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ABSTRACT
Casiers are a class of tangible interface elements that structure the physical and functional composition of tangibles and complementary interactors (e.g., buttons and sliders). Casiers allow certain subsets of interactive functionality to be accessible across diverse interactive systems (with and without graphical mediation, employing varied sensing capabilities and supporting software). We illustrate examples of casiers in use, including iterations around a custom walk-up-and-use kiosk, as well as casiers operable across commercial platforms of widely varying cost and capability.

Author Keywords
core tangibles; cartouche tangibles; casier tangibles; tangible interfaces; reality-based interaction; slotted widgets

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 has grown rapidly for more than a decade. Some common research platforms have begun to gain broad traction (e.g., [4,5]). However, tangibles which serve common roles across multiple applications on a given platform – and especially which function across dissimilar platforms – are not yet widespread. Several papers have argued such developments could be an important foundation for broader adoption of tangible interfaces, framing these ideas in terms of *core* and *domain tangibles* [24, 30].

The objective of core tangibles is to provide common, interoperable interface elements for physically embodying digital information and operations within and between a variety of interactive systems. Example systems include tangible user interfaces (TUIs), other reality-based interfaces (RBIs) [15], and traditional graphical user interfaces (GUIs) and their more recent variations (e.g., multitouch). Domain tangibles are more specific physical+digital elements, often both in form and function, which are frequently particular to specific application domains, datasets, etc.

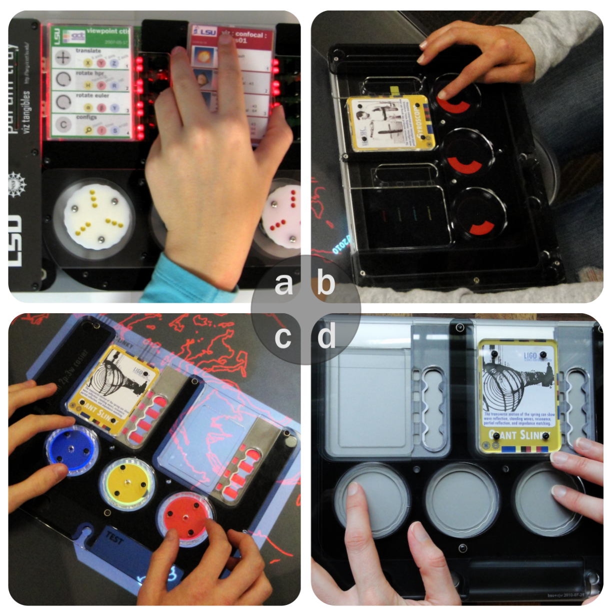

Figure 1. Casier operating across different platforms: *(a) standalone tray from [20]; (b,c,d) casier on Apple iPad, Microsoft Surface, Wacom Bamboo Fun – systems marked by diverse sensing, display, and cost. This is prospectively compatible with many other interactive systems.*

One example of core tangibles, cartouches, has been discussed at some length [24]. Cartouches serve variously as physical containers, tools, and tokens for representing and engaging digital data and operations [13, 14, 31]. They are distinguished from other tangibles in several respects. Cartouches employ a regular constellation of physical footprints, supporting both mechanical interoperability and the composition of multiple cartouches. Other cartouche conventions include an identifying visual mark (the cartouche colorbar, with both humanly and computationally legible representational aspects); ensembles of visible and RFID tags; and metadata and protocols supporting interoperability.

To be meaningingfully employed, cartouche tangibles must be used in combination with other interface elements [24, 30]. For example, interoperability across diverse physical contexts raises the question of how cartouche-capable interaction locales can be identified by users. This includes interface loci supporting the use of cartouches in general, and also interface compatibility with specific subclasses of cartouches (e.g., operations, parameters, or data).

Another property of cartouches relates to expanded interaction "real estate" – the ability to represent interface content both on and off dynamic interactive display surfaces. Moreover, the design of cartouches is intended to support multi-cartouche composition (e.g., as illustrated by the multi-tile composition of DataTiles [19, 24]). Taken together, these suggest the potential desirability of migrating cartouches on and off different systems collectively as groups of elements.

