Glume: Exploring Materiality in a Soft Augmented Modular Modeling System

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Abstract
We introduce Glume, a modular scalable building system with the physical immediacy of a soft and malleable material. The Glume system consists of soft and translucent augmented modules, which communicate capacitively to their neighbors to determine a network topology and are responsive to human touch. Glume explores a unique area of augmented building materials by combining a discrete internal structure with a soft and organic material quality to relax the rigidity of structure and form in previous tangible building block approaches. We envision Glume as a tool for constructing and manipulating models, visualizations and simulations of organically based three dimensional data sets.

Keywords
Tangible User Inteface, 3D visualization, materiality

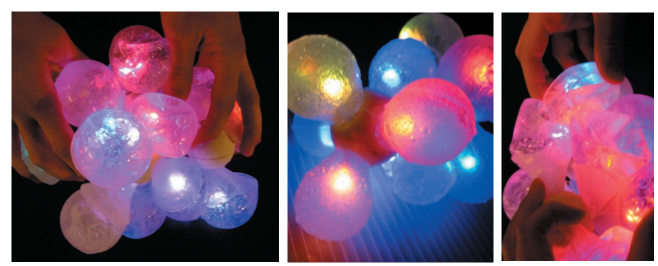

figure 1. The Glume System in use.

ACM Classification Keywords
H5.2. User Interfaces: Prototyping

Introduction

The development of Tangible User Interfaces [1] have allowed us to bring physical form to digital information. However, their materiality remains largely steeped in the bounds of rigidly delineated material systems. The challenge becomes to bridge the organic structures in the natural world which we seek to emulate and manipulate with the exactness of the digital systems which provide the tools for manipulation. As Ellen Lupton comments, "organic forms and materials provide designers with a humanist vocabulary that affirm society's place within the natural world" [2]. The constructed and the organic are converging, and the digital materials and tools in development should address this phenomenon by providing an organic material means to engage the tactile senses in the act of creating and modeling.

Model-making in both physical materials as well as computational analysis and simulation provides a methodology to understand and represent the world. Data visualization provides a powerful educational technique as well as a important activity for professionals, particularly in scientific and creative fields such as architecture, geology, hydrology or medicine. In many of these fields, physical 3D model-making is still preferred over, or applied in conjunction with, on-screen GUI modeling tools because physical modeling employs the hands and body in the creative process and allows rapid experimentation with a system to understand its limitations.

However, most of the existing digitally augmented modeling materials consist of solid and rigid building blocks (e.g. MERL blocks [3], or ActiveCube [4]) which offer constraints to form. To enrich and expand our relationship with interfaces, they must perform, respond and react in ways that mimic the body and our surrounding environment in their materiality as much as their intelligence.

This paper presents Glume, which seeks to provide such a material means. Glume is a system modular primitives – six silicone bulbs, embedded with sculptable gel and a full spectrum LED- attached to a central processing "nucleus." The nodes communicate capacitively to their neighbors to determine a network topology taking advantage of the novel conductive characteristics of hairgel. As a modular, scalable platform, Glume provides a system with discrete internal structure coupled with a soft organic form, like the skeleton defines the structure of a body, to provide a means for expression and investigation of structures and processes not possible with existing systems.

Related Work

Glume occupies a unique space among digitally augmented building materials [figure 2]. It derives conceptual and technical inspiration from a variety of different areas. Determination of a three dimensional form by communication through a set of connected shapes, has been demonstrated by numerous systems which act as physical networks of a digital information topography. John Frazer's 3D Intelligent Modeling System from 1980 [5] set an early precedent as a set of stacking building blocks which send messages to adjacent blocks to determine geometric configuration. This work was followed by projects such as Digital Clay [6] developed at Xerox Parc, a system of rhombic dodecahedrons whose modules have the capacity to sense their own orientation in space with respect

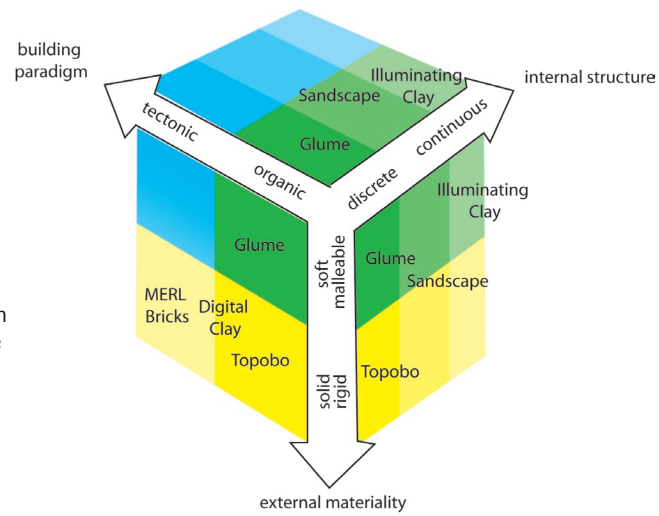

figure 2. Glume placed in the context of other augmented building systems. It occupies a unique space combining a soft materiality, an organic building paradigm with an internal structure of discrete elements

to other modules. An attempt to move away from a techtonic building system, to a more biological inspired model based on crystal structures, exists in the constructive assembly Topobo [7].

