folding origami combined with the blueprint for regular polyhedrons: the tetrahedron and cube. However, the detailed 3D shapes were iteratively explored and revised by experimentation.

To aid in the assembly process, the folding line was designed as a dotted line and the cutting line as a continuous line. We added wings on each edge to ensure a nice seal to prevent the leakage of the filling while folding.

At first, we constructed the cube out of one piece, however that resulted in a less appealing shape because of the asymmetry in folded and sealed edges. Therefore, we composed the stamp for the cube in two parts to generate symmetrical edges when fabricated.

All the models are designed parametrically with several parameters, like the length of the edge (for size), the thickness of the dough (for accurate cutting), and the size of the inner circle (for easily detaching the dough after stamping).





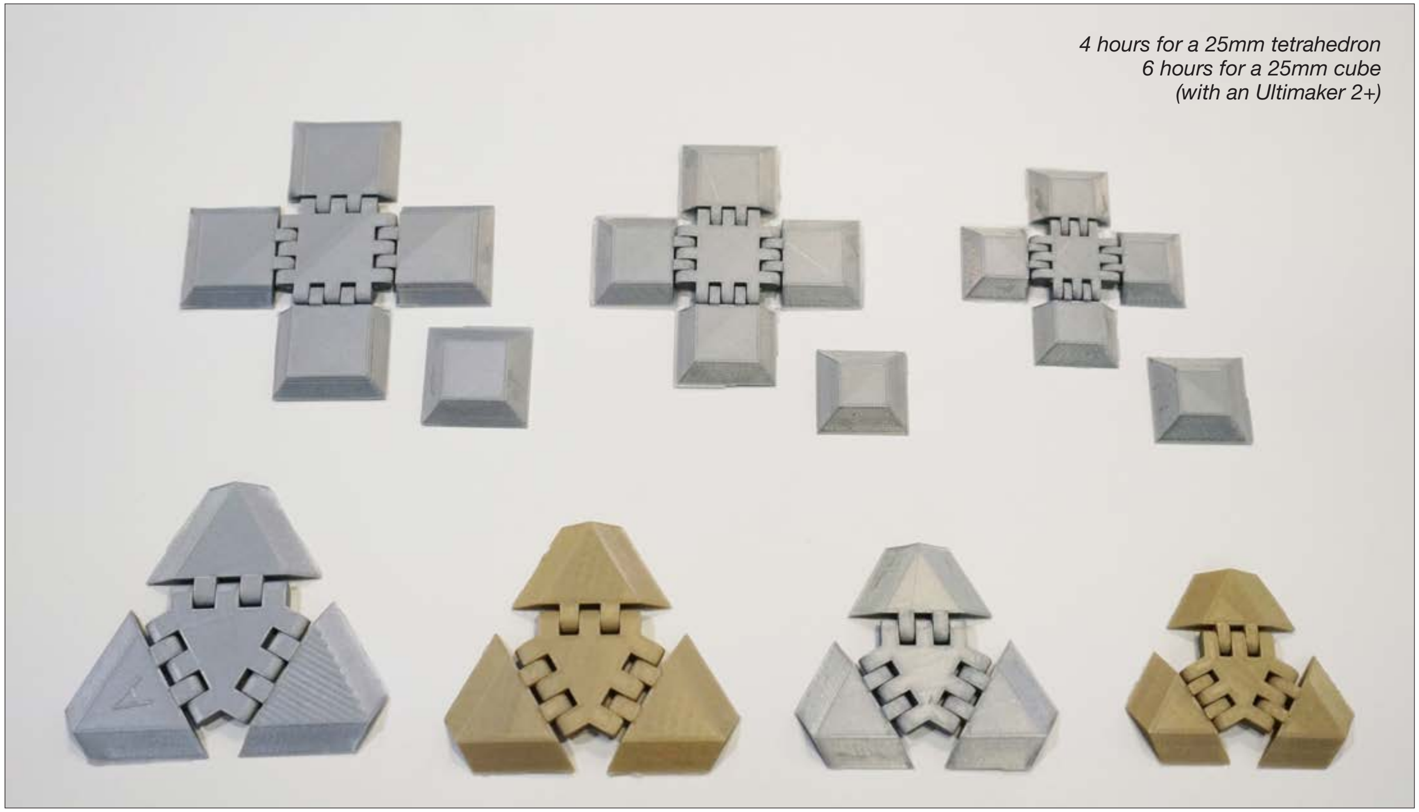
Ori-mandu Jig

