Assembly furniture

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ASSEMBLY FURNITURE

by

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PUBLIC ABSTRACT

This project aims to design a set of flat packing furniture that can be easily assembled without any tools. The flat packaging concept targets the growing e-commerce market where all products get delivered from supplier to consumer. This body of work explains the design process that used both digital and physical models to understand the visual and physical balance and figure out the joinery mechanisms.
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INTRODUCTION

Early 20th-century architect, Frank Lloyd Wright once said, “form and function are one”– an adaptation of his mentor, Louis Sullivan’s famous axiom “form follows function.” Both phrases highlight how ‘function’ was an essential element in the Modern Design movement. Modern designers put more emphasis on the functionality of a piece, simple geometric shapes became more favored over elaborate and decorative elements of Arts and Crafts movement. Simple geometries such as square were used extensively and can be found in many modern furniture pieces. Especially from the Bauhaus School architects, who were one of the major groups that influenced the modern movement in the 19th century.

Walter Gropius, the first director of the Bauhaus School, designed the F51 armchair (Figure 1) in 1920 for his office at the Bauhaus School. He considered the relationship between the chair and the office, then designed the cubical chair that followed the rectilinear structure of the room. In 1925, Marcel Breuer designed two simple metal framed coffee table Laccio (Figure 2). The lower rectangular table fits under the taller squared table as a set. That saved space when they are put together or provide more table surface when they spread out. Josef Albers designed the four Nesting Tables for his private apartment in 1927 (Figure 3). All four pieces nest inside each other to save space when they are not in use.
Figure 1. F51 Armchair, Walter Gropius, 1920, Solid Wood Frame with Upholstered Cushion, 27.5” x 27.5” x 27.5”

Figure 2. Laccio Coffee Table, Marcel Breuer, MDF Laminated with Plastic Top with Steel Frame, 53.5” x 19” x 13.5”
As shown in the given examples, the Bauhaus architects considered functionalism in design. The two coffee tables are transformable based on its use which is a growing trend in the 21st century. More and more people are willing to move to bigger cities, and therefore, the limited city areas are divided into smaller areas. The smaller the space is the less decorative and more functional piece a user will seek for.

The United Nations Economic and Social Affairs published the 2018 Revision of World Urbanization Prospects on May 16th of that year, noting that 55% of the world’s population live in urban areas. That number is expected to increase to 68% by 2050. Due to the high population density found in urban areas, larger cities tend to have smaller apartments. For example, Yardi Matrix ranks the top 20 cities in the United States with the smallest apartments including Seattle (WA), Manhattan (NY), Chicago (IL) and Washington DC that top ranks (Figure 4). With
the average size of urban apartments getting smaller by the year, the issue of utilizing furniture in limited space has become a critical challenge.

1 Figure 4. Top 20 cities with smallest apartments in the U.S.

Another challenge for the 21st-century designer is to create a flat-packaged product for the growing e-commerce market. The online shopping market is only getting bigger, and as one of the most successful online shopping malls in the world, Amazon has seen their stock make huge gains over the past five years (Figure 5).

![Market Summary > Amazon.com, Inc.](Figure 5. Amazon stock history for the past 5 years)

The ability to pack flat is an advantage for online suppliers because smaller volumes are cheaper and easier to ship. IKEA is a notable company with flat packed DIY furniture, but I would like to address the issue of complicated instructions by creating a more straightforward assembly process. The solution is to eliminate the need for hardware or tools and simplifying the building steps. The design process starts with establishing the order of putting together the
pieces. The process is achieved by visualizing the joints through computer software, then using CNC (Computer Numeric Control) technology to test and build physical models. Joints cut in 90-degree right angles, with modules moving up and down, right and left, forward and backward to get together.
FURNITURE - JOINERY

My MA and MFA research targets the growing population in urban areas and the growing e-commerce market. The primary goal of the project is to design modern rectangular furniture that packs flat with simple tool-free assembly steps.

For my Master of Arts research, I designed ‘Gather-In,’ a set of folding furniture that was named after the way units nested into each other. Gather-In is composed of a coatrack, an accent table, and a stacking stool. They fold and unfold to be assembled and disassembled. As shown in Figure 6, each piece of furniture has a defined axis allowing pieces to rotate and nest. All rotating components are connected with fabric that acts as a hinge. Connecting components also reduced the number of units that needs to get assembled.