Other related projects investigate physical techniques for volumetric modeling. Phoxel Space [8] projects a voxel dataset onto the surface of a physical material and the 3D volumetric display from Actuality Systems [9] displays a 3D volumetric image by sweeping a semi-transparent 2D image plane around a vertical axis. Although Illuminating Clay [10] offers one exception employing a soft clay in modeling, it does not provide the means to edit the underlying structure.

Technically, the Glume system architecture builds on developments in distributed and decentralized hardware and software architectures. Zimmerman's Personal Area Networks: Near-field intra-body communication [11] demonstrated how capacitive coupling of currents through the body could allow electronic devices on the body to exchange digital information. Later systems offered offered insights into algorithmic simulations in distributed systems such as Pushpin Computing [12], a hardware and software platform used for experimenting with algorithms for distributed sensor networks.

System Design

The Glume system was designed to retain the tactile experience of a soft modeling material, while creating a new identity and extended functionality for the material. To achieve this goal we established guidelines for the physical and digital design of the system:

- Retain a flexible malleable form while incorporating a regular recognizable stacking geometry
- Induce a tactile sensation similar to sculpting with a soft moist material
- Provide translucency to see inside a model
- Allow for distributed or centralized functionality
- Incorporate a touch response as feedback to the user

A Glume Module - A Flexible Primitive

An individual Glume module consists of six silicone bulbs connected to a central 'nucleus' containing a custom PCB and a 3.8v 1.5mAh lithium polymer battery [figure 4]. The silicone skin of each bulb has been cast in Smooth-On® Sorta-Clear 40, a translucent silicone rubber. The hollow castings were made from molds modeled in Autocad and then 'printed' using a 3D starch printer. The bulbs are embedded with Softee® Protein Styling Hairgel chosen for its optical clarity and conductive characteristics. The combination of the thin silicone shell and the embedded gel provides the tactile effect that each bulb will retain the shape as sculpted in place by the user.

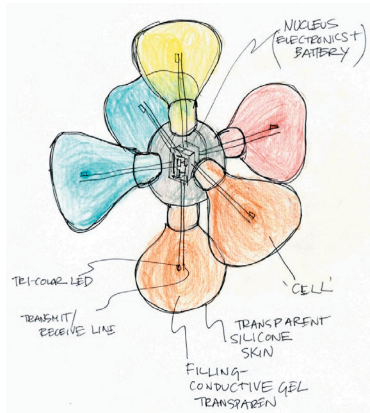

figure 3. Concept sketch of a single Glume module.

Technical Hardware Implementation

We devised the system architecture in three distinct modules: a PWM display adapter and six RGB LEDs; an FSK modulator-demodulator and six gel electrodes; and an 8-bit RISC micro-controlling unit. The Glume system is driven by an ATMEGA32L AVR® microcontroller running at 8MHz. The FSK module uses the PWM unit provided by the AVR® to modulate two different frequencies into a multiplexer that redirects the signal to one of the six electrodes. The same multiplexer also redirects the incoming frequencies into the input capture unit of the AVR®. The transmitter shifts from 31.25KHz (1) to 3.91KHz (0) at a baud rate of 200 bps.

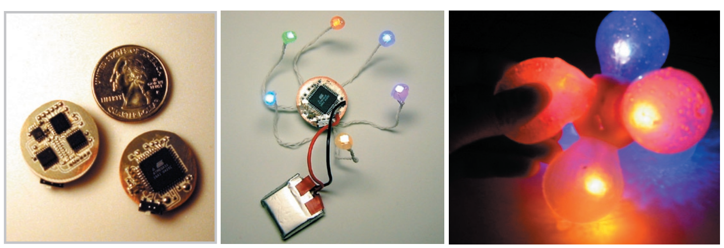

figure 4. a) Glume double sided PCB b) Glume internal hardware: PCB, lithium polymer battery and 6 full spectrum LEDs c) an assembled Glume module

The network topology of the nodes is determined through capacitive communication of neighboring nodes. This proximity is crucial for our system architecture, as is the distance between the transmitter and the receiver, as signal strength between two nodes decays linearly as the distance between the nodes decreases. The FSK module also acts as a capacitive sensor to determine when a user is manipulating a Glume unit. The display adapter consists of two PWM drivers controlled serially by the AVR®. Together, they independently drive six full spectrum RGB LEDs.