The jig was designed in conjunction with the stamp, and shares the same custom parameters. The role of the jig is not only to hold the dough while inserting the filling or to guide the users on folding the dough, but also to seal the edges at the same time. Therefore, the hinges were designed to enable the former, and the sealing edge angles were carefully designed for the latter.

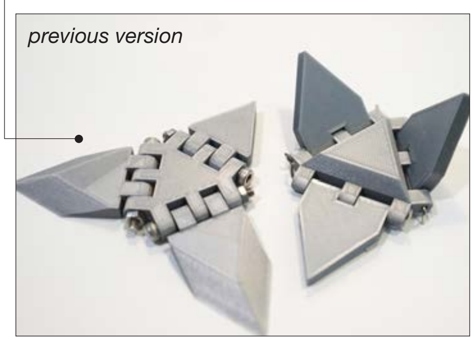
Although the previous version of the jig required metal bolts for the hinges, the final structure was designed to be fabricated at once on a 3D printer. Again, we constructed the cube out of one piece, but then changed it into two pieces to match the stamp.

The angle of the sealing edges was carefully calculated to fit perfectly when assembled together. This way, the jig seals the edge of the mandu when being closed while also keeping its shape.

It took 4 hours to print a jig for a 25mm edge tetrahedron, and 6 hours to print one for a 25mm edge cube with Ultimaker 2+.



4 hours for a 25mm tetrahedron
6 hours for a 25mm cube
(with an Ultimaker 2+)



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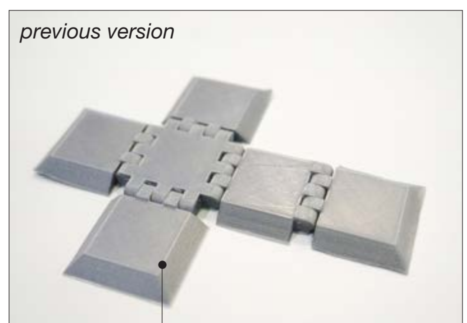

