Generative AI syntheses of platform, content, visuals, and kinetics for cyberphysical computationally-mediated posters and broader applications

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ABSTRACT

We demonstrate a modular display device that interweaves artificial intelligence, tangible interaction, and an ACM IUI corpus. Our design incorporates a low-cost, shape-changing tangible interface with an array of illuminated, actuated physical interactors and hexagonal tokens (hextoks), within a structure of varying scale, sidedness, materiality, and computational hardware composition. The demonstration illustrates generative AI syntheses of varying-scale physical and virtual platforms; of rich content, drawing upon all published ACM IUI articles and Wikipedia; visuals, automatically synthesized for varying-scale & medium displays; and kinetics, as well as illustrating paths for generatively upcycling second-life computational technologies.

CCS CONCEPTS

• **Human-centered computing → Interaction design process and methods**.

KEYWORDS

situated interaction, mixed-initiative touch, tangible interfaces, actuated tangible interfaces, hextoks, cyberphysical interfaces

ACM Reference Format:

Sida Dai, Jasmine Davidson, Brygg Ullmer, Winifred Elysse Newman, and Miriam K. Konkel. 2024. Generative AI syntheses of platform, content, visuals, and kinetics for cyberphysical computationally-mediated posters and broader applications. In *29th International Conference on Intelligent User Interfaces - Companion (IUI Companion '24), March 18–21, 2024, Greenville, SC, USA.* ACM, New York, NY, USA, 5 pages. https://doi.org/10.1145/3640544.3645225

IUI Companion '24, March 18–21, 2024, Greenville, SC, USA

ACM ISBN 979-8-4007-0509-0/24/03
https://doi.org/10.1145/3640544.3645225

1 INTRODUCTION

Loosely and densely tiled displays and interaction devices have a long history. Where NASA's Mercury/Gemini control center have been pictured with four graphical screens [1, 13] – three of them off – NASA's Apollo control center included hundreds of graphical screens, densely interwoven with many interaction devices [12]. In specifically interaction- and graphics-focused domains, the Infinity Wall and Power Wall [3] realized early tiled displays – first with projectors, then more frequently with LCD, OLED, and other flat-panel technologies with progressively narrower bezels. While many instances of these involved flat screens, some (e.g., CAVE and CAVE-2) engaged curved, cylindrical, and cubical configurations [6].

In 2022 deployments at the Smithsonian National Museum of American History and the Greenville, SC Artisphere, we began to deploy a new genre of interaction platform which combined a plurality of tangible interfaces with ensembles of multitouch displays, illuminated interactive paper, and interactive floors. Figure 1 illustrates three such configurations, with one, three, and six ensembles of screen and actuated illuminated paper displays – one configured in an S curve; the other two, in simple, more compact curves. As we contemplated paths forward – especially with an eye toward fostering broader content authoring, replication, and engagement – we identified a number of opportunities for employing analytic and generative AI approaches.

Among these, we identified a promising opportunity amidst the heterogeneity and complementarities across a constellation of interaction opportunities. The deployments pictured in Figure 1 prominently incorporated a juxtaposition of 28" diagonal LCD displays with dual-flanking actuated rolls of interactive illuminated paper. Subsequently, we unexpectedly inherited several dozen 50"-65" displays of varying size and capability (e.g., stereo); all functioning, but 8 years old, using proprietary chained video feeds. Resonant with [7], we were exploring scale-model representations of tiled display installations with small grayscale epaper and OLED display modules; and with 2D and 3D immersive head-mounted display virtual renditions. Further, in our University context, we noticed a frequent surplus availability of screens of widely varying size; and online, on (e.g.) eBay, the daily availability of *millions* of screens

Figure 1: a) initial single interaction ensemble + display deployment, situated within a University libray; b) six display and dual interaction ensemble deployment, situated within the Smithsonian National Museum of American History; c) three display and single interaction ensemble deployment, situated in Greenville, South Carolina's Artisphere event

of widely varying size and functionality. These display examples were complemented by a landscape of input technologies, again including off-the-shelf at widely varying costs, legacy second-life devices, and research prototypes often with limited availability.

This landscape of possibilities struck us as resonant with the Design Galleries work of [9]. There, the authors investigated "methodologies for computer-assisted parameter setting... Design Gallery™ (DG) interfaces present the user with the broadest selection, automatically generated and organized, of perceptually different graphics or animations that can be produced by varying a given input-parameter vector." By contemporary language, this illustrates generative AI toward mixed-initiative human-AI co-design (further illustrated by recent citing works including [8, 14]).

