**Robotics and Ice structure fabrication**

Investigation of mechanical precision and efficiency

In conjunction with the department of mechanical engineering, the ice architecture team is speculating on how to use parametric software for form-finding, and in turn, how to translate parametric models into task planning for the robots that will build the ice structures.

Our first experiments involve established means of translating 3-dimensional STL digital models into physical models using techniques of rapid prototyping, and CNC milling. However, as we determine which processes work best, we hope to scale up from small objects to architectural projects, at which point the robot itself will have to move. It is this ambition that distinguishes our project from other engineers interested in rapid prototyping involving ice.

**Rapid Prototyping**

RP is a Solid Freeform Fabrication technique which means that solid parts are built by material deposition…RP is a SFF technique that is often used in industry to produce prototypes quickly and at low cost. RP with ice has additional advantages, namely, further reduced cost, small environmental impact, and high part accuracy and surface finish. (Eric Barnett – Robot-Assisted Rapid Prototyping for Ice Structures)

**Rapid Freeze Prototyping**

Rapid freeze prototyping, developed by researchers at the University of Missouri-Rolla, is the process of rapid prototyping using water as the base material. The process involves a technique that sprays droplets of water layer-by-layer in a freezing chamber.

**FAB@HOME Robot**

This desktop rapid prototyping machine was the first robot used in the project and had to be modified to make small-scale objects, such as a martini glass, in a -23°C environment.

**Adept Cobra 600 Robot**

Produces finely detailed 3D ice objects up to 300mm across and 200mm high. The Cobra is faster, more accurate and more robust than the FAH. At the same time, it was not designed for RP, so much more retrofitting is necessary.

**Micro-nozzle fluid delivery system**

This dual-nozzle system delivers droplets of water consisting of a few micro-liters with every pass. This fluid delivery system was designed to be compact, well-insulated, and rigid. The deposition system must be well-insulated to prevent fluid in the liquid lines and the valves from freezing before reaching the nozzles.

**Flat spray nozzle fluid delivery system**

The flat spray nozzle is designed to yield a more uniform spray distribution spray than a hollow cone and solid cone spray patterns. The spray angle affects the amount of pressure acting on a certain area: the larger the angle, the smaller the pressure. As a result, it is better to use a nozzle with a wider spray angle.

**Scaffolding**

A support structure is required to produce slanted or overhanging parts. After several options were explored, we decided to use a solution of potassium chloride in water (KCl brine), to build the support material. Both water and KCl brine freeze in deposition environment of -23°C. Thus, when a part is completed, it is placed in a -4°C environment and the frozen KCl brine is melted away, leaving the finished ice part.

**Manufacturing time**

With the current deposition systems, build times range between five to twenty hours.

**Scaling up!**

In the winter of 2010, we plan to scale up again, this time to the architectural scale. We will use a larger robot having a reach of 20ft, with a slush/snow delivery system, now in development. This system will be designed for outdoor deployment, using the natural freezing winter environment as its workspace. The varying outdoor temperatures, humidity and wind speeds will require the ability to continuously adapt the rate of flow and the speed of deposition to optimize the ice building process.