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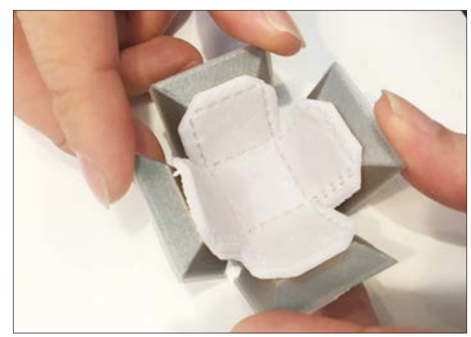
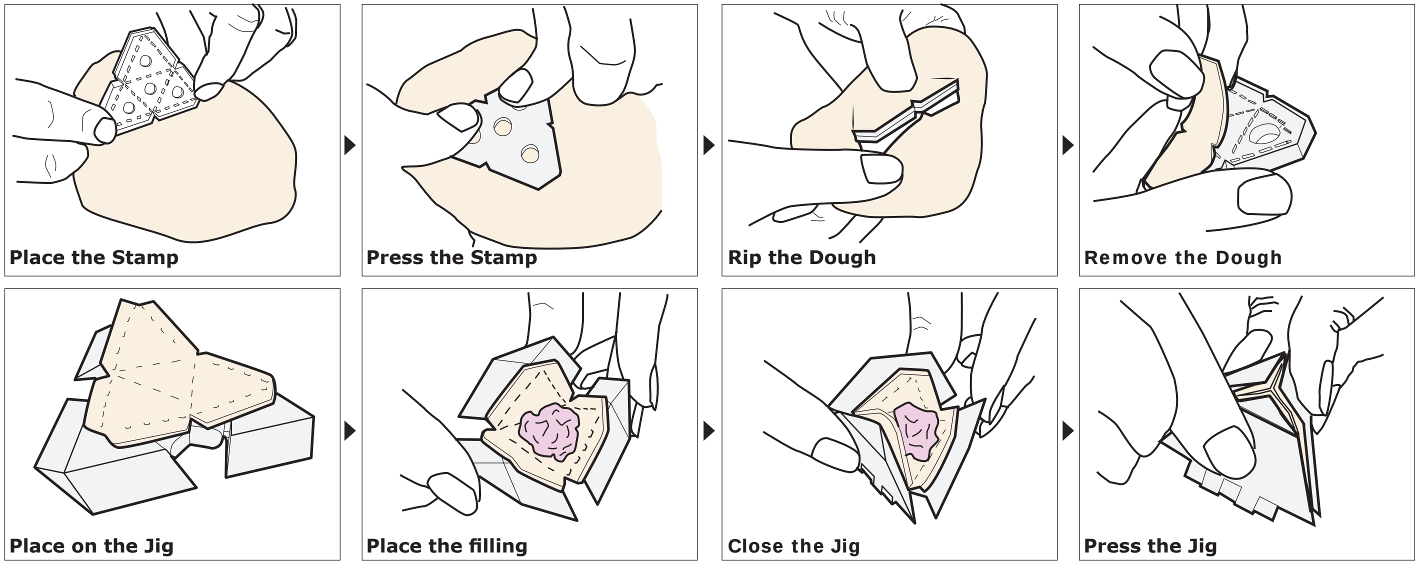


Using Ori-mandu

We shared the guide and models with step by step instructions. This enabled people to use Ori-mandu easily, quickly, and repeatedly.

