RO-PUZZLE

A robotic proposal for moving architecture

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Abstract. This paper presents a project-based research study called Ro-puzzle—a robotic architectural “puzzle,” using robotic solutions to illustrate the possibility of an animated/dynamic architectural composition and configurations in the physical world. Through studying super-comportment (Wiscombe, 2014) in both dynamic and static scenarios, this research proposes a new reading to the traditional robotic task of “pick-and-place”, through an intuitive motion design process using a custom-made bridge software, Oriole. By revisiting the notion of robotics in the field of design/architecture, Ro-Puzzle investigates the design possibilities of robotics, not merely as fabrication tools, but possibly as physical extensions of the design software into the physical world of architecture, and as a way to expand the digital design imaginations/possibilities beyond the digital screens. In this manuscript and initially tested at the desktop scale, Ro-Puzzle research investigation demonstrated the possibilities of robots as architectural “components” within the architecture/building. This research shows that through the development of custom software/hardware platforms, it is possible to domesticate robotic technology as an active agent in the design process through physical simulation.

Keywords. Robotics; Design; Animation; Robotic Architecture; Dynamic Architecture.

1. Introduction

1.1. ANIMATED ARCHITECTURE

For almost the past three decades, the introduction of digital design tools as a new medium for architectural/design thinking, has reshaped the design process in merely through digitalizing the analog design processes, but via augmenting the design process through computation or computerization (Leach, 2018). As part of this introduction and using animation software platforms as mediums for architecture, many designers started to speculate-again, about the potential of movement in architecture through the lens of animation and digital motion.

One of the immediate responses to the reintroduction of motion into architecture was capturing movement as “frozen frames” of motion (Gehry, 2004).
These responses are clearly visible in the growing interest for “deformation” in the formal/architectural language of designers in the early 2000s (Pongratz, Perbellini, 1999). Peter Eisenman’s The Max Reinhardt Haus (Eisenman, 1992), Greg Lynn’s idea of phenomenal motion (Lynn, 1999) and many projects including the Korean Presbyterian Church of Brooklyn (Lynn, Garofalo and McInturf, 1999) and embryological houses (Lynn, 2002), and Marcos Novak projects, Liquid Architecture (Novak, 1993), or Variable Data Forms, (Novak, 1999), are very few examples of using “digital” motion in architecture as a driver for form/space/experience making. Similarly, places and platforms such as TED, the MIT Media Lab, the Netherlands Media Art Institute, and Banff Center became a place for architects, media artists, and technologists who were searching for new environments and experiences related to the transformation of the building (Lynn, 2016).

Now as part of the contemporary design culture, animation became an accepted important experimental architectural design, simulation, and representation tool through which, animation concepts-such as deformation, blend-shapes, constraining, keyframing, graph-editing and gradual transformations, and physic simulations-to name a few, grown into architectural, formal and spatial strategies and language. As a result of this growth and in today’s conversation about design and architecture, animation and its frame of mind play a serious role when it comes to design thinking.

Following a similar interest, Ro-Puzzle design-research project focuses on “literal” motion-as Lynn describes. However, different from Lynn’s notion of projection of motion/animation through a sequence of parts transformation/deformation or carving space based on the motion-phenomenal motion, Ro-Puzzle looks into the effect of the literal motion through the lenses of flat architectural ontology and as a way to create dynamic parts and objects that are frequently and spatially changing.

1.2. ARCHITECTURAL ROBOTICS

Originally coming from industrial set-ups and other disciplines-e.g., engineering, domestication of robots/robotics as part of the design/architectural set-ups has been an ongoing question. Many researchers and projects looked at the novel ways of using a robotic arm and robotics as advance tools for fabricating parts beyond human fabrication capabilities. Although projects such as ICD/ITKE Research Pavilion 2014-15 (Doerstelmann et al. 2015), Wood Chip Barn (Devadass et al., 2016), and Mobile Robotic Brickwork (Dörfler et al. 2016) among many other projects, are advancing the robotic fabrication in creative ways, they all-more or less, use robots in a familiar industrial approach. In another word, while in these projects, robotic fabrication is used in novel ways, robots are not beyond makers and optimizers of the fabrication process.

As a result of such approaches, it is arguable that even though the process of making is digitally controlled, the outcome of the process-the architecture, is still-more or less, operating as an analog composition (Leach, 2018).

Seeking an answer for using robots as more active agents in architectural
design and experience, there are multiple research projects investigating the representational capabilities of robots as a medium for experience. Box by Bot and Dolly (Bot and Dolly, 2013), The “Impossible Objects” design series by Kruysman-Proto (Kruysman-Proto, 2011), Mixed Robotic Interface (Poustinchi, 2018), and the “Aether Project” by Guvenc Ozel studio at University of California Los Angeles (Ozel, 2013) are some examples of these attempts to use robotic technology beyond its capability as a fabrication tool. However, it is arguable that these projects are mostly representational, and the robot has hybridized/animated the experience, not the architecture itself.