In this paper, we extend and generalize "interaction trays" [24, 30] in a class of core tangibles and a conceptual approach we call *casiers*. We introduce several examples of casier tangibles which frame the manipulation of cartouches across several interaction platforms. We discuss implications for interaction real estate and composition. Finally, we consider implications for paths by which tangibles might find broader incorporation within our physical environments, and some of the design, technical, and community opportunities and needs that likely shape these prospects.

RELATED WORK

Casier tangibles build upon a long series of related work. Most directly and recently, they extend the interaction tray concept [30]. Building upon this and [24], we extend interaction trays with conventions for an open-ended constellation of form factors; tagging and interaction mechanisms supporting interoperability across different platforms; visual conventions that complement cartouche colorbars [24]; an improved conceptualization; and a broader set of examples.

The introduction of interaction trays briefly referenced Bricks, MagicBook, and DataTiles as related work [7, 12, 19]. In Bricks, the GraspDraw drawing system introduces a "physical tool tray" integrating two sets of digitally-bound receptacles [11,12]. These include a 2x3 array of circular "ink-well" compartments, each with a unique color binding; and a linear array of six rectangular compartments bound to "brick" function bindings (each labeled with both text and icons). Both sets of interactors operate by "dipping" the brick handle into the respective compartments.

The Bricks tool tray was located off the ActiveDesk display surface, thus providing extended interaction real estate. The tray also provided passive haptic feedback. Per [11], "the physical tool tray has advantages in that the user always knows what functions are available (predictableness), learns the approximate gesture to get to the tool, and can use the physical constraints of the tool compartments to make a coarse, imprecise, ballistic gesture to activate the tool."

The MagicBook system describes books containing a series of paper pages, with each page bearing a combination of printed text, imagery, and visual codes parsable with computer vision [7]. In text labeled "putting everything together" in the context of a tangible augmented reality interface, the authors describe using a "[magic]book as a menu object... one stack of tiles as *data tiles*... [and] *operator tiles*... used to perform basic operations on the data tiles" [8].

DataTiles is a system of transparent, RFID-tagged acrylic tiles used in conjunction with an illuminated surface that senses tile placement+ID as well as pen gesture [19]. The function of each DataTile is labeled on its rim. Many DataTiles also have "partial printing" – fixed information that is printed or etched onto the tile – and/or "grooved widgets" – passive haptic constraints which guide the motion of a stylus. On placement upon the display worksurface, DataTiles are back-illuminated with interactive text and graphics. This content responds to the composition of multiple tiles (a "physical language" expressed by juxtaposing application, parameter, container, and portal tiles); to stylus-based interaction within and between tiles; and to the software dynamics between the underlying constellation of DataTile applets.

As with these examples, we seek to leverage augmented interaction real estate (both in the presence and absence of augmenting dynamic graphical displays). We endeavor to engage and extend the kinds of passive haptic feedback within Bricks and DataTiles; the multi-page ensembles of interaction surfaces within MagicBook; and the open-ended composition and multi-device ecologies of DataTiles and TAR tiles [8]. We are particularly motivated by the ways DataTiles and TAR tiles span multiple interaction genres, and similarly seek to realize interfaces relevant to a range of reality-based interfaces [15] and modern graphical interface variations.

A number of other past systems are also relevant and inspirational to casier. The Slot Machine was built around a set of colored bars, each containing a series of slots within which cartouche-like action and data cards could be inserted [17]. Building upon Bricks, the metaDESK system used "phicons" (physical icons) with a physical tray, which was described as an analog of GUI menus [25]. The mediaBlocks and tangible query interface systems mapped sets of physical racks, pads, and slots to digital operations, which were used in conjunction with a set of media-tagged blocks and wheels [26, 27]. ToonTown, LogJam, and QBA also mapped physical racks to digital operations performed upon physical data-tokens [9, 10, 22]. Strata/ML, a predecessor to DataTiles, also used systems of RFID-tagged transparent tiles with partial printing and grooved widgets on an ensemble of back-illuminated, pen tracking worksurfaces [29].

Each of these systems employs mechanical constraints to channel and map digital semantics upon the manipulation of digitally-tagged tokens, per previous discussions of token-and-constraint and relational object semantics [21,28]. Generally, these constraints have been tightly integrated (both from electrical + mechanical fixturing and software integration perspectives) into existing ad-hoc interfaces.

CASIER

With casier, we seek to de-integrate and generalize the compositional use of tangibles with diverse interface platforms, allowing reuse and composition between multiple applications and systems. We begin by considering the casier name, then elaborate upon some of casiers' distinctions from prior work before continuing with specific examples.