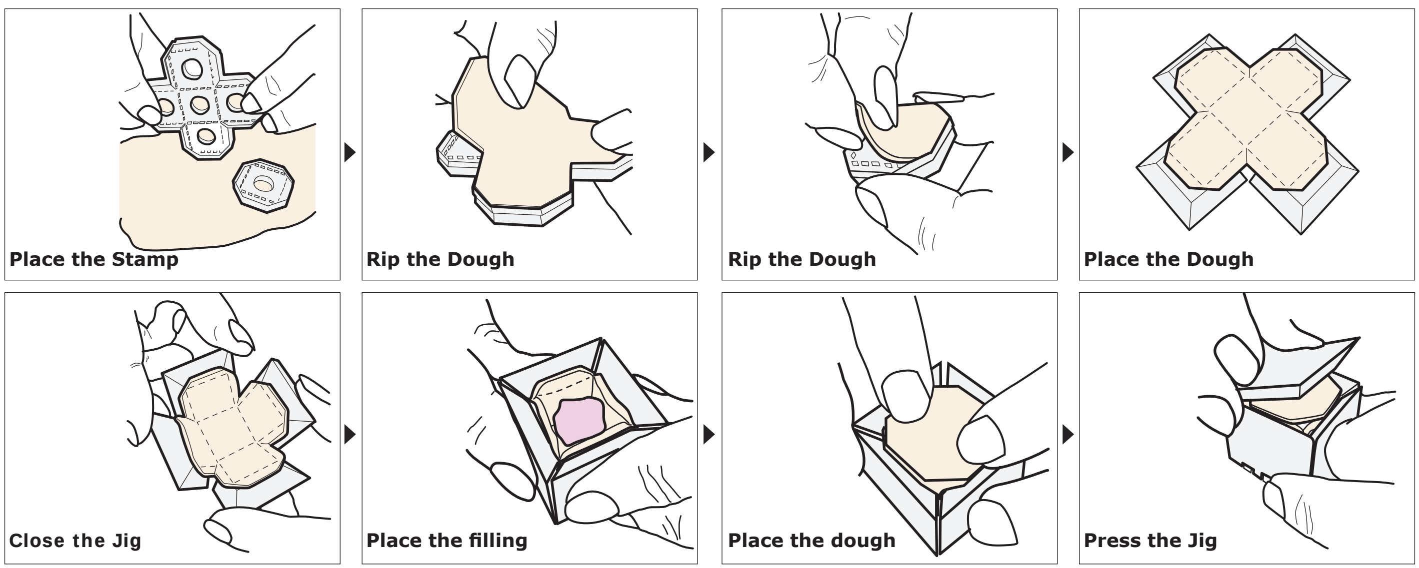
Tetrahedron Mandu

The user cuts the dough with the stamp, and places it on the jig. After placing the filling, the user closes and presses the jig firmly. It takes about 30 seconds to make one tetrahedron mandu with our Ori-mandu tool.



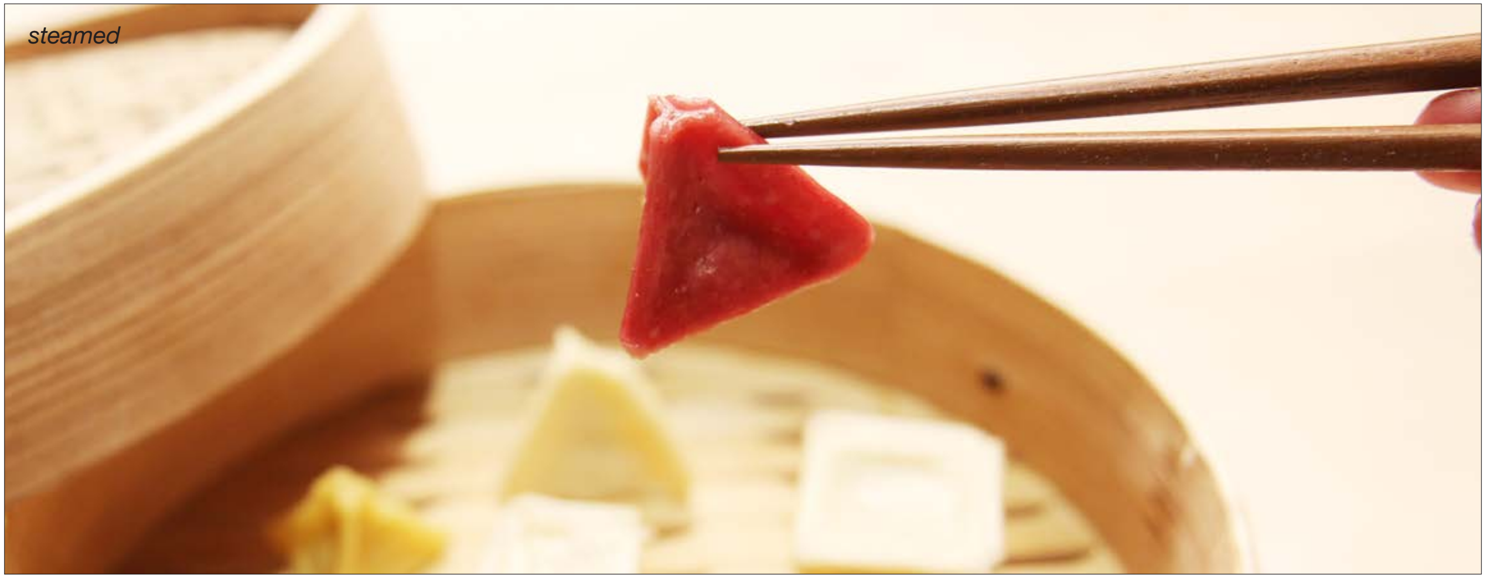
Cube Mandu

Unlike the tetrahedron mandu, the user needs to cut two pieces of dough. The user first places the cross-shaped dough on the corresponding jig, and closes it. Then, he /she puts the filling inside, places the other piece of dough and jig on top, and presses it. It takes less than a minute to make one cube mandu with our Ori-mandu tool.



