

***Sustainable*: a generative, robotic installation**

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1. Introduction

Sustainable, is a dynamic, autonomous, robotic installation that is comprised of a network of seven independent water gongs that communicate through water tubes that link adjacent nodes (see **Fig. 1**). The network models a water resource allocation algorithm that yields a perpetual evolution of the sonic, visual, and timbral elements. Each gong node functions independently and autonomously and is functionally equivalent, but through their simple networked interactions, the system exhibits dynamic, emergent behaviors that yield local and large scale forms in sound and light.

A water gong is a musical gong that is dipped into a tank of water. As the gong is partially submersed, the water alters the resonant properties of the metal such that the sounding frequency of the gong descends as it is immersed below the water's surface.



Figure 1: Portion of the gong network

We have built a collection of robotic water gongs, each with two solenoid beaters that strike a gong that is fixed above a water tank. Rather than raising and lowering the gong itself, using water pumps, we raise and lower the water level in the tank to produce the desired effect. Lamps positioned below the transparent tanks illuminate patterns on the surface of the water as it ripples and splashes. Each gong has one upstream and one downstream neighbor, and is connected to its two adjacent neighbors via water tubes. Thus, water can be distributed throughout the system, and as the gongs resonate above the ever shifting water levels, chords and rhythms emerge that reflect the state of the population. A water resource sharing algorithm governs the global behavior of the system, and each water gong node is modeled as a water consumer with individual needs and behaviors that must be balanced against the actual water supply. One can imagine that each water gong is a farmer or golf course along a river that must negotiate with its neighbors for water access and priority.

2. Design and Conception

The network plays a formative role in the design and conception of this piece. Rather than simply implementing a network to facilitate communication, we conceive of the water network in *Sustainable*, as a powerful metaphor for the intellectual, social, and cultural networks that link our communities. The following three concepts inform the piece: (1) *Water network as an important force and metaphor*. As residents of the western United States, where water rights and access are critically important, we are driven to address this issue in our work in a manner that is demonstrative and compelling. Water also serves as the exclusive means of communication between nodes in the network, and this anachronistic mechanism references the use of waterways as the traditional vehicle for communication and transportation. (2) *We explore the relationship between organic materials and technology in robotics, and seek to balance these forces in the piece*. This goal informs the decision to have the visual and sonic events originate from 'natural' (e.g., striking the physical gongs) and not electronic sources. Furthermore, despite the presence of microcontroller circuitry and other technologies, we have chosen to use water as the exclusive network protocol in the piece. Water introduces numerous irregularities into the otherwise deterministic system that yield favorable organic results. (3) *The evolution of sonic and visual materials addresses the passage of time on multiple levels*. The behaviors of this dynamic system can be understood on multiple levels. Locally, one can appreciate the actions of individual water gongs. Globally, viewers can appreciate the more gradual sonic and visual transitions of the system as activity and textures shift around the network, and complex composite sonorities emerge. As a consequence of the resource sharing algorithm, a high-level meta pulse emerges from the system with alternating periods of stability and instability. This is a key feature of the generative system that yields compelling musical tension and release.

3. Realization

Physically, each component of the work was custom designed and fabricated by the artists and is intended to be both functional and aesthetically communicative. Different gongs and beater elements have been selected for each node to allow for a great diversity of composite sounds. Computationally, each node has a cycle that is iterated perpetually, and control of these sensing and actuation tasks is implemented on microcontroller circuitry embedded within each water gong. There are five simple steps to each cycle: (1) sense the current water level, (2) update the water pump state, (3) update the gong striking pattern, (4) update the lamp illumination state, and (5) if appropriate update the target water level (i.e., water need).