Figure 6. Gather-In, Joan Kim, 2017, Birch Plywood with Duck Canvas, Table: 18” x 15.6” x 25”, Stool: 16” x 11.5” x 15”, Coatack: 21.5” x 13.5” x 65”
The coatrack turned out to be the most successful piece because it fulfilled most of my goal in design. If a user wants to assemble the coatrack, they take out the main unit that is connected with fabric hinges, unfold the two nesting components, and lock down two beams from the back. It is functional, simple, comes with straightforward assembly instructions that require no hardware or tools, and packs flat which makes it easier to deliver.

That said, applying the folding mechanism was not the best solution for an accent table and stacking stools. The table required a horizontal surface, which was not strong enough to hold the legs altogether. Furthermore, the legs had two folding axes that made the structure unstable. The stool had two tall beams under the seat to lock all the components together. However, the folding components were not able to nest into each other which made the fabric hinges unnecessary. Gather-In concluded that it was an interesting concept to fold and unfold the nesting components to assemble a piece of furniture, but the mechanism had limited efficiency. The fabric was not strong enough to hold all the components together. To reinforce the set of furniture from the MA research, I eliminate the use of fabric and hardware to only used wood, which became ‘The Joinery.’

‘The Joinery’ focused on simplifying the assembly process by reducing the number of components and steps. Also, it is a tool-free furniture with all components locking into each other by just pushing in and out or up and down.
The Joinery chair assembles with five components (Figure 7) in six steps (Figure 8). I was able to minimize the number of components and assembly steps by evaluating the necessary components of a regular chair. A standard wooden chair is built with ten components; four legs, four beams, a seat, and a back. The first modification was to combine the leg and beam components on each side. On the left side, the front and back legs and the beam connecting the two legs were combined into a single piece. The same principle was applied to the right side. Therefore, six components were reduced to two leg components. The seat and back remained as single components. Overall, I was able to condense ten components into five components.

Figure 7. Five components of the chair, Joan Kim, 2019, Adobe Illustrator software

To simplify the assembly process, joinery mechanisms were embedded inside each component. The most essential and complicated piece was the seat. It was the central components that holds the components together. There is an area underneath the seat for the legs to lock in (step 2-3 in Figure 8), and there are two tabs on the back of the seat to hold the chair back in place (step 4-5 in Figure 8).
Building a functional joinery mechanism required many tests with scaled-down models and prototypes. The mechanism would start from a hand sketch followed by a CAD modeling software. A two-dimensional profile is drafted in the AutoCAD program (Figure 9). The drawings were then exported as DXF files, which is a type of file that could be read in different types of software. The DXF files were imported into the Rhino program so that the two-dimensional profiles could be extruded into three-dimensional solids (Figure 10). The solids are orientated and assembled into position to check if all pieces and joineries are working without any flaws (Figure 11).

Next comes the CNC technology to test the furniture with physical models. The physical models are required to check if it has any gravity issues or has enough weight capacity to function its purpose. The first quarter-size model is built by the CNC laser cutting machine with white foam board (Figure 12). I prefer using the white foam board for the first physical model because it is easy to make immediate adjustments and the white color allows me to focus on the form of the design without any interruption. After the form and joineries are figured, I used
the CNC router to cut a half and full-size prototype with ACX plywood (Figure 13). ACX plywood is a type of plywood with lower quality wood sandwiched inside a better-quality wood. It does not look nice as the final material, but it is good enough to test the functionality of the joints.

Figure 9. Two-dimensional profile, Joan Kim, 2018, AutoCAD software screenshot

Figure 10. Extruded profile, Joan Kim, 2019, Rhino software screenshot
Figure 11. Assembled Model, Joan Kim, 2019, Rhino software screenshot

