Cartouche: Conventions for Tangibles Bridging Diverse Interactive Systems

Brygg Ullmer[1,2], **Zachary Dever**[2], **Rajesh Sankaran**[2,3], **Cornelius Toole, Jr.**[1,2], **Chase Freeman**[4],
Brooke Cassady[5], **Cole Wiley**[1,2], **Mohamed Diabi**[1,2], **Alvin Wallace, Jr.**[1,2], **Michael DeLatin**[2,3],
Blake Tregre[1,2], **Kexi Liu**[1,2], **Srikanth Jandhyala**[1,2], **Robert Kooima**[2], **Chris Branton**[1,2], **Rod Parker**[4]

Louisiana State University: Dept. of Computer Science[1], Center for Computation and Technology (CCT)[2],
Dept. of Electrical Engineering[3], Graphic Design Program[4], Ceramics Area[5]
ullmer@lsu.edu

ABSTRACT

We describe an approach for a class of tangible interaction elements that are applicable across a broad variety of interactive systems. These tangibles share certain physical, visual, tagging, and software conventions, while fostering diversity in many aspects of design and function. Building on related techniques using paper and graspable artifacts as interactive embodiments of digital information, we propose several fixed and free parameters, present illustrative examples and applications, and discuss the resulting design space.

Author Keywords

core tangibles; domain tangibles; cartouche tangibles; tangible menus; tangible interfaces; reality-based interaction

ACM Classification Keywords

H.5.2: User Interfaces (D.2.2, H.1.2, I.3.6)

General Terms

Design

INTRODUCTION

The tangible interaction community is experiencing great vitality and growth, but tangibles remain relatively uncommon outside lab settings. What forms might tangibles take, in a time when they are common? How, where, when, why, and by whom might they be used? [17] Who might design and manufacture them; where, of what materials, and with which trajectories through time? And what implications might prospective answers have today for our community's efforts?

While details are unknowable, progress by the tangible, embedded, and embodied interaction (TEI) community suggests several broad trajectories. Some systems seem likely to converge toward general-purpose tangibles upon illuminated interactive surfaces – e.g., physical handles which are readily shared across diverse applications (cf. [12, 27, 29]). Other tangible interfaces seem likely to continue and expand the use of specialized physical forms embodying particular information and operations (cf. [10, 18, 40]).[1]

We see these two paths as examples of a special/general tradeoff. While a continuum, we feel present momentum tends toward the edges – i.e., either toward general interactive surfaces inheriting many of the strengths and limitations of mainstream graphical interaction, or toward isolated microworld "point systems" [16, 38].

We believe there is significant value in a middle ground. Here, a subset of tangibles might share conventions where certain physical and digital properties are consistent, while many other aspects are left free to take on diverse forms and behaviors. Specifically, we propose, demonstrate, and discuss the implications of conventions describing:

- a regular constellation of physical footprints, partially consistent with both ISO/metric and U.S. standards;
- a general approach for employing ensembles of tags; and
- supporting visual structures and digital descriptors.

Beyond these, we see many design and engineering dimensions as unconstrained, including height, shape, physical material, visual form, and software integration.

We describe embodiments of this approach as "cartouche tangibles." These serve as containers and controls which physically+visually reference and describe online digital information [15, 18], cast within forms and conventions to aid their identification and passage between diverse interactive environments. Ideally, common usage expectations can also apply to cartouche tangibles. We believe this approach could carry a number of advantages, including:

- *interoperability:* enable increased interoperability – both by a given tangible across multiple applications on a single interaction platform, and across diverse platforms.
- *composition:* open new prospects for functional composition between multiple tangibles – both between tangibles explicitly designed to function together, and among broader, more open-ended ensembles of tangibles.

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[1] While common approaches, these two paths do not represent the whole of activity in the TEI community. We regard these as a useful departure point for discussions, while hoping our approaches are applicable to other tangible interfaces and interaction genres.

- *decoupling:* help decouple the interwoven design and engineering concerns (e.g., electronics, software, mechanics) of tangible user interfaces (TUIs). This has implications for participation by new communities, where (e.g.) a person skilled in traditional physical crafts but of limited technical expertise can design tangibles, knowing their artifacts will be operable across a wide diversity of systems.
- *attention:* help mediate attention in complex environments.
- *authentication:* facilitate security for ID, licensing, etc.
- *aggregation:* provide paths for single physical artifacts to legibly, actionably represent multiple digital associations.
- *bridging interaction genres:* facilitate use of tangibles across diverse interaction genres – per [19] et al., broaden pathways for integrating tangibles in virtual reality, augmented reality, convention GUIs, and other interactive systems.
- *spanning multiple physical scales:* provide a non-arbitrary path toward diverse physical scales, from jewelry to landscape, addressing diverse design contexts and constraints.
- *fabrication:* suggest specific paths for reproducibly fabricating and distributing certain tangibles, including both paper, "relief," and three-dimensional forms.
- *network effects:* building upon the above, strengthen prospects for tangibles which have value individually, and substantially increase in value as their numbers grow.