2. Methods
Ro-Puzzle aims to examine the possibilities of robotics and robotic motion in architecture, beyond their capabilities as a representation medium or fabrication tools. Tested and proposed at the desktop scale—with scalability considerations, Ro-Puzzle, looks closely at the possibility of architectural motion design, through the lens of robotics. In another world, different from representation and fabrication approach, this research investigation proposes robotic motion as part of the architecture itself and not as a method to represent it or to make parts of it.

Ro-Puzzle has been developed around three central themes: 1- How can literal motion become a design input to inform the design process from early stages of the design and though the formal, spatial, and organizational developments? 2- How can robotic technologies in architecture, move beyond the fabrication and representational capabilities, and augment the design process and the architectural outcome of it? 3- How can robotically animated architecture, move outside of the digital screens, and become a tangible reality?

3. Ro-Puzzle
Developed as part of the Hetero[Animo]genous design-research studio at the Robotically Augmented Design (RAD) Lab at Kent State University, Ro-Puzzle studies the potential of robotically animated architectural components and their effect on the design. Employing inside-outside relationships, miss/loose fit design language and the notions of part to part and part to whole relationships—as architectural and compositional design vehicles, this project examines the possibilities of physically animated architectural composition and its effect on the design process, form development, massing, and interior strategies. Conceptually, borrowing the ideas from Wiscombe’s reading of a flat architectural ontology, Ro-Puzzle revisits the potentials of “super-component” and “interior object,” as space-makers and through the lens of time-based custom-robotic motion design.

To be able to examine motion in relation to architecture, it was crucial to develop a theoretical and organizational formwork for the design language of the project. As an original form-making idea, two main ideas have been considered: 1- bounding the architectural parts and components and their motion as a three-dimensional whole-continuous approach, or 2- Breaking the mixture into parts that are distinguishable.

Through the lens contemporary readings of “Discrete,” and in favor
of scalability possibilities (Retsin, 2019), Ro-Puzzle looks at architectural composition as a mixture of separate parts and components. Keeping the project independent from scale-by considering scalability throughout the process, is specifically critical for this project since it is a robotic-design investigation at the desktop scale (Figure 1).

However, different from digital “discrete” discourse and to produce spatial independency, the project borrows the idea of super-component from the Object-Oriented Ontology (Wiscombe, 2014). Super-component in summary is a component-part, that is small enough to be part of something else and big enough to operate as an independent object-whole. As a result, Ro-Puzzle is based on a hybrid concept of parts as “discrete super-components” (Figure 2).

By investigating multiple iterations in both animated and static scenarios, we
reimagined the idea of super-component as an object like component that coexists as part of the “building object”, to complete it, and as an extension to the “building object” to expand it. Precisely curating these different puzzle-like alignments, the orientational reconfigurations result in the new composition of parts and new spatial scenarios, where interior surfaces become exterior, the ceiling becomes the floor, and a component/part becomes object/whole itself. In another word, through motion, part to part and part to whole relationships are constantly changing from one to another; parts (components) become new wholes and whole divides into fragments and parts to address spatial and compositional interests. During these transitions, interiors-as an object or active void, continually changes its shape as well as its relationship to the exterior. Interior surfaces become the new façade for the moved- the re-oriented chunk of the interior object, and the absence of the animated part becomes a new interior surface to “complete” the “new” interior object (Figure 3 and 4).

Figure 3. A physical test of the dialogue between inside and outside through an animated super-components.

Figure 4. Through video post-production, the idea of “animated void” has been tested as a form-making solution.
To develop the project as a conceptual proposal for moving architecture-using robotic arms as possible scalable motion solutions, the design team studied the robotic motion and its relationship to the motion of parts from the early stages of design. Employing Oriole-as a custom-made robotic motion design plug-in for Grasshopper 3D (Poustinchi, 2019), we studied the robotic motion design as part of the design process. Put differently, it was aimed-from early stages of design, to design the “motion” and the architectural composition in a cohesive back and forth process, where the designer is not only designing the form, special organizations, and compositions but the robotic motion and physical animation scenarios (Figure 4). Oriole as a workflow platform enables designers to design the robotic motion of the “building” proposal, within the same digital environment of the schematic design, and as a “native” component of the process instead of a luxury add-on.