Our demonstration illustrates applications of the original Design Galleries concept [9] across generative AI syntheses spanning a variety of parameters and data. These include:

(1) *platform:* we illustrate parametric synthesis of varying numbers of displays and interactors, as well as varying kind – including large and small physical variants, as well as screen- and immersively-rendered virtual editions;
(2) *abstract content:* analytic and generative AI interweaving explicitly and implicitly authored content (e.g., posters, the ACM Digital Library, and Wikipedia);
(3) *visual content:* diverse rendering of content for (e.g.) large and small dynamic screens,epaper displays, and stereo immersive environments;
(4) *kinetic content:* complementing and sometimes substituting dynamic visual content with legible, applied kinetic/mechatronic systems; and
(5) *upcycling:* in addition to realizing the above with newly purchased and fabricated hardware,generative AI approaches potentially offer new paths for integrating second-life screens and other devices in "upcycled" configurations.

For example, Figure 2 illustrates 2, 3, 4, 5, and 6-sided interaction columns, each faced with a display and a kinetic "MorphMatrix" tangible interaction device [4] and/or grid controller using "hextok" tangibles [11]. Here, it is interesting to consider alternate scenarios regarding choices amongst them and many variants, whether used toward (e.g.) interactive posters at an academic venue like (e.g.) ACM IUI or ASHG, or in many other contexts.

Which is "better," and what are the core and cumulative costs? Were all materials newly purchased, the screens might be the most expensive element. However, toward our IUI'24 demonstration, we mention inheriting several dozen second-life screens, leaving the screens of no incremental cost. However, in a context like the ASHG genetics conference (where we routinely present), with (e.g.) 3,364 posters in 2019, screen – and energy – cost and availability become central constraints.

In earlier years, computers capable of driving the (e.g.) six large screens might be a particular expense. However, especially once availability resumed after more than three mid-COVID19 pandemic years of non-availability, we have found the US$35 Raspberry Pi 4B – each capable of driving two large screens – fully sufficient for 2D content; and the late-2023 release Raspberry Pi 5, fully capable of 3D content. Our IUI'24 demo combines a Raspberry Pi 4B and a Hackboard 2 (incorporating a laptop processor, given several in-hand). From a cost perspective, the next constraint varies between framing materials+hardware and fabrication. Figure 2a-e illustrate three different framing approaches. In Figures 2d-e, all structural framing is with aluminum t-slot extrusions and like-purposed fixturing hardware. Here, the framing sums to several thousand US$. Even the triangular fixturing bracket (an open-gusset angle bracket), at US$15 each, at 14 per face x 6 faces, sums to US$1,300. For some commercial contexts, this cost may be nominal; while in many educational contexts, less so. In Figure 1a, more than half of the aluminum framing elements are replaced with wood, and the brackets, with a <US$1 apiece alternative. Here, for instance, the core screen-support pillars are US$110 each in t-slot aluminum (McMaster 6812N14); but of material cost US$2-$30 each (in softwood and oak) from a local hardware store. Figure 3 illustrates several small-scale representations alternately using dynamic touchscreens and epaper modules – whether as scale models, as proxies in immersive environments, or other uses.

In our demonstration, we will illustrate an embodiment of these ideas specific to the content and venue of the IUI conference. Building upon tangible interactive poster research [5], we will illustrate three variations on Figures 2 and 3: a 3-6 sided structure at 2m height; a 3-6 sided structure at 10cm height; and a screen-based synthesized virtual rendering. We will illustrate an application of these with ACM IUI posters. Specifically, we will link a SQLite database and Prolog representation of the complete publications of the ACM IUI conference (synthesized from Bibtex exports from the ACM Digital Library), further abstracted with stemming and abstraction of user-selected keywords; a subset of ACM IUI 2024 accepted posters; and our SDOW-derived full linkage model of Wikipedia. Together, these will both allow viewing and engagement with the 2024 ACM IUI posters; as well as parametric search and augmentation of these for engagement with varied audiences (e.g., toward outreach efforts reaching non-experts).

In two specific software prototypes underway, alternate hardware compositional elements are described in YAML, with alternate system compositions parametrically synthesized in SWI-Prolog, using Prolog dictionary ingestion through YAML support libraries. On the ACM IUI content front, our current prototypes map per-year BibTex exports of the ACM Digital Library to YAML, then ingest these into a SQLite database. Following successful testing of this, we explored four alternate fulltext keyword identification techniques described in [10]. Of these, YAKE and rake-nltk were found to make strong autoidentification of fulltext keywords. (Spacy was determined to extract too few + abstract keywords; while Gensim.summarization is presently deprecated.) We are evolving consensus algorithms between YAKE and rake-nltk, and are developing interaction code based upon PyGame Zero together with PyGame MIDI controls.

Through these, we aim to offer an experience that is explicitly of and toward the ACM IUI community; and that illustrates a specific, generalizable fusion of artificial intelligence mediation with tangible interaction.