We next consider related work contributing toward our proposed conventions and objectives, including our use of the term "cartouche." We then introduce several example usages and consider our proposed fixed and free parameters, illustrating these with example cartouches, before returning to our leading questions in the discussion.

RELATED WORK

Our work builds upon two particular lines of argument and a broad body of related work. One motivating thread is the concept of core tangibles – physical interaction elements serving common roles across a variety of tangible and embedded interfaces [37]. The "cartouches" of this paper are conceived as a particular class of core tangibles, building directly on the "tangible menu" concept introduced in [37]. Another foundation is the observation of certain modal forms among many tangibles and systems, prospectively as affordances relating to human anatomy [14, 36]. We seek to employ modal forms with the set of artifacts described here.

More broadly, our work has been shaped by many precedents and influences within and outside the human-computer interaction community. One longstanding thread is the use of paper or plastic cards specifically designed as carriers of digital information. These typically draw heavily from visual (e.g., text + graphics) design languages. Early examples include the action, variable, and number cards of Perlman et al.'s Slot Machine [28]; and the paper storyboards of [23], each divided into three regular partitions in fashions directly relevant to our work. Other examples include [4, 7, 18, 26, 34]. While we not are aware of common visual conventions, most have adopted credit or business card form factors.

In addition to these purpose-designed paper artifacts, there is a broad tradition of using pre-existing paper artifacts as interfaces to interactive systems. Examples include paper pages [33, 41]; books [3, 35, 42]; sticky notes [20, 24]; and maps [24]. These benefit from rich existing design and work practices, leveraged by computational mediation.

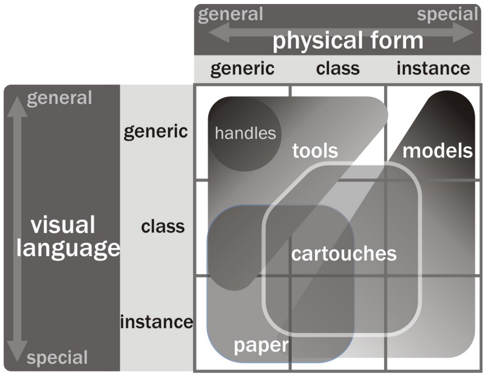

Figure 1. Relation of tangibles to physical form and visual language: *movement in increasing specificity – from generic, to class, to instance (using language from computer science). Several regions associated with genres of tangibles are identified. Some are filled with gradients; darker regions loosely indicating increased frequency for the associated approach. [40].*

In Figure 1, we illustrate paper-based and other genres of tangibles from the design standpoints of physical form and visual language. While there are exceptions, our examples suggest paper-based tangibles tend to employ relatively generic physical forms and relatively specific visual language.

This contrasts with two other common genres of tangibles. First, as observed in [15], tangible tools often employ relatively generic physical form and generic visual language. This includes physical handles as in [12, 27, 29]; and more representational tools like the clocks and wands of Urp [40]. As also observed in [15], another genre of tangibles – described alternately as phicons [18], tokens [15], or models [40] – tends to employ literal or abstracted physical representation, often with little use of text or visual imagery.

In this paper, we focus on cartouches as a prospectively distinct genre of tangibles. As illustrated in Figure 1, we see cartouches as sharing physical and visual characteristics with tangible tools, models, and paper-based interfaces, but also spanning previously unaddressed design spaces. Cartouches are applicable to both to novel and prior functional roles employed by earlier tools, models, and paper-based tangibles.

CARTOUCHE TANGIBLES

This paper builds upon and extends the "tangible menu" concept of [37]. There, tangible menus were described as "integrating aspects of graphical and culinary menus; file dialogs; web pages; phicons; and the container concept." Tangible menus of three "standard sizes" were discussed: one of 2.5"x 3.5" (playing card-sized); one of double width (5"x3.5"); and one of double width and height (5"x7").