Cooking

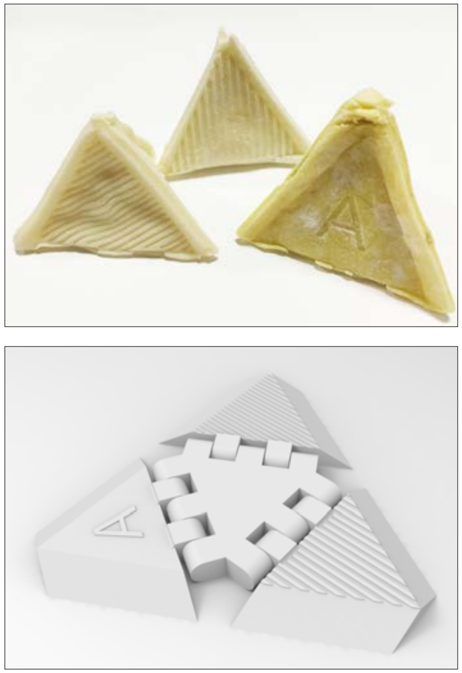
The dumplings can be steamed or fried. We tried both methods to test our approach, and the results show that our Ori-mandu kept the dumpling in shape. The edge sealed by the pressure from the jig was strong enough to keep the shape even when moving around in the oil. Our tool enables people to make mandu quickly, easily, beautifully, and also joyfully.


steamed


fried

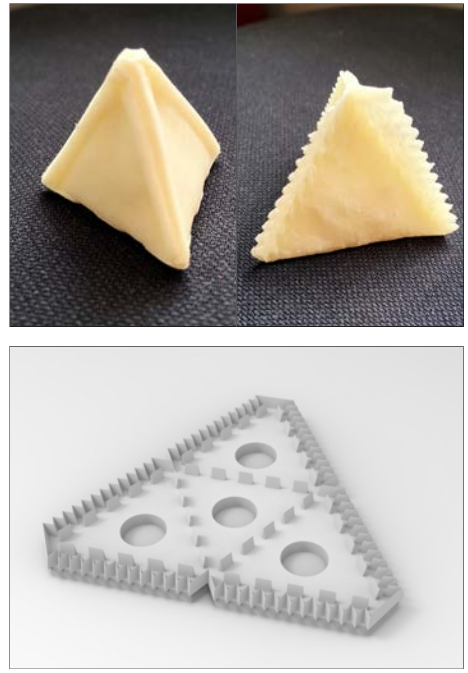
Decorating Mandu

Traditionally, mandu is sealed with a fork or toothpick, and this provides patterns on the sealed edges. We experimented with our Ori-mandu system with textures, both as patterns on the edges as well as on the faces. Also, we explored adding colors to the mandu dough.



Textures on the Mandu Face

As our Ori-mandu system forms and closes the mandu by providing pressure with the jig, we thought of adding patterns on the jig to create textures on the mandu surface quickly and easily. We tried out several patterns on the jig: straight lines, diagonal lines, round patterns, triangular patterns, and texts. Patterns were tested with different thicknesses. The optimal extrusion was more than 0.3 × dough thickness to make the textures clear, and less than 0.7 × dough thickness to prevent ripping. Most of the textures were retained after being fried or steamed.



Decorating the Mandu Edge

Additionally, decorating the edges of the mandu was possible by modifying the stamp design. Here, we modified the outline of the stamp from linear to decorative (wavy or angled). The small details on the jig or stamp itself decorates the mandu, so the user does not need to spend extra time or effort on decorations.

