The ICE Project at McGill University

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Introduction

- Over the past few decades, P. Sijpkes has led several manual ice construction projects at McGill
- The objective of the Ice Project is to develop computer-assisted ice construction techniques
- Here we present the Cobra 600 rapid freeze prototyping (RFP) system
- Ice parts are built by depositing water and shortning methyl ester (SME) scaffolding through nozzles, which are positioned by the Cobra 600

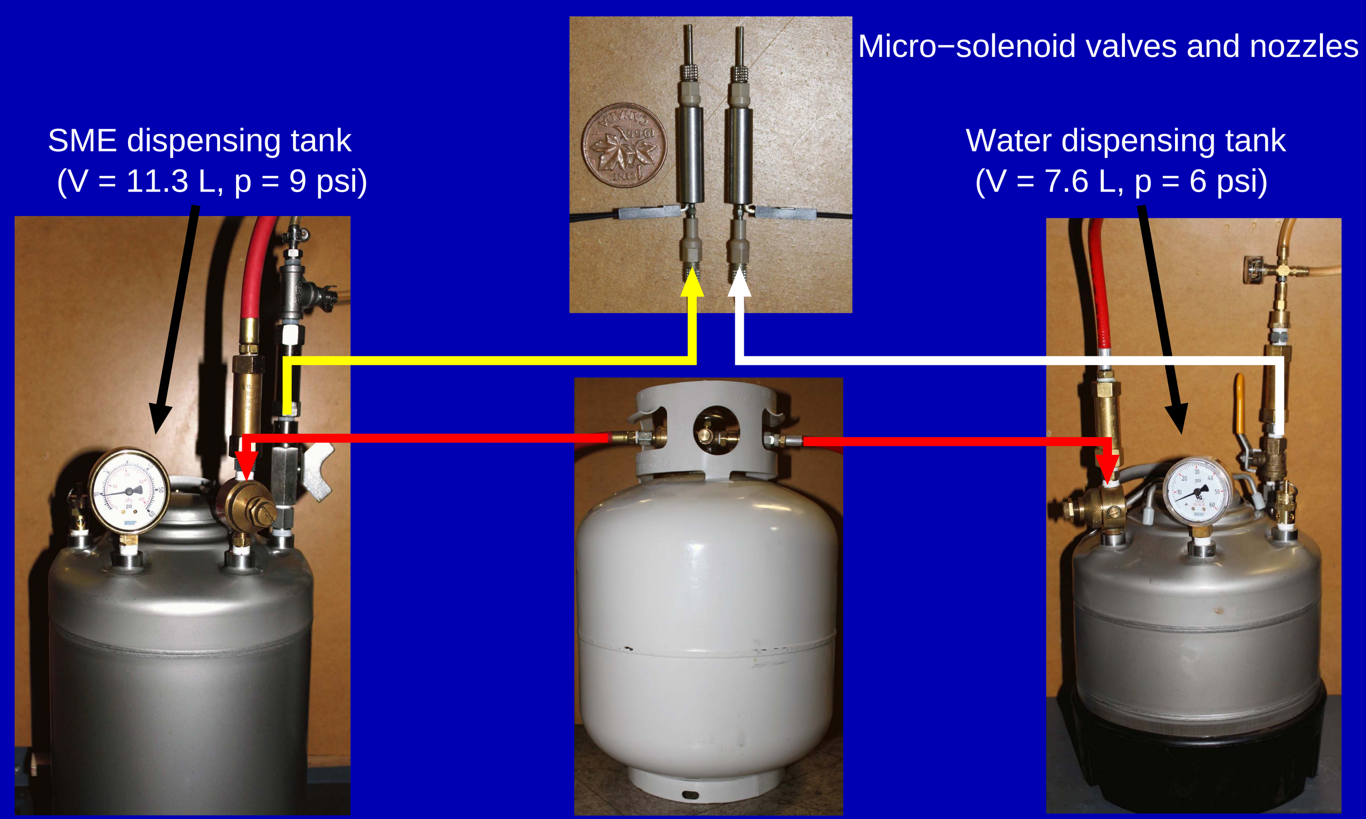
Hyperbolic paraboloid ice structures (1970s)

A catenary ice arch(1983)

Adept Technology's Cobra 600 SCARA system

Dispensing Subsystem

- The dispensing subsystem supplies water and shortening methyl ester (SME) to the robot end effector
- A portable air tank is used to pressurize the materials in liquid form
- Air pressure is regulated to the dispensing pressure desired for each material
- Micro-solenoid valves mounted in the Cobra 600 end effector control material flow



Portable air tank (V = 17.4 L, p = 20–120 psi)

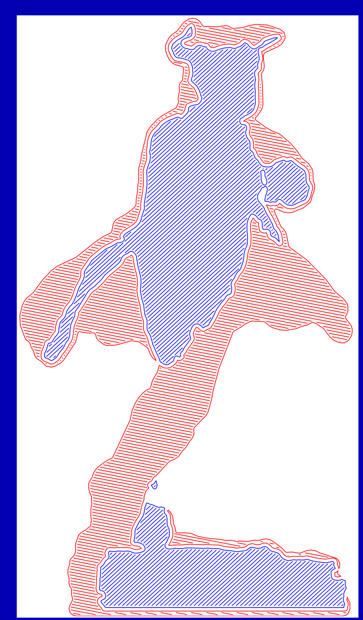
Generation of RFP Control Data

- RFP trajectory and valve control data is generated using `rpslice`, a Matlab algorithm we've developed
- The input file format is STL or PLY, which can be generated from almost any CAD program
- The James McGill STL file was generated by 3D-scanning a 30 cm-high bronze statue