We seek to preserve these form factors and the range of applications described in [37]. Simultaneously, we feel several aspects of the "tangible menu" name are potentially limiting. While we still see benefits in the term, a number of instances we have developed and envision do not seem well-described as "menus." The earlier identification of three physical sizes

		x-in	0.6	1.3	2.5	5.0	10.0	20.0	40.0
		x-cm	1.6	3.2	6.4	12.7	25.4	50.8	101.6
y-in	y-cm		4	5	6	7	8	9	10
0.9	2.2	E							
1.8	4.4	F		DF5:*B10*	*B9*				
3.5	8.9	G			DG6:*B8*	DG7:*B7*			
7.0	17.8	H				DH7:*B6*	*B5*		
14.0	35.6	I					DI8:*B4*	*B3*	
28.0	71.1	J						*B2*	*B1*
56.0	142.2	K							*B0*

Table 1. Dimensions of cartouche tangibles: *subset centering on the DH7 = 5"x7". The corresponding metric format, CH7, is equal in size to ISO B6. ISO B-series formats are highlighted in light gray.*

raises questions of whether other sizes are possible; and if so, following what pattern. Here, we propose a systematization based on the ISO B-series paper formats, also allowing larger and smaller sizes, as well as varying aspect ratios (Table 1). Also, [37] states that "tangible menus are spatially partitioned according to a consistent format," but without elaboration; and that "[tangible menus] may be diversely tagged, including RFIDs and front or rear barcodes," without describing how this might be realized. We describe approaches for these in the "Fixed Attributes" section.

We have grown attracted to the French term *cartouche.* We are aware of several different meanings:

1. *Egyptian hieroglyphic:* A distinctive oval frame indicating that the enclosed text is a royal name [31]. The cartouche was instrumental in deciphering the Rosetta Stone [8]. We find this inspiring for tangibles which work to bridge the interaction languages of diverse systems [19].
2. *cartridge:* Literal translations include cartridge, carton, and shell casing. In modern French, cartouche is used as a name for data or game cartridges [2].

The combined meanings of *cartouche* seems a compelling fit for generalization of the tangible menu concept.

EXAMPLES BRIDGING DIVERSE INTERACTIVE SYSTEMS

We have introduced cartouches as tangibles which follow certain conventions, serving as foundations within and bridges between diverse interactive system. We introduce three genres of interactive systems which employ cartouches:

- in combination with interactive walls, tables, and rooms;
- with custom interaction kiosks; and
- with conventional fixed and mobile displays.

Engagement with interactive walls, tables, and rooms

Our first cartouches were in response to requests from users of an immersive display wall (described and pictured in [37]. There, a number of applications and demonstrations were driven by a scientific visualization software environment. Prior to our efforts, normal use required a mixture of immersive interaction with VR-based 3D menus, and frequent trips to a keyboard/mouse console. Both production users, demo-givers, and the developers sought new ways to make "reference-in-absence" access to data and operations.

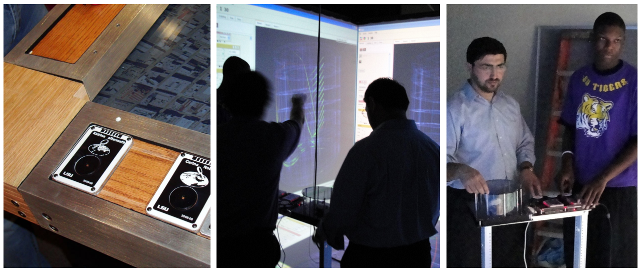

Figure 2. Cartouches on table and in CAVE: *a) cartouches on a TacTile multitouch interactive table. b) cartouches used in podium-based interaction devices in immersive CAVE environment; c) two CAVE users interact with cartouches to access data and operations in eyes-busy context (in development; here, podium moved outside of CAVE).*

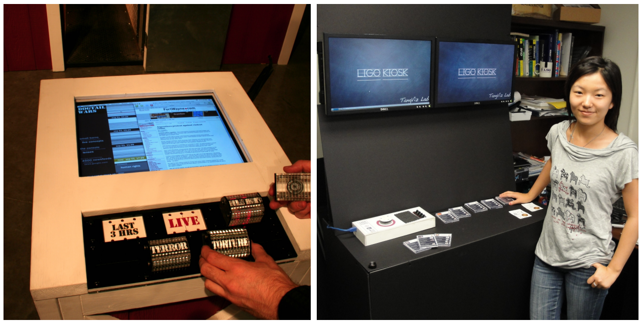

Figure 3. Cartouches with interaction kiosks: *a) sculptural cartouches used to access live news feeds from interaction kiosk in kinetic sculpture museum exhibit (deployed at two sites for multiple months). Streaming results from cartouche-based searches displayed on in-built screen and trigger agitation of sculptural elements. b) cartouches used to access information, games, and quizzes on a K-12 interaction kiosk (in development).*

A second example is in combination with a multi-touch interactive table [11]. Here, we investigated how some representations of data, applications, and controls could be moved from dynamic screen real estate to the rim of the interactive table. Our approach leverages the persistence of tangibles in reflecting and manipulating the state of (e.g.) running applications on the table. Another motivation related to providing capabilities for easily migrating information between the table and nearby workstations (e.g., by domain scientists).