Earlier work introduced interaction trays as a generalization of the tool tray term and concept introduced by Bricks [12, 30]. We regard this as a potentially enduring term, with a stronger case for continued use than the tangible menu term [30] (reconceived as "cartouche" in [24]). In parallel, we have interest in a term that, like "cartouche," has multiple complementary nuances; is applicable across diverse embodying physical scales and mediums; and invites generalizations and broader applications. We are also attracted to terms from languages other than English, partly motivated by efforts toward culturally-specific tangibles.

One candidate is the Japanese term 盤 (ばん, "ban," with an English pronunciation closer to "bon"). This term's ensemble of meanings includes a tray, bowl, phonograph record, grid, and board (as in board games) [1]. Among other attractions, many of these artifacts have proven fruitful points of departure for tangible interfaces. However, the typical English pronunciation of "ban" seems likely to yield confusion. The term we suggest, "casier" (pronounced "kah-zee-ay"), is a French word with meanings including pigeonhole or set of pigeonholes, filing cabinet, rack, compartment, and locker [2]. The term resonates with the earlier "cartouche" usage [24], and has been supported by French colleagues.

Operability across diverse interaction platforms

A primary function of casiers is to identify and structure the use of cartouches and other tangibles in combination with other interaction elements, in fashions operable across diverse interactive systems. This can take several forms. First, an individual casier can function without modification on different interactive systems. For example, the casier pictured in Figure 2 contains no internal electronics (beyond RFID tags), and currently functions on the Wacom Bamboo Fun, Apple iPad, and Microsoft Surface platforms. Casiers can also incorporate significant supporting electronics. For example, the "parameter tray" of [20, 30] is is implemented in [20] with active electronics, and here without; we seek to make both addressable by identical software [23].

Form factor conventions

In introducing core tangibles, several specific form factors for tangible menus (cartouches) and interaction trays (casiers) were described [30], with an assertion that these had implications for tangible interoperability and composition. The introduction of cartouches [24] extended this concept from three specific sizes to an open-ended constellation of physical sizes. This proposition partially mirrored the ISO B-series formats and common imperial-unit approximations (e.g., 2.5×3.5", 5×3.5", and 5×7"), but also supporting alternate

Figure 2. Views of new param casier. *This casier currently operates on Microsoft Surface, Apple iPad, and Wacom Bamboo Fun (multitouch+pen), and likely is compatible with numerous other platforms. a) View from design software. A graphical "halo" is visible surrounding all detected tangibles, with cartouche and casier colorbars graphically "extruded" as an indication the correct artifact is detected. b) View as placed upon Microsoft Surface. Three rotary "slotted widgets" are present. In Figure 1c, these are pictured with Surface-tagged wheels inserted. Here, they are pictured with touch interaction bounded by the passive haptic constraints. Two cartouche pads are present, each with four adjoining button/slider slotted widgets. The left pad is occupied by a cartouche. All interactors are placed so as to allow functionality on the sensing surfaces of both the iPad and Bamboo. RFID sensing by supporting electronics is being realized from underneath the Bamboo, and alongside the iPad. The three holes at the bottom of the casier facilitate storage within a traditional three-ring binder.*

aspect ratios. However, while trays with several different physical footprints were illustrated, only one tray form factor was proposed: letter (8.5×11") or ISO A4.

Just as the original "tangible menu" dimensions were found limiting, we have found need for larger and smaller trays than letter/A4, and also for different aspect ratios. In response, we propose conventions for varying casier footprints modeled after the system proposed for cartouches [24] (Table 1). As with cartouches, we envision a halving and doubling of form factors, this time referencing ISO/DIN A and the U.S. letter series. This yields many of the advantages for casier as described for cartouches – storage and organizing products, available media and printers, etc. There are also size complementarities between the ISO A and B series (and their imperial approximations) which support cartouche+casier composition.

		x-in	1.4	2.8	5.5	11.0	22.0	44.0	88.0
		x-cm	3.5	7.0	14.0	27.9	55.9	111.8	223.5
y-in	y-cm		4	5	6	7	8	9	10
1.1	2.7	E							
2.1	5.4	F		FF5:*B10*	*B9*				
4.3	10.8	G			FG6:A6	FG7:*A5*			
8.5	21.6	H				FH7:*A4*	*A3*		
17.0	43.2	I					FI8:*A2*	*A1*	
34.0	86.4	J						*A0*	
68.0	172.7	K							

