Building on previous and current work, this research utilizes the Single Point Incremental Forming (SPIF) process to produce mass customized, double-curved (both positive and negative Gaussian curvature), three-dimensional forms from sheet metal. These forms are produced at a scale that suggests their use as cladding elements in a building envelope. This, combined with the relative speed and efficiency of production and the variability of resultant geometries, allows for speculation on the production of high performance façade systems directly from digital models.
This project demonstrates a number of proof of concept studies for single point incremental forming as a viable technique to produce highly variable, double curved panels in sheet materials, without the requirement of expensive forming dies (Figure 1). The project also provides a model for the development of a materially informed production process, integrating design and fabrication into a streamlined production methodology.

Single point incremental forming is a process whereby a sheet of metal is incrementally deformed at local points to achieve an overall geometry (Figure 2). Typically, the stock is formed using a hemispherical tool that can be attached to a robotic arm or a CNC machine. The tool moves along a pre-programmed toolpath, as it gradually steps down into the stock, until forming is complete (Bambach et al. 2009) (Figure 3). Several materials were tested to find the limitations of the forming process and viability. The sampling of sheet metals included cold rolled steel, aluminum, copper and brass (Figure 4). Cold rolled steel was used in most of the forming tests because of its high ductility and strength, which allowed for forming deeper parts (Figure 5). Once trimmed from the rest of the stock, the formed geometry would often deform into a new relaxed shape. This release of internal forces is called springback. The deeper a panel is formed, the more it would become rigid and resist this deformation (Kreimeier et al. 2011). Several design strategies, most prominently the use of performative textures, were utilized to stabilize the components pre-trimming (Kalo and Newsum 2014).

Since this investigation seeks to build on previous research on incremental sheet forming, it addresses questions which are essential to its applicability at an architectural scale, notably the ability to aggregate multiple panels into a performative system. Various strategies were explored for connecting formed panels into a larger...
aggregation. One technique overlapped the valleys and peaks of doubly curved surfaces and then tack welded the surfaces together to create a self-structured thickened porous skin condition (Kalo et al. 2014) (Figure 6).

Similar to bead rolling, adding ribs serves to locally corrugate the sheet metal, where the geometry is the shallowest, to prevent it from deforming. The ribs not only function as a performative part of the process but also have a unique aesthetic quality. In addition, the ribs could drive a global panel connection strategy. These ribs were then used as identification points at the edges of panels to align the aggregation (Figure 7). Geometries were also developed that shared the same edge perimeter geometry. This allowed for varying shapes to be formed within this boundary that could be connected to one another as a continuous aggregation.

REFERENCES


AMMAR KALO is currently the Director of CAAD Labs in the Department of Architecture, Art, and Design at the American University of Sharjah. He recently received a Master of Science in Architecture with concentrations in Material Systems and Digital Technologies at the Taubman College of Architecture and Urban Planning, University of Michigan. In 2014 he received the Kuka Young Potential Award at the Rob|Arch 2014 conference. Prior to graduate school, Ammar has gained experience working on international projects of various scales and typologies.

MICHAEL JAKE NEWSUM is the Robotics Lab Coordinator at the Southern California Institute of Architecture where he works with students and faculty on research projects that investigate the role of robotics in architecture and design. His work currently focuses on developing robotic design platforms that rethink the interactions between man and machine. He holds a Master of Science in Architecture with a concentration in Digital Technologies from the Taubman College of Architecture and Urban Planning, University of Michigan. He is also the recipient of the Kuka Young Potential Award at Rob|Arch 2014.

IMAGE CREDITS
Figure 1. Kalo, Ammar and Michael Jake Newsum (2013) Forming Variations. Ann Arbor, Michigan: Realized
Figure 2. Kalo, Ammar and Michael Jake Newsum (2013) SPIF. Ann Arbor, Michigan: Realized
Figure 3. Kalo, Ammar and Michael Jake Newsum (2013) Toolpath. Ann Arbor, Michigan: Realized
Figure 5. Kalo, Ammar and Michael Jake Newsum (2013) Forming Slopes. Ann Arbor, Michigan: Realized
Figure 6. Kalo, Ammar and Michael Jake Newsum (2013) Porous Aggregation. Ann Arbor, Michigan: Realized
Figure 7. Kalo, Ammar and Michael Jake Newsum (2013) Performative Ribs. Ann Arbor, Michigan: Realized