2 DEMONSTRATION OVERVIEW

2.1 Design and Implementation

The design and implementation of our modular display device encompass a dual-component system: a low-cost, shape-changing tangible interface, and a 48" LCD display, each designed to enhance user interaction in situated environments. The tangible interface features a unique mechanical system based on 3D-printed camshafts, efficiently utilizing just two motors to animate an 8x8 cube matrix. This design allows for complex morphing capabilities while maintaining cost-effectiveness and mechanical simplicity. The LCD display complements this setup with its adaptive arrangement, capable of horizontal or vertical orientations to cater to various display needs. Together, these components are underpinned by a suite of software algorithms ensuring seamless interaction and synchronization. The overall user interface design prioritizes simplicity and intuitiveness, balancing the physicality of the tangible interface with the clarity and accessibility of the digital content on the LCD display. This integration of innovative mechanical design and practical software solutions embodies a user-centric approach, harmonizing tangible and digital elements to enhance the experience of situated interaction.

2.2 User Interaction

In the proposed user interaction mode for our AI-assisted, tangible interface system for computationally-mediated posters, users initiate interaction as they approach the display, with the AI recognizing their presence through a LiDAR sensor (priorly successfully used in our Smithsonian and Artisphere deployments) and activating the system.

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3 DISCUSSION

Our integration of tangible interface with AI-assisted interaction illustrates the potential for more responsive, context-aware digital interactions, exploring new roles for physicality and adaptability. Future research include hardware+software iteration and evaluation (including integration of additional sensing modalities). We believe the behaviors and system facets we have described illustrate the synergistic potential of tangible interfaces and AI, grounded in a real-world, ACM IUI-specific context.

ACKNOWLEDGMENTS

This work has been partially supported by the NSF "Enodia" MRI CNS-1828611. We thank Clemson University's College of Engineering, Computing, and Applied Sciences (CECAS), the Watt Center, and the South Carolina Regional Authority (SCRA) for enabling costshare support.

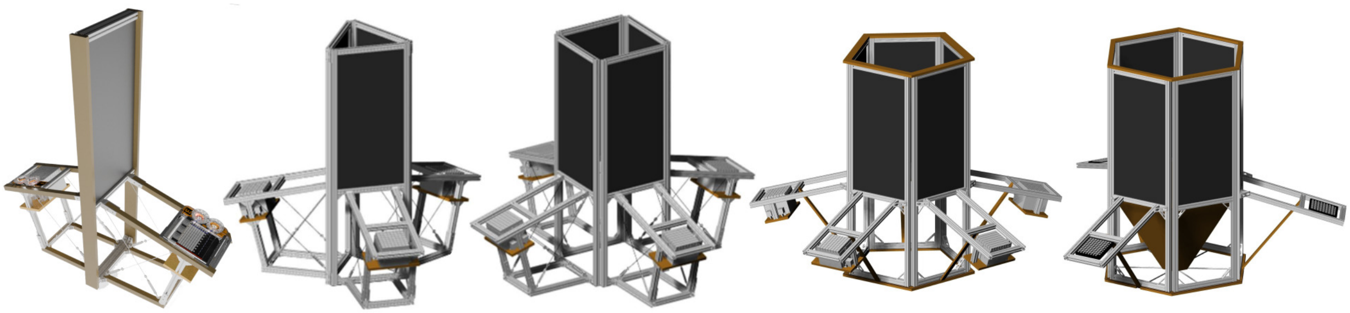

Figure 2: variations on module count with homogeneous display type and size: 2, 3, 4, 5, and 6 modules.Two different staggers are employed for the MorphMatrix interactors: per-face and every-second-face.

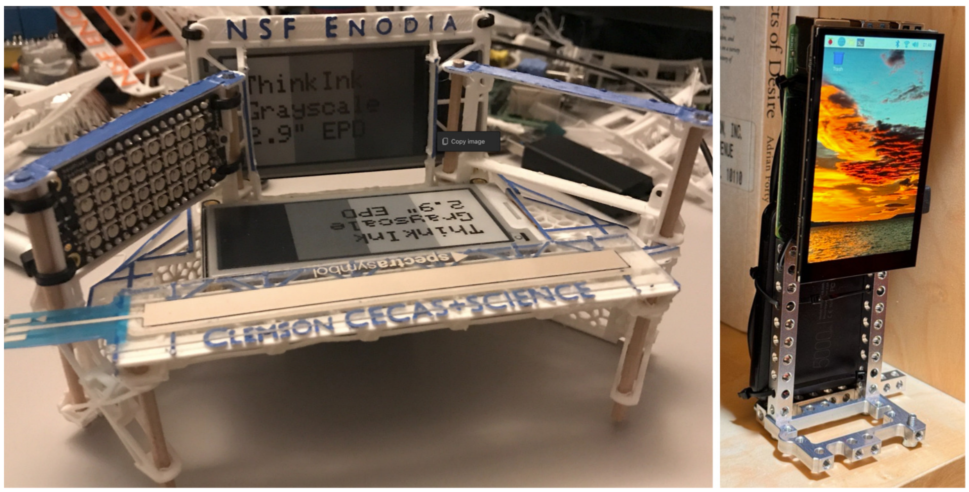

Figure 3: a) partial scale cyberphysical prototype integrating two grayscale epaper displays, two addressible RGB LED matrices (intended to back-illuminate paper overlay), a touch strip,and 3D printed structurals.b) partial scale cyberphysical prototype integrating a touch-sensitive LCD display, Raspberry Pi 4B+compute driver, and GoBilda aluminum beams.