When presented at SIGGRAPH'09, we noticed many unaided visitors placed cartouches directly upon the illuminated table, as is common on some existing interactive tables. This is accelerating our efforts to operationally combine RFID+visual tags; and to provide graphical and print visuals to help users employ cartouches. Our RFID capabilities also proved important for table operability, as show floor lighting nearly obscured normal touch-based launching.

Another related application is in CAVE environments (Figure 2). As with our wall and table applications, we seek to provide access to users immersed in the CAVE itself (absent a keyboard/mouse); and to enable easy migration of content between the CAVE and other interaction environments.

Interaction with custom kiosks

Our second usage context for cartouches is within custom interaction kiosks. As with the wall, table, and CAVE, our kiosk applications have been environments where a mixture of open-ended and restricted access is desired. Deployments include several museum installations; the SIGGRAPH'07 show floor; and informal education contexts (Figures 3a,b).

Figure 4. Cartouches with desktop screen: *a) single user simultaneously controlling multiple visualization applications. b) two co-located children and two remote children to collaboratively control shared visualizations.*

Interaction with desktop and meeting room displays

A third class of use is with conventional desktop and meeting room (wall-mounted) displays. These have included single user; co-located multi-user; and distributed multi-user applications (Figure 4). Users have included scientists, university students, elementary students, and the general public. Applications have included control of visualization environments, navigation of multimedia content, and engagement with other legacy and purpose-built applications.

FIXED ATTRIBUTES

We propose conventions for three cartouche attributes: a constellation of physical footprints; ensembles of visual and RFID tags; and visual structures and digital descriptors.

Footprint conventions

We propose to constrain the physical footprint (base profile) of cartouche tangibles to a rectangular form factor/bounding box, with sizes following integral multiples of width and height. This family of formats is illustrated in Table 1. We align our approach with the dimensions of playing and trading cards (2.5”x3.5”); the ISO B8 paper standard (2% wider and 1% taller); and the broader ISO B-series. We consider the credit card-sized ISO ID-1 alternative in the discussion.

A number of benefits follow from these formats. From a mechanical perspective, standard footprints allow cartouches to be designed with expectations they can be physically accommodated across diverse supporting systems. Conversely, supporting systems can be designed with expectation of compatibility across varied cartouches. Compatibility may be expressed in the form of physical surfaces or receptacles sized to accommodate one or more sizes of cartouches[2], and also via printed and dynamic visual footprints. These include graphical regions on interactive surfaces (e.g., [27]) and mechanically constrained receptacles (e.g., [36]).

We have adopted this constellation of footprints for several reasons. One relates to inclusiveness for different physical sizes. Reflecting on culinary influences of the “tangible menu” term [37], we realized few restaurants choose to print their dining menus on playing cards. This observation lead us to explore both larger and smaller physical formats.

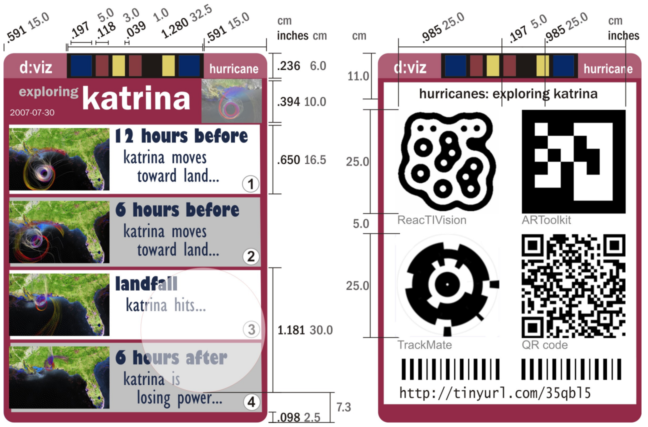

Figure 5. Layout of DG6 cartouche tangibles: *a) front, with silhouette of 30mm RFID tag visible in bottom right; b) back, with barcode ensemble.*

Another reason, illustrated by DataTiles [30], relates to the composition of multiple tangibles. With size doubling, smaller tangibles can combine in width or height to the dimension of the next-larger tangible. Our belief in the potential of tangible composition has been a driver for our efforts.