Figure 12. Quarter size model of the Joinery Chair, Joan Kim, 2018, Foam Board, 4.25” x 4.5” x 5.75”
The CNC router was primarily used for its ability to make ‘pocket cuts’ that do not entirely cut through the wood thickness. Pocket cutting is a massive advantage for any design that wished to hide joineries and reduce the number of wood layers. For example, the locking mechanism underneath the chair seat required three layers of material to create space for the male section to lock in. However, by pocking cutting with the router, I was able to compress them into two layers (Figure 14). The last mockup is the full-size prototype also cut on the router with low-quality plywood to make sure it has the right dimensions and proportion in relation to the human body.
Modifying the mechanism changes the visual of the chair because the assembly units themselves are the joineries and the components that form the chair. Each unit has a varying number of layers based on their necessity and functionality, which also affects the visual form. The Joinery chair legs are the only units with three layers of wood since it had to be strong enough to hold human weight. It also grounds the whole piece of furniture and makes it look functional. The horizontal frame under the seat has a cut out in the middle to reduce the weight of the chair, and the chair back has a rectangle cut out on the top to function as a handle. The whole piece of furniture is not only functionally balanced but also visually balanced to the user.
THE JOINERY SIDE TABLE WITH A DRAWER

The Joinery side table has five components that come together in assembly much like the chair. It has two leg components with a surface locking them together (Figure 15 step 1), and a tabletop surface (Figure 15 step 3) with a back that locks down, complete with a drawer (Figure 18 step 5). Unlike the chair, the joineries are hidden because I did not want the side table to clash with the chair visually. Instead, the tabletop was made to match the height of the chair, and accent colors were added on both pieces to add harmony to the furniture set design (Figure 16).

Figure 15. Side Table Assembly Process, Joan Kim, 2019, Rhino software 3D render
Figure 16. Grey Area Indicating Painted Surfaces, Joan Kim, 2019, Rhino software 3D render

The drawer component does involve the use of hardware for the rail, but they are already on the piece, and the user does not need to deal with any tools. Eliminating the hardware by building a wooden rail was considered, but compared with a metal rail, the opening and closing motion would not have been smooth enough.
THE JOINERY STACKABLE STEP STOOLS

In keeping with the “form follows function” mantra, the step stools were designed to stack on top of each other to save storage space. Stools can be nested on top of each other by turning them 180 degrees (Figure 17). The method allows many stools to stack stable.

Figure 17. Stool Stacking Instructions, Joan Kim, 2019, Rhino software 3D render

The stools assemble in five steps with five total pieces (Figure 18). Each beam is glued to the back legs with a wooden dowel in between, and the front legs combine into a single piece with a small cut out for a handle. The stool and chair both hold a human weight, but the stool looks more solid and bulky because they have different functionality and weight-points. When you on a chair, there is a distributed weight point on the whole seat. However, when you step on a stool, the weight points are gradually applied, step by step. The stool should remain stable when only one foot is on top, and this first step will be off centered because it needs room for the other foot to go on top. Therefore, it requires extra stability than other furniture.
Unlike with the other furniture, I was able to skip a half-sized model since the joineries were less complicated and the pieces were smaller.

Figure 18. Stool Assembly Process, Joan Kim, 2019, Rhino software 3D render
CREATING VISUAL CONNECTIONS

One of the biggest challenges of designing a set of furniture was building the visual connections between each piece without making them look all the same. Gather-In had the blue fabric hinges all over the furniture, which clashed with the different material and color of the wood. The second set of furniture found a better sense of harmony through a painted surface and some standard dimensions between the set pieces. For example, the height of the chair seat is 15 inches, which is the same height as the side table top (Figure 19). The chair is 17 inches deep, which equals the depth of the side table (Figure 20). The side table is 14 inches wide, which is the same width as the stool (Figure 21).

Figure 19. Front View of Side Table and Chair, Joan Kim, 2019, Rhino software render

Figure 20. Top View of Side Table and Chair, Joan Kim, 2019, Rhino software render
Figure 21. Front View of Stool and Side Table, Joan Kim, 2019, Rhino software render
CONCLUSION

Through the MA and MFA research, I developed my interest in designing different styles of joinery mechanism that matured into the ‘Gather-In’ and the ‘Joinery.’ The flat packing furniture targets the growing e-commerce market customers with its functional design. Understanding the purpose of each furniture was the critical point in figuring out how to break down a piece of furniture into assembly pieces and building the assembly mechanisms. Since the assembly mechanisms are figured, I would like to invest in designing bigger furniture in the future such as a console table, a space divider or a bed. Moreover, I see the possibility of colors being involved in giving an identity to a piece of furniture or use them for instructions in the assembly steps.