Glume in Use

As the first implementation of Glume, we have built a prototype set of nodes and will illustrate its interaction capabilites using a hydrology modeling scenario, chosen because it makes use of 3D data sets in organic structures (such as soil) and requires direct manipulation of spatiotemporal parameters. Other possible applications include architecture, geodynamics, medicine and archeology.

Constructing and manipulating a model

To construct a model, users combine Glume modules, interlocking and shaping the nodes into place. As the user builds, the system determines the model's morphology, first defining an origin point at the base of the model and recursively looking at the neighbors of the 'base' node to define a crude morphology which is then optimized into a 3D mapping of the structure. During the construction process, the system can assist the user by providing colored cues within the model by, for example, displaying a color gradient changing from the centre of the structure outwards or a color-coded elevation map of the model. Once the model is constructed, users can associate it with a predefined semantic model of a specific volumetric map related to

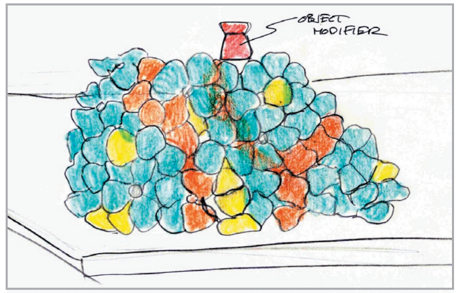

figure 5. Concept sketch of a multiplicity of Glume modules in use and with an object modifier.

the construction. In a hydrologic assessment situation, users construct the 3D geologic map of a terrain while taking into account important physical parameters for the simulation such as soil characteristics and land surface slopes.

Object Modifiers and Probes

To manipulate a model, users modify the parameters of a node or a group of nodes by introducing an *object modifier* into the system. Object modifiers can affect a single node directly during the building process, and its color is adjusted to reflect the change, mapping different properties (such as types or density of particulates) to different colors. If object modifers are added to an existing model, the system will regenerate its semantic model to reflect the new parameters. In a hydrology model, users could simulate the propagation of a pollutant plume and visualize its effects on the geological map, by placing several object modifiers representing pollutant sites on the surface and simulate the pollutants propagation over time.

Glume also enables users to get an extended set of properties associated with a specific node in the physical model using *probes,* which automatically provide the parameters associated with each node when touched. Finally, users can also *touch* nodes to highlight isovolumes as part of a simulation, for example, touching a 'polluted' node to highlight the propagation of that specific pollutant.

Issues and Limitations

Based on our interacting with our initial prototype, we observed the main issue of the system to be resolution and accuracy in determining the structural form. Glume works best to simulate the overall global behavior of a model, or as a close up of a particular region. Also, we observed that the transparency did not penetrate as deeply into the model as hoped. We seek to address these issues in future prototypes of the system.

Future Work

Multiple Materialities

While our current implementation consists of the geometry of a central sphere surrounded by a six malleable bulbs as the basic Glume module, we envision a system which would incorporate multiple shape geometries and varying material properties for different modeling scenarios. Possible geometries include a four bulb tetrahedral model, a single unit sphere or rectilinear block with a rigid internal frame. Using a combination of varying primitives, models could be constructed with elements their reflect the appropriate structural and material properties within a simulation, for example, representing an underground concrete foundation running through soft terrain.

Incorporating a GUI

Our future directions also include incorporating the Glume system with an onscreen model and GUI. The GUI would address issues of resolution and accuracy by providing additional detailed information about the model including showing the larger region (such as a map) that surrounds the area of investigation. The GUI could also provide controllers for global variables of the model such as the nature of the soil or temperature of the system.

Conclusion

We have presented Glume, a tangible 3D modeling and visualization medium, based on translucent soft silicone modules, which provides display and data manipulation capabilities by combining an internal digitally discrete structure with soft material affordances. We have implemented a working prototype as a proof of concept and an initial application scenario in a hydrology simulation. As computational systems become more and more integrated in our everyday physical environment and tied to our tangible materiality, we believe the invention of new physical/digital materials which afford the forms and structures of the natural world becomes crucial. Current computational modeling media, such as CAD, are rigid in comparison with the continuous scale of variation in physical materials. We hope the system presented in this paper contributes to an emerging discussion to promote creation of new digitally augmented but less-rigidly defined materials which seek to match different realms of human expression and natural materiality.

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