Regularization has other pragmatic benefits. Twice the width of the playing card format (5”x3.5”) is a standard photographic and notecard format in the U.S. Similarly, double width+height is 5”x7” – again a standard photographic format (with common metric analogues). Consequently, there is widespread, inexpensive, diverse, growing availability of physical media; storage products; and printers for these formats. We hope these synergies can offer significant applied support for the creation and use of tangibles.

As a numbering scheme we propose a one-letter prefix; a second letter specifying the horizontal dimension; and a decimal digit coding for the vertical dimension. For metric-referenced cartouche tangibles, we suggest ‘C’ as a prefix (referring to **c**artouche); for inch-referenced formats, we suggest the next letter, ‘D.’ This is illustrated in Table 1. The metric-referenced series would begin at CA0 (roughly 1 x 1.4mm); the imperial version, DA0. The 2.5”x3.5” playing card format would hold the abbreviation DG6; the metric version (equivalent to ISO B8), CG6. We do not find this numbering scheme appealing in spoken language, and use other terms (card, bar, etc.) in daily practice. However, given the diversity of forms and aspirations for international use, we feel a standard identification scheme has value.

Tag layout conventions

Standardizing the footprint of cartouche tangibles has implications for standard tag placements, as well as for tag ensembles supporting the cartouche concept of interoperability across diverse interactive systems. A number of tag technologies require close proximity between the tag and tag reader. For example, we sense our current cartouche tangibles using embedded RFID tags. Our supporting interaction devices incorporate a commercial RFID antenna which has a read range of less than a centimeter. Also, we currently tag our cartouches with RFIDs having a diameter of 3 cm.

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[2] Cartouche tangibles can also be accessed with systems that do not incorporate rigid, fixed-format access surfaces. Wearables (e.g., the gloves of [21]) and mobile devices (e.g., cell phones) offer specific examples. In parallel, we find access surfaces and receptacles to be attractive for reasons articulated in [36].

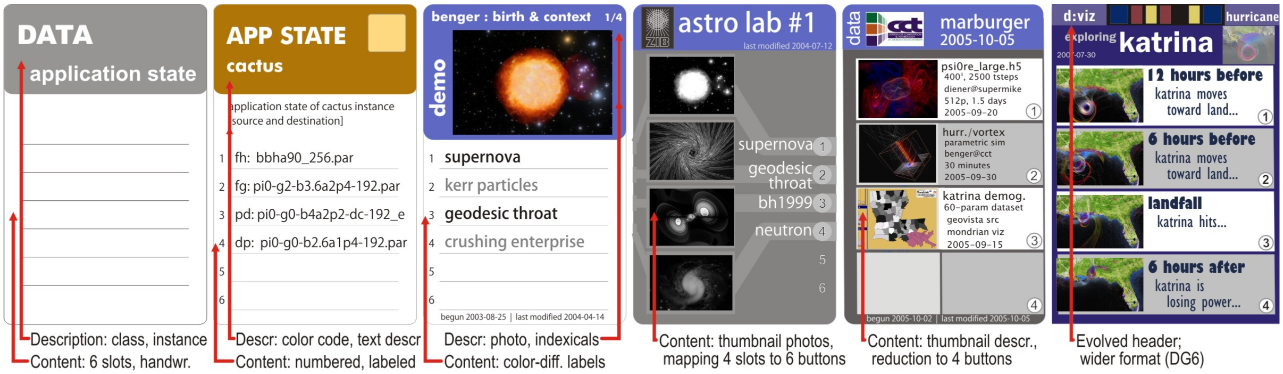

Figure 6. Design evolution toward DG6 format (a-f). *Figure 7 depicts further evolutions. Portions blackened to preserve anonymity for review.*

For interaction devices to support a variety of tangibles with such tagging, standardizing tag locations is thus important.

We see a variety of tradeoffs between RFID, 1D and 2D barcodes, dot paper, and other tagging technologies; and feel one can reasonably anticipate the co-existence of multiple tag technologies indefinitely forward. Given this, rather than suggesting convergence toward a single tag technology, we propose the use of tag ensembles. Our approach includes a colorbar intended to be both machine readable, and human-identifiable as a distinctive identifying mark for cartouches.