Bronze statue

STL model (1 million facets)

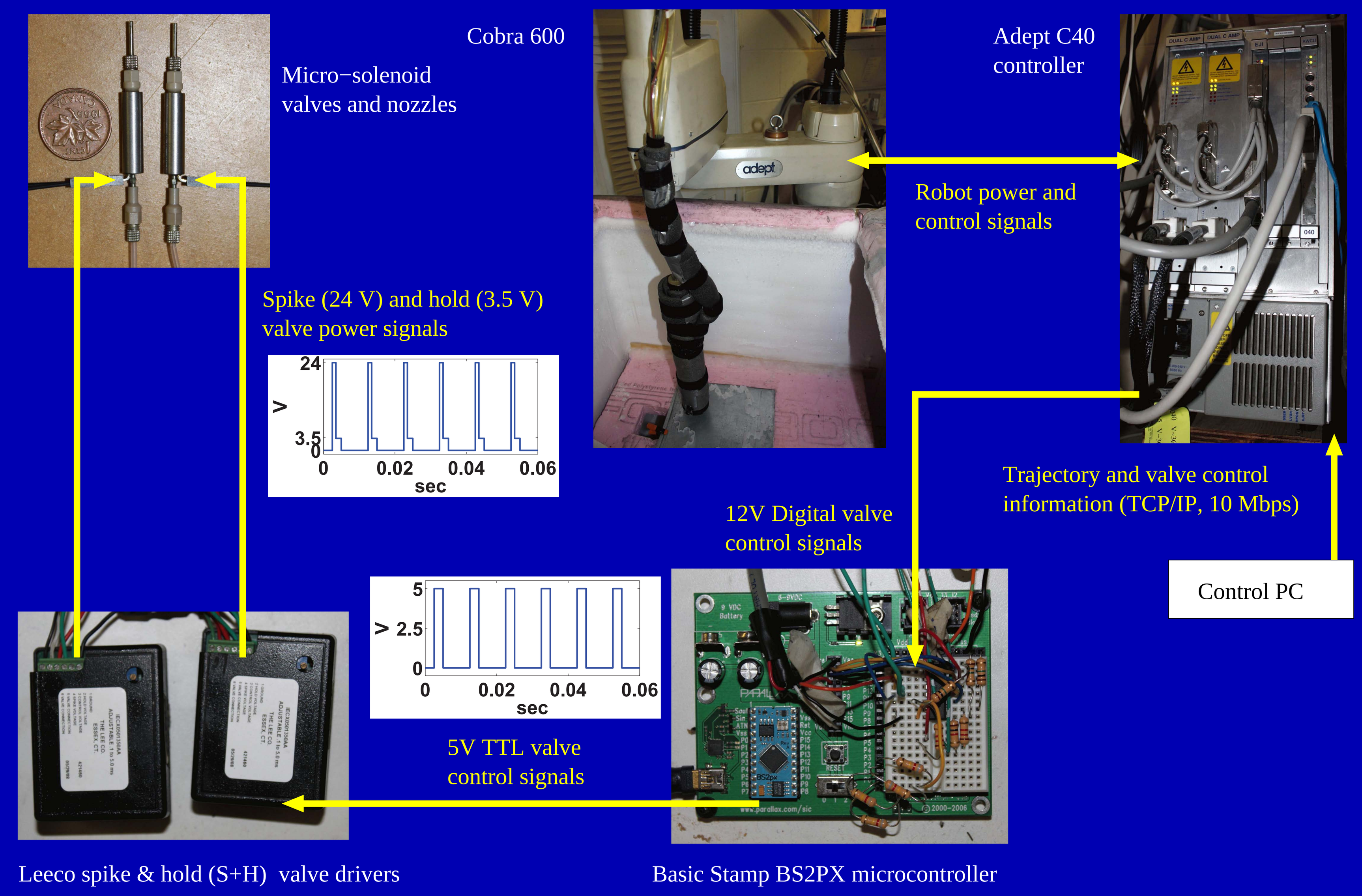
Part slices, 2 mm apart here for improved visibility (normal separation is 0.4 mm)



Part (blue) and scaffolding (red) deposition paths for one layer

Information Flow During Part Construction

- Part construction is initiated when the deposition control program is executed on the Cobra controller
- A PC on the local network acts as a terminal for the controller
- During construction, the controller accesses trajectory and valve signal control data stored on the PC
- 12 V digital signals from the Cobra controller are used to select the dispensing state
- There are two dispensing states for each valve, which correspond to boundary and fill paths



The Build Process

- A part is manufactured layer-by-layer
- Two ice layers are built for every shortening methyl ester (SME) layer
- The bulk of the SME is removed manually and saved for re-use
- The model is placed in kerosene for several hours to remove the SME remnants
- Ice statue characteristics:
  - 30 cm high
  - 862 layers thick
  - 132 hours to build
  - 24 million trajectory points followed

Start of deposition

Intermediate state

After deposition completes

After SME removal

The finished product

Future Work

- Improvement of the accuracy, robustness and speed of the Cobra 600 RFP system
- Testing and installation of a deposition feedback system
- Configuration of the system for use by those who don't have specific technical expertise

Acknowledgments

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http://www.cim.mcgill.ca/ rmsl/Index/ice/index.html

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