Technical Abstract

Smart Tools: Robotics for Construction is a 4th year project designed to investigate and implement the integration of CAD software with real time construction tools on a worksite. The aim behind the project is to create a smart tool, i.e. one that is aware of its location and position with respect to its local environment.

There is a particular emphasis on developing a faster and more efficient method of building vaulted arch structures. Traditionally, in the construction of timbrel vaulted arches, non-structural formwork, or guide-work, is used to assist masons in laying tiles in the correct manner. Wooden guides are temporarily constructed in the vaulted space, roughly mapping the general shape required. This guide-work, however, severely limits the working space available under the vault, making the construction difficult and ultimately more time consuming. Skilled Catalan masons required little more than two strings as a guide to accurately trace a vault, but when it comes to more complex degree-of-curvature structures, using two strings becomes obsolete. But, the method does not.

The smart tool that I have created aims to work in the same way that a string attached to a single point traces a hemisphere, except that in this tool, the string's length changes to reflect the shape of the vault as the string is moved around the space. A model is loaded into a CAD program, and the smart tool uses this as the basis of the vault to trace with the "smart" string.

This is accomplished through creating a polar coördinate measuring system in the working space so that the position of the end of the string can be determined. The direction that the string is pointing is calculated by an optical rotary encoder and the angle of the string, with respect to the ground plane, is calculated with an accelerometer. The length of the string is calculated through looking at the number of rotations that a string-spool has gone through (this also uses a rotary encoder). These values of direction, elevation and radius allow the position of the end of the string to be expressed in polar coördinates.

The position of the unit and the end of the string can then be compared to the CAD model of the vault, and feedback to the end of the string can be applied if necessary. Feedback is applied through a stepper motor connected to the axle of the spool of string. If the end of the string is coincident with the vaulted arch surface, then feedback is applied to the string,

holding it, so that it cannot be extended further. As the end of the string is moved around the vaulted space, it may go inside the vault, in which case the feedback on the string is loosened so that it can extend further. The string may also go outside the vault in which case the motor switches on, shortening the string until its end is within the vaulted surface.

The measuring and feedback platform is based on an Arduino micro-controller that interfaces closely with a CAD system, allowing simultaneous real time two-way communication. The CAD system is based on Rhinoceros, and uses a parametric modeling plugin, Grasshopper, alongside Firefly, a program that allows for the Arduino integration.

The completed measuring unit was laser cut out of perspex and assembled using M3 bolts and Tensol 12 fusing agent. The electronic sensors and Arduino micro-controller board were integrated and the complete model was tested. Test cases for the system included a 2m hemispherical surface and a small vaulted surface, similar to the kind that the unit was designed to trace. In both test cases, the smart tool performed well, accurately tracing—through the application of feedback—the surface of the vault as the string was moved around the construction space.

Future work could revolve around refinement of the tool, making it more accurate and suitable for use in a construction environment, or additionally through extending the feedback so that it is applied in more than just one axis.