Figure 5 illustrates our current candidate for this code, drawing upon [39] and [10]. This uses five rectangles of red, yellow, or black, framed by two blue squares. From a machine perspective, these serve as trits (trinary digits) coding for an address space of $3^5 = 243$ distinct patterns, flanked by a lead-in/lead-out. From a human perspective, the complementary colors provide a relatively harmonious, distinctive visual design element for identifying cartouches and communicating certain expectations about digital behaviors.

This $\sim$8-bit address space is not sufficient to uniquely identify all cartouche tangibles. Instead, the cartouche colorbar serves as a readily visible (both to human and machine eyes) "relative address" that can be temporarily paired with the cartouche tangible's unique ID through sensor fusion with an embedded RFID(s), back surface barcodes, or other tag(s). For systems employing top-down computer vision, alternatives include the use of compact visual codes (e.g., bocodes [25]); flipping cards on demand, allowing foveation on back-facing 2D barcodes; or the use of front-facing 2D barcodes in invisible (e.g., IR or UV) ink. For the colorbar, we see tradeoffs between representing high-order or low-order address bits, indicating the class or instance of objects.

Tag ensembles: As previously discussed, our pursuit of tangibles that function across diverse systems suggests a combination of RFID and visual tagging. There is existing work in combining RFID and barcodes [9]; multiple co-present barcode symbologies [1]; and multiple co-present RFIDs [6]. Common motivators include international shipping (in the presence of differing local standards), supply chain compliance, and migration between standards. The TEI community's needs impose additional constraints relating to performance, resolution, cost, and identification (object presence, class, unique identity, or locally encoded information).

Figure 5b illustrates a candidate cartouche tag ensemble we have tested. We are also testing invisible IR/UV codes, allowing the back surface to be used for human-readable information. As in [1], different constellations of codes might be appropriate for different applications – even for the "same" cartouche. Also, different tag technologies can exhibit complementary properties. For example, a TrackMate code [22] may support high framerate tracking without providing a globally unique ID. Tracking this with (e.g.) fixed wide-angle under-surface camera(s) could be used to guide foveating camera(s) to read a cartouche's unique QR Code (a higher-bitrate barcode common in Asia) at an inferred location.

Visual layout conventions

Building upon our footprint and tagging proposals, a next step concerns approaches for visually/physically labeling the "contents" of cartouches in ways legible to humans and congruent to sensing and display mediation. An additional objective has been to support ways to associate and engage multiple digital associations within individual tangibles.

Six waypoints in the evolution of DG6-format cartouche tangibles are illustrated in Figure 6. The front surface of Figure 6f and 5a's DG6-format cartouche is divided into three general regions: a 16mm header; four 16.5mm content cells; and a 2.5mm footer. The header is split into two subregions. The upper 6mm band centers on the cartouche colorbar, flanked by 15mm-wide indexicals (borrowing from the design of playing cards), each with shorthand text or graphical identifiers. These are designed for legibility when held in a hand or stacked with vertical or horizontal offset. The header base is populated with human-readable text and graphics.

We envision being able to use the same cartouche tangibles with quite different sensing and display systems; e.g.:

- *capacitive sensing and rear-illuminating displays/lamps*, allowing direct touch-selection of content cells;
- *multitouch display worksurface*, allowing direct or adjacent selection, and screen side- and rear-illumination;
- *integrated electronics* in cartouches or adjacent trays [37].

As a cartouche is migrated between different systems, designers can expect mediating capabilities will vary; e.g., back-illumination or touch-sensing may or may not be present.

We have experimented with rendering the “same” cartouche in different media (see Figure 7) – e.g., paper vs. wood+glass – for different audiences. These choices of materials also impact mediation. We sometimes fuse two or more content cells together. Also, we have implemented examples which subdivide individual content cells into arrays of subelements. We see this as especially attractive when combined with stylus-based interaction (partially in the style of [30, 33]).

Figure 7. Illustration of diverse forms in cartouche formats: *a) diverse form factors (DH7, DH6, DG8, and DE5; rendering); b) stacked, boxed cartouches with edge labels (back edges show cartouche colorbar); c) relief cartouche, with static pegs representing conference publications (inset); d) relief cartouche with back-illuminated ridges representing parameters (prototype); e) mixed media cartouche with aluminum frame and two-tone surface; f) ensemble of cartouches integrated within concept drawing of interactive representation of 16k-core supercomputer. Each of four vertical banks to be represented with a DJ10 cartouche composed of back-illuminated stained glass DH7 cartouches; g) mixed media identity card, co-designed by inner city youth and undergraduate student; h) sculptural cartouche with DG6 footprint and four inserted DG6 cartouches.*

Software infrastructure conventions

There are many software dimensions underlying the use of cartouche tangibles. For cartouche tangibles to be potentially interpretable across diverse systems, digital conventions are required. Key elements include metadata format; distributed metadata storage and permissions schemes; and application event APIs. We briefly elaborate on these in the implementation section. Specific objectives include:

- access from diverse programming languages and platforms;
- support for scalability and backward compatibility; and
- function in both online and disconnected environments.