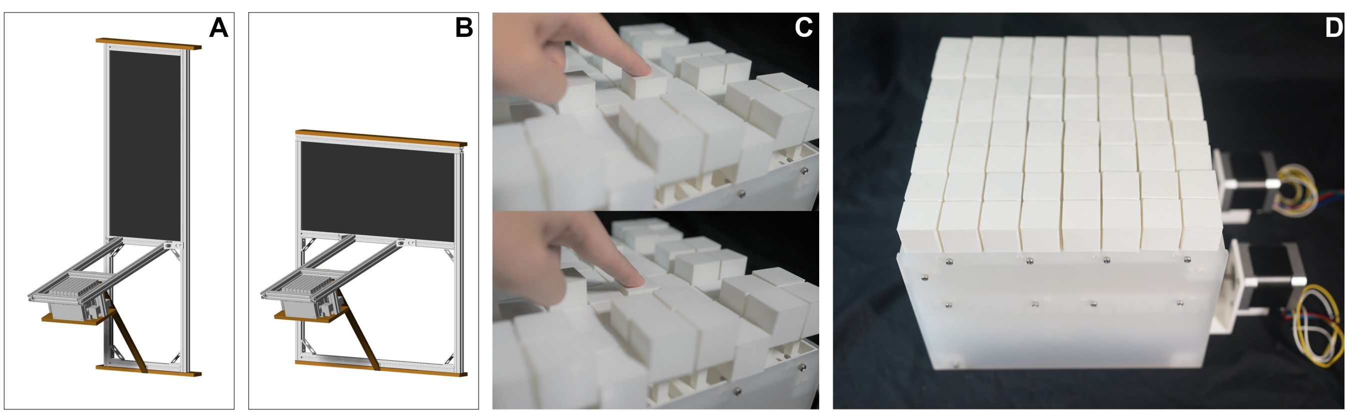

Figure 4: a) basic interaction unit, vertical display configuration; b) ibid, horizontal display configuration; c) interaction with MorphMatrix tangible interface system elements [4]; d) assembled MorphMatrix tangible interface with dual driving stepper motors

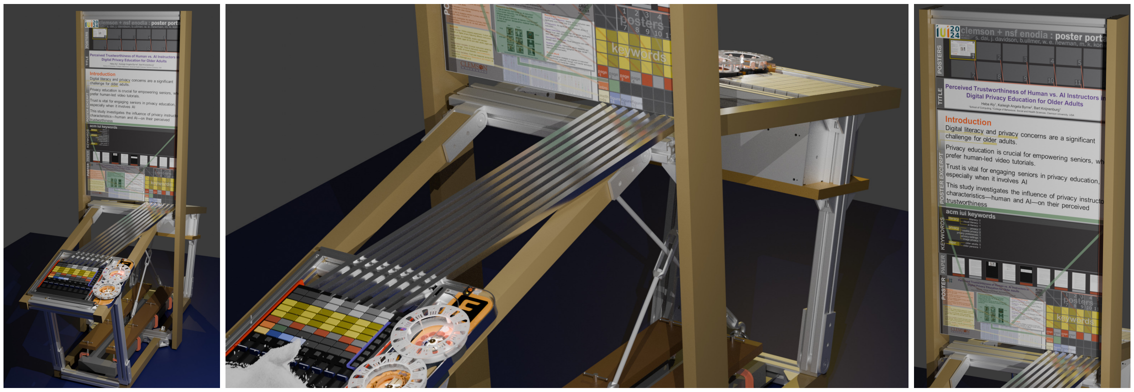

Figure 5: a) late-stage virtual prototype of two vertical-orientation screen configuration,integrating interactive digital poster presenting [2].b) inset on juxtaposition of Akai APC Mini Mk2 with hexplinth tangible interactors [11] with bottom of large-format display, with spatial mapping interlinked using aluminum tubing; MorphMatrix [4] visible on the opposite side. c) inset displaying in-progress screen contents, for interactive rendering with PyGame Zero.Complementary representational zones labeled on the left, with transparent lines depicting mapping to either the Akai MIDI controller grid or the MorphMatrix, as well as curated AI-extracted keyword linkage with complementary conference articles, Wikipedia entries.

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