Adding Colors in the Dough

By adding natural powders (pumpkin, mugwort, beetroot, and purple potato) into the flour, we were able to make colored dough. Also, we created gradients by mixing different colored doughs and pressing them together with a pasta maker. For our current iteration, we mixed random colored doughs, but there is an opportunity to create DIY color guides for custom dumplings. Additionally, the color powders we used seem to affect the flavor. However, we didn't take taste into account while mixing different colors. As our future work, we need to consider both aspects together while making.

Curve-Shaped Mandu

The stamp and jig system we proposed works for polyhedrons: a tetrahedron and a cube. But since the flour dough is soft and flexible, we explored making mandu with curved surfaces.

For organic shapes, we combined the stamp and jig into a two-piece, reusable mold. The user places and presses the flour dough onto the inside of the mold carefully. Then, he or she inserts the stuffing in and presses the two halves together to secure the seams. The user then simply cuts out the excess dough that is sticking out from the mold. Finally, the mandu is carefully removed from the mold.

By using the molds, the mandu can be formed into almost any shape, but still there are some limitations. In our experience, the thickness of the dough should be more than 0.4mm, otherwise it will tear. Also, the depth of the organic mold should be less than 25mm, or else it is hard to eject the mandu out of the mold.

Discussion

Cooking is usually a complicated and nonlinear process, and hard to complete with a food printing machine. In this pictorial, we have presented a hybrid and novel way of cooking by fabricating customized tools that assist in the entire cooking process. Here, we share our reflections on our process, and suggestions for future works.

1. 'Being the Machine' offers new insights on fabrication.
Inspired by the method of '*Being the Machine*,' [3] we acted as a robot arm, similar to *experience prototyping* [1]. For developing fabrication devices, this method plays a very strong role as it enabled us to quickly try out diverse approaches and to explore the design space before building a machine. This was especially helpful for mandu-fabrication, as the material was uncommon (high viscosity & soft) and the process of cooking was not simple (extrusion is impossible).

2. Tools as guides for the entire cooking process.
Mandu making is quite a complicated process, starting from dough cutting, stuffing filling, folding, and sealing. As a result, most people buy pre-made mandu. However, we found that our Ori-mandu tools can act as a guide during the entire cooking process and let them make mandu without any experience. The stamp indicates which part of the dough is for folding and sealing by controlling the type of cut it makes. Also, people can fold and seal the mandu by using the jig for assembly. We prepared a guidebook on how to use Ori-mandu for cooking with step-by-step illustrations, and it enabled expert amateurs [6] to use fabricated tools easily during the hybrid cooking process.

3. Tools as a means to customize shapes.
Ori-mandu tools do not only guide the users but also enable them to customize the shape into whatever they want. They do not need to struggle with shaping the thin dough and simply fabricate the tools, then the tools will create the mandu into their ideal shape instead of the users. It seems that tool-based hybrid cooking provides the potential for the integration of digital procedures into the food planning stage. However, there seems to be a need for feedback on the manufacturability with the dough while designing the digital model. From our iterative process, we found that some stamps and jigs were unfeasible. For instance, the intended patterns were too dense to leave an imprint on the dough clearly. In the future, we can prevent these issues by guiding the users in advance.

4. User-centric interface for customizing tools.
Currently, we made parametric digital models with Autodesk Fusion 360 and the user could customize their own mandu tools by personalizing the parameters. However, a dedicated application is required to let users customize all aspects, from shape to decoration, for instance, generating jigs and stamps for arbitrary 3D models or using drawings as input for textures and edges.

5. Food safety issues
Like many other digital cooking developments, Ori-mandu also has food safety issues. The possibility of food being contaminating might be lower than food injection devices [1,6,8], as the food itself does not pass through the machine. However, the tools that are fabricated from the 3D printers are not hygienic. We can overcome this issue by wrapping our tools in plastic wrap.

As our future work, we can conduct in-wild user studies with Ori-mandu instructions and sample CAD models that are available on Instructables [5]. From these studies, we wish to have active discussions and get feedback on the process of making and the future of digital gastronomy.

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