FREE ATTRIBUTES

We have discussed a number of fixed parameters proposed for cartouche tangibles. At the same time, many design parameters remain free to designers, developers, and users:

- *visual layout:* beside a few constraining sizes and alignments, most aspects of visual layout are open to designers.
- *physical design:* many aspects of physical design remain free variables, including material, thickness, texture, and relief. Several examples are illustrated in Figure 7.
- *digital design:* most aspects of digital design remain unconstrained. At a software level, these include the digital content and operations, API and protocol, and (perhaps most exciting to us) different grammatical compositions between different cartouche tangibles. The specifics of tagging, sensing, and display technologies also remain compelling open-ended dimensions for development.

IMPLEMENTATION

Implementing cartouches involves a wide range of activities. We briefly identify and describe a subset of these.

- conceptual, visual, and mechanical design;
- software for specifying text, graphics, etc. describing the cartouche’s appearance and digital associations;
- software for generation of the cartouche’s facade;
- reader technology for identifying the cartouche;
- software for retrieving and processing metadata associated with the presence and manipulation of the tangible;
- software for mapping cartouche-related events to triggering of supporting software systems.

Visual design and implementation: We have tended to use graphic design software like CorelDRAW, Adobe Illustrator, or Intaglio for initial cartouche design. Sometimes, all visual design has remained confined to these tools, with metadata associated manually. We have also had success with automatic generation of cartouche tangibles based upon design templates. Our approach has been to insert special strings – e.g., `<<textCell1>>` – in the desired fonts and locations. Then, we export an XML-based .SVG file, which is parsed with appropriate libraries in Python, Java, etc. After combining with the metadata, a PDF or design file for fabrication can be generated, sometimes customized, and printed.

Mechanical design + fabrication: Cartouche tangibles integrate visual and physical substrates with tagging elements. We based initial efforts on RFID-encapsulated ISO ID-1 plastic cards, labeling these with printed or thermo-rewrite paper. After shifting to the formats described in Table 1, we evolved several approaches. One involves paper cartouches, often with adhesive RFID tags. With heavy paper, the cartouche can be self-standing. We use lighter papers with semi-rigid plastic sleeves or boxes, originally for protecting trading cards and photographs. We also use layered designs fabricated with laser cutters and machine tools (Figure 7).

Tagging: The particular barcode types and arrangement of Figure 5b is an example, and likely subject to evolution. In principle, there is some risk of interference between computer vision libraries for different 2D barcodes. We have tested cartouches with the TrackMate vision library [22]. Tracking was stable, with no loss of tracking on TrackMate tags, and no false recognition of other tags. For RFID, we have used Philip HiTag and EM-Marrin 125 kHz tags in a variety of encapsulations, read with a bladed IBtechnology RFID reader [32]. We place these tags at the lower-center-right of the DG6-format layout, centered with respect to a DF5 (∼domino-shaped) southeast quadrant. This allows short-range (possibly arrayed) readers to read DF5, DG5, DG6, DH7, and other formats of cartouche tangibles. The particular RFID tag selections, their physical arrangement, and underlying reader engines are topics for future research.

Software: Many software dimensions underlie the use of cartouche tangibles. We summarize early steps below.

- *metadata format:* we anticipate support for multiple metadata formats will be important. After evolving several ad-hoc flat file and language-specific formats, we are currently implementing systems using XML RDF N3.
- *metadata storage and distribution:* we expect multiple mechanisms are likely to coexist. After early uses of SQL and filesystems, we currently use Subversion (SVN) as a storage and distribution mechanism. This has desirable properties for online and disconnected operation; weaknesses include speed and centralization. We suspect Git and future technologies will eventually prove preferable.
- *messaging protocols and APIs:* for distributing interaction events describing the presence, identity, and manipulation of cartouches, we first used ad-hoc sockets and XML-RPC; we now use ICE, and are evaluating Elvin as multi-language, multi-platform intercommunication engines.

DISCUSSION AND FUTURE WORK

We began our introduction with several leading questions, and now return to consider them. Regarding future tangibles and the general/special spectrum of physical+visual forms, we feel both general purpose and highly specific tangibles will long persist. Complementing these, we have identified a number of advantages which could result from conventions relating to physical+visual form, tagging ensembles, and underlying information descriptions and software, toward a new class of tangibles we describe as cartouches.

We have chosen the word "convention" over "standard." Various forms of standards could be a future step; development and use by others engaging with diverse systems, applications, and audiences would be an important precursor. In support of the standards prospect, Friedman asserts "without standards, there can be no real innovation" [13]. This speaks to our mention of decoupling and network effects.

In parallel, there is wisdom in the adage "the great thing about standards is that there are so many to choose from." We are not aware of explicit alternative proposals in the TEI community – particularly with regard to physical form – but see strong arguments for alternate (perhaps parallel) conventions. A number of tangibles have employed 5cm- and 10cm-squared and -cubed forms [36]; [30] uses a $(7.5cm)^2$ footprint. These could be points along a complementary trajectory. In fact, we typically use cartouches upon ensembles of $(10cm)^2$ tiles [32] as a design decision in this direction.

Many TEI groups (including our own) have used the ISO ID-1 credit card format. This could serve as an interoperable alternative for our DG6/CG6 forms. As G6 is slightly larger (6..19%), device footprints accommodating G6 also accommodate the credit card format; the converse is not true. Additional support for our approach comes from the aligned ISO B-series standard; composability with larger and smaller cartouche forms; and widespread industry support with storage and management products for the DG6, DG7, DH7, and C-format (ISO B-series) forms (perhaps among others).

embodiment of data and applications	general		core operations
device configuration and state			compositional uses
expanded interaction real estate			multi-device interaction
niche eyes-busy applications			
scientific workflows	science	business	software licenses
screening masks for large datasets			advertising, goods
lab/field annotation			games, entertainment
telepresence, instant messaging	cultural		trading, collectibles
culturally-specific digital content carriers			social networking
souvenirs, gifts, commemoratives			identity cards

Table 2. Examples of broader application areas of cartouches

Radial forms seem important to TEI, and are appropriate targets for parallel conventions. We have not tested our cartouche colorbars with computer vision, and do not claim our colorbars, 2D barcode ensembles, or visual layouts as stable conventions. Rather, we propose that variations or analogues of these – and more generally, of all our proposals – would serve valuable roles for tangible interaction. We neither seek nor wish cartouches to be universal replacements for other kinds of tangibles. However, when there are not strong reasons to the contrary, we have argued adoption of cartouche conventions carries many present and future benefits.

Usage: how, where, when, why, and by whom?

Toward these leading questions, our one-word summary response – consistent with responses at the TEI'08 conference panel [17] – is *diversely.* The publications of TEI have vividly illustrated the broad and growing diversity of applications for tangibles. We have summarized and augmented some of those we see as relevant to cartouches in Table 2.

Like many physical artifacts of work and home, we suspect tangibles may tend to find their way into niche physical contexts – say, a meeting room table or living room bookshelf – and often reside within a few meter radius throughout their lifecycle (whether days or decades). The varied nature and roles of rooms and buildings, of human presence and activities within them, and of the physical + visual materials of co-present artifacts, present rich opportunities for diverse cartouches to knit into the ebb and flow of daily life.

Design+manufacture: actors, materials, and temporality

Additional leading questions related to the design and manufacture of tangibles in general, and cartouches in particular. In time, we suspect many tangibles are likely to be produced in similar locations as other consumer electronics, driven globally by labor costs and availability. Other tangibles seem likely to be produced with minimal labor by end-users on personal printers and fabricators.

As we have moved to complement cartouches of paper and plastic with others of wood, metal, stone, glass, and clay (Figure 7), we have been inspired by implications of materiality for the design, art, and craft communities. With objects such as music boxes, there has long been a decoupling between the industrial makers of "movements" and (sometimes) craft producers of the physical interfaces themselves. We feel the embrace of conventions for certain classes of tangibles could support such decouplings in the TEI community. This could have powerful implications for tangible composition [30] and network effects.

In time, these trajectories could lead to crafting of tangibles by broad communities of skilled hands across both developed and developing regions. Some such artifacts, like wine glasses, might in time evolve to universal forms. Others might employ culturally-specific forms and visual traditions which might serve as compelling carriers for (e.g.) live music and virtual presence from specific regions. In a time when consumer electronics may face lifecycles of a year or less, amidst a world increasingly concerned with sustainability [5], we see the shaping of tangibles with prospects for well-worn passage to functional heirloom status as both an aspirational and attainable goal for the TEI community.

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