![Figure 5. Overall preview of Oriole environment and its components and settings as part of Rhino and Grasshopper 3D environment.](image)

Our research also verified that different from many digital animation investigations, physical tests with robots, are able to scale up to the scale of architecture since the kinematic and the mechanical logics of the robotic arms-KUKA industrial robot arms specifically, are similar in a variety of scales and payloads. We used a KR6 R900 Sixx robot arm to examine Ro-Puzzle design ideas at the desktop scale. A KUKA robot arm has been precisely chosen given KUKA’s diversity in robot arm payloads, with an exact same kinematic mechanism-discussed further below. Designing a custom magnetic end-effector for the robot arm, as well as the moving part of the architectural puzzle, the robot arm was able to move the part in different orientations and re-configure them in different organizations. It is important to mention, different from the traditional robotic pick-and-place task, in this iteration of Ro-Puzzle, the robot and the moving super-component remain connected, and the robot moves the component around, without “picking” or “placing” (Figure 6).
Figure 6. As an ongoing robotic pick-and-place task, the super-component—moving part, remain connected to the robot as an end-effector.

Through designing the motion and parts at the same time, designers were able to curate different special and organizational scenarios where the inside/outside relationships of the architectural composition—at the model scale, blur into a hybrid time-based mixture. Specifically designing the motion of the robot in relation to parts and their operations, the design team was able to employ the robotic motion to test the movability of parts in a puzzle-like desktop architecture model (Figure 7).
Figure 7. Using the physical animation of the parts and super-components, Ro-Puzzle also operates as a hybrid design medium to study design in relation to motion.

Although the Ro-Puzzle project has been defined as a compositional study-without any specific program, to be able to examine the inside/outside transitions of parts, the interior surfaces of components have been designed differently from their outside (Figure 8). This difference has been used as a vehicle to inform the motion design.

Figure 8. Feedback from physical videography and 3D printing resolution informed the digital design as feedback. The surface detailing is a result of this back and forth.
4. Discussion

As discussed above, Ro-Puzzle-at its current stage, is an investigation on moving architecture at the desktop scale, which is far different from the building scale. However-as mentioned above, it has been one of the core interests of the project-both from theoretical and performative views to consider architectural scale in its proposed workflow. Using a hybrid combination of notions of digital discrete, and super-component, theoretically enables Ro-Puzzle-as an experimentation and a conceptual workflow, to remain independent from the scale. Conceptually, the idea of architecture as a puzzle-like mixture of parts (components and super-components) is relative and valid at multiple scales, from product scale to the urban scale.

On the other hand, it is arguable that the second main component of the Ro-Puzzle project, the robot arm is also scalable. Using a KUKA KR6-R900 Sixx robot as part of this project and given the specific inverse-kinematics of KUKA robot-arms, the motion of these robots are scaleable by scaling up the robot arm and its payload. In another word, although this experimentation is done at the desktop scale, its solutions-including the motion-provider, are not limited to this scale; In fact, there are already robotic arms-KUKA KR 1000 Titan for instance, that are capable of moving 1000KG with six-axis of freedom. Other industries such as entertainment are using these robots to move chunks and part of the stage, cars, and clusters of amusement parks.

It is crucial, however, to mention that the design of the motion is not scalable. Ro-Puzzle is not proposing a motion-type, instead, it is proposing a workflow that involves designing the composition of the architectural parts, as well as their motion-through robotic motion design, at the same time and as a seamless workflow. Testing the motion in a physical workflow, considering connections, materiality, gravity, the imperfection of fabrication among other physical characteristics—even at the desktop scale, enables designers to think beyond the existing workflow of architectural robotics. Animated facades, moving rooms, and shells and tumbling buildings have already made their ways into the contemporary world of architecture. It seems essential to study these possibilities in both conceptual and practical manners. Ro-Puzzle proposes a workflow, to physically test a possible way to animate architectural components through using a scalable mover: robot arm.

5. Limitations and Future Plans

Although proposed as a design process/proposal instead of a final outcome, Ro-Puzzle-at its current stage, faces some limitations. One of the major limitations of the current research is the difference between the robotic motion, designed at the desktop scale and the one which ultimately will be used at the building scale. While-and as discussed above, the direct translation of the motion between scales is not one of the goals of the current project, it can be a valuable component to Ro-Puzzle research to investigate its possibility. To address this issue, currently at the Robotically Augmented Design (RAD) Lab at the College of Architecture and Environmental Design, at Kent State University, we are working on scaled
chunk models of a building. Another limitation of the current research is the interface for these robotic motions. Although Oriole is an intuitive and visual platform for designing the motion of the robot—suitable for designers, it is still housed within Grasshopper 3D as a node-based programming platform. We are currently working on developing a fully intuitive platform for designers with no programming or Grasshopper skills to design the motion more fluidly as part of a routine design process of a building.

References


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