Table 1. Dimensions of casier tangibles: *subset centering on FH7 (U.S. letter, 8.5"×11"). The corresponding metric format, EH7, is equivalent in size to ISO A4. ISO A-series format parallels are highlighted in light gray. (Cartouches were proposed with prefixes beginning C and D, for metric and imperial units, respectively [24]; we suggest E and F as prefixes for casier formats.) As with cartouches, these abbreviations are not envisioned for end-users, but rather for clarity in work by designers and developers.*

Visual conventions supporting legibility

One challenge with tangibles – especially those intended for walk-up-and-use contexts – relates to how users can distinguish between "ordinary objects" and those loaded with digital semantics. The prospect of ecologies of tangibles raises the question of which tangibles can be expected to interoperate, and which not. Once interaction begins, how can diverse systems consistently communicate with users that their physical interactions are being interpreted (and with what consequence)? These issues relate to the five questions for sensing systems posed by Bellotti et al. (esp. #2 and 4) [6].

One strategy introduced in [24] is a specific colorbar, with both human- and machine-legible aspects, which labels cartouches. We have attempted to carry forward this strategy in several ways. First, we also label casiers with these colorbars, thus identifying them as physical/digital artifacts (Figure 2a). Second, we have investigated several ways to embed "shadows" of these colorbars, as well as colored borders matching cartouche colors, within casiers on cartouche pads (e.g., Figure 4c). Third, we are beginning to employ digital shadows [14]/halos of cartouches and casiers on graphically-mediated surfaces as a feedback mechanism (Figure 2).

CASIER EXAMPLES AND DESIGN EVOLUTION

Building on the interaction trays of [30], we have conducted two extended design studies and deployments of casier. These are a walk-up-and-use tangibles-based interaction kiosk; and several FH7-format (US letter-sized, page-format) casiers initially designed for use across the Apple iPad, Wacom Bamboo, and Microsoft Surface platforms. These each illustrate the casier concept and our associated design evolutions.

Walk-up-and-use kiosk

Our first effort has been in the context of a walk-up-and-use use interaction kiosk designed for informal science education, with middle school students (age ∼11-14) as the target audience. This effort is aligned with a regional science education center (operated within a national science facility) which conducts extensive outreach activities throughout the state. State education personnel expressed interest in extending the "hands-on" style of science exposure afforded by the science center exhibits, but in lower cost, computational variations potentially deployable in schools, libraries, and other public venues.

Figure 3. Mid-stage implemented kiosk + envisioned next-gen iteration. *In left (implemented) kiosk, a relatively long (32x7"), black casier with captive cartouches and a haptic navigation wheel is visible as manipulated by a student. In the right (envisioned) view, five casiers on two worksurface tiers are depicted. Four are for storage (potentially sensed and illuminated) of thick (here, 3.5x2.5x2.5") and thin DG6 (card) cartouches. The lower-center casier houses a composition of data, operation, and parameter cartouches on an iPad touch-display surface (see Figure 5 for inset).*

Several views of our developing kiosk are pictured in Figure 3, with inset views of our developing casier and cartouches in Figures 4 and 5. In an early kiosk prototype, we employed a small standalone casier, surrounded by a small ensemble of cartouches (Figure 4a). We quickly encountered concern from those familiar with informal science installations and middle schools that this style of approach might not fare well (at least unattended) in our target contexts. We were encouraged to develop a "hardened" approach geared toward an active audience inclined to "move whatever moves."

In our next kiosk generation, we attempted to follow this advice. We decided to engage with graphic design collaborators in most visual aspects of the kiosk, including the kiosk façade and cartouches (Figures 3a and 4b). This variation employed the same interactors as the first generation, but with recessed buttons and indicator LEDs that allowed captive cartouches to slide over the cartouche interaction area.

This installation included four cartouches, each associated with a subject area relating to space science. Each cartouche contained four subregions: details, video, explore, and quiz. These contained introductory images and navigable video, small games, and simple review quizzes associated with the given subject area. Interaction was expressed through placement of a chosen cartouche on the cartouche interaction pad; selecting a category of interaction with the selector buttons; and rotating and pushing the selection wheel. Feedback relating to this interaction was graphically mediated on the kiosk's left embedded screen; video, game, etc. content was primarily channeled to the right screen.

Our team had very limited previous experience in the targeted deployment context. Interaction was intentionally limited both to increase likelihood of the kiosk's physical sur-

Figure 4. First three generations of kiosk casiers. *a) Standalone casier (4×10"), including embedded selection buttons and rotor. b) Embedded casier (32×7") with captive cartouches. c) Evolved casier and cartouches.*

vival, and to reflect the small initial corpus of accompanying digital content. We deployed this system in our collaborating science education center for several months.

Focusing here on lessons relating to the kiosk's casier and cartouches, one major finding related to interaction legibility for first-time unsupervised visitors. This was most users' first experience with cartouches (by this or any other name). For a number of visitors, it was not clear how to engage with the system. It was not obvious that the cartouches should be moved within their captive channel; that the adjacent recessed buttons should be pushed to trigger content; or how the physically-offset rotor played into the interaction.

We also felt there were challenges relating to the cartouche and casier visuals. The graphic designers had no prior experience with designing cartouches, and faced a very tight deadline (far earlier than anticipated). We expressed general interests to them, and shared a copy of [24]. In retrospect, [24] seems oriented to academics, and not (e.g.) practicing graphic designers. We also did not express a specific brief, identify design challenges to be resolved, or provide many exemplary reference examples. We implemented the casier, without sufficient attention to how it complemented cartouche visuals. We feel these decisions were problematic.

Consequently, we conducted a third design iteration on the kiosk's casier and cartouches (Figure 4c inset). In this, we:

- selected a border color for cartouches, and used this color to indicate cartouche interaction areas on the casier;
- included a thumbnail image on each cartouche and visual icons complementing each subfunction (video, quiz, etc.);
- faced the casier with a silhouette hand and short text highlighting the cartouche interaction buttons; and
- added back-illuminating LEDs to the cartouche pad, thus directly illuminating selected subfunctions on the cartouches.

We returned this third iteration to the field, and received more positive feedback from staff and visitors. Ultimately, the kiosk faced larger conceptual and content challenges. Simply adding tangibles, even with attention to design, was not enough to ensure a strong overall interaction experience.

Implications of early kiosk experiences for casiers

These first kiosk experiences raised many questions and possibilities for next-generation casier design. As one example, we followed the cartouche form factor conventions described in [24], but did not initially envision form factor conventions on the casier iterations of Figure 4.

After spending time with our second-generation kiosk, an education professor challenged us – "the laptop is tough competition; you need to go beyond what's already possible there!" This led us to feel our intentionally conservative initial design was in fact too conservative, with success likely depending upon high-risk entangling of physical and digital media.

To our surprise, embracing this challenge seems to have implications for casier form factor conventions. As we began to plan integration of robotic and multitouch interaction into the kiosk, each design alternative seemed to potentially transform the kiosk's physical structure.

From this and other experiences, we came to believe that one way to support frequent TUI iteration – both from physical design and field end-use perspectives – was to systematize the footprint and other aspects of casiers. This could allow their modular exchange and (potentially) ad-hoc composition. This might resemble the kinds of tangible composition realized with DataTiles [19] and envisioned for cartouches [24] (albeit perhaps at longer time-scales). This led us to propose Table 1, and to adopt a revised design approach for the remaining interfaces of this paper.

As another lesson, while the cartouche proposal explicitly sought operability in the absence of dynamic displays [24], at least as a bootstrapping process, learning to use a new medium requires considerable user education. Even highly successful interaction platforms like Apple's iPhone and iPad make use of explanatory animations and text labels for tasks as basic as unlocking the home screen. Thus, we have begun to re-embrace use of animated graphics with input-space proximal to output-space (at least for some system elements), even as many of our envisioned casier applications have no dynamic graphics capabilities.

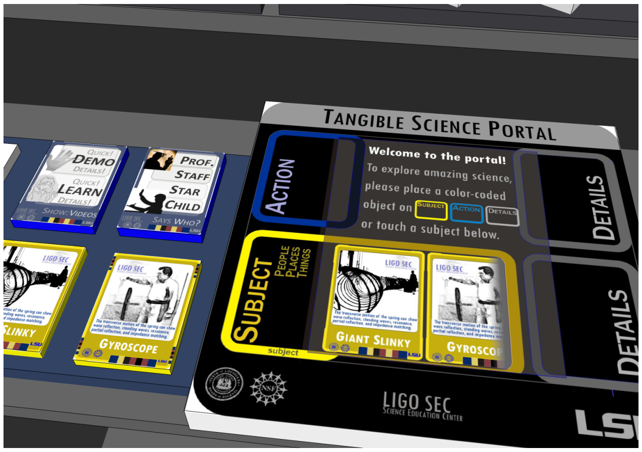

Figure 5. Next-generation interaction kiosk casier (envisioned). *Inset view of Figure 3b, described briefly there. Several color- and text-labeled classes of cartouches (blue action, yellow subject, gray details) mate with both physical casier constraints and dynamic touchscreen graphics.*

Figure 6. Example of two FH7 (letter page) three-wheeled parameter casiers used on a Microsoft Surface.

Casiers for heterogeneous interaction platforms

After embracing the integration of richer sensing and display technologies with casiers and cartouches, we began to consider different interaction platforms for bearing out this functionality. We were also attracted to the prospect of casiers that could function across heterogeneous interaction platforms. An example envisioned casier employing such capabilities for our kiosk is illustrated in Figure 5.

We began work toward interoperable casiers with the Wacom Bamboo multitouch tablets. We noted the smallest family member – the Touch – physically fits within our second- and third-generation kiosk casier. From a sensing perspective, this raised the prospect for supporting some of the intertile physical gestures demonstrated by DataTiles [19] – potentially both with stylus and touch. With the more recent release of Apple's iPad and our laboratory's acquisition of a Microsoft Surface, the diverse capabilities and costs of these platforms nicely complemented the Bamboo. This lead us to co-design casiers toward all three platforms.

As a point of departure, we initially focused upon a casier reimplementing the three-wheeled, two-pad "parameter tray" of [30]. Figures 1, 2, and 6 illustrate an FH7-format (8.5"$\times$ 11") casier which functions in combination with both the Microsoft Surface, Apple iPad, and Wacom Bamboo Fun platforms. Each platform senses the casier, cartouches, and interaction with casier interactors in a different fashion[1].

Figure 6 provides a view of multiple casiers in operation. One casier is placed directly upon the Surface's sensing+display region. The casier and its three physical wheels are recognized and tracked with four separate visual Surface tags. On the right, the same casier is placed upon an augmented Apple iPad. The TouchOSC iPad app is used to sense touch-based wheel and button interaction. The casiers' wheels allow parametric interaction with a Deepwater Horizon visualization, complementing Surface-based spatial interations.

As pictured, the iPad-based casier sits upon the Surface, but is placed outside the Surface's sensing+display region. The Surface's active work area is relatively limited, and would quickly be obscured if many Surface-tracked casiers were simultaneously in operation. Using casiers as shown with the iPad both increases interaction real estate, and allows casiers to be used (literally and conceptually) on and off the Surface. Among other implications, this allows both colocated and distributed collaboration with more people than could fit around the Surface's physical perimeter.

We have also implemented other casiers on both the Surface and iPad. Figure 7 illustrates one simple casier (again, FH7/letter format) which contains four DG7 (5x3.5") cartouches. These are special cartouches which, like the earlier parameter casier, employ what we call "slotted widgets." Grooved widgets provided passive haptic guidance and constraint for the tip of a stylus [19,29]. Slotted widgets perform a similar function, but for (finger-based) touch (potentially as well as stylus, depending upon the sensing platform).

Like grooved widgets, slotted widgets allow users to manipulate "soft widgets" while attending visually to visual screen real estate, conversation partners, or other demands that require visual attention. Unlike grooved widgets, slotted widgets do not necessarily require a stylus, thus offering reduced "set-up/tear-down" time, at the cost of increased physical real estate and lower precision. Also, our examples of casiers on the Surface (Figure 2b + 6) illustrate a case where parameters can be manipulated either through slot-constrained touch contact with the Surface, or using a Surface-tracked knob as a physical proxy. We see this as another attractive, promising usage modality of slotted widgets.

IMPLEMENTATION

To realize our kiosk casier implementations (Figures 3a, 4), we used the blades and tiles hardware/software library [20]. This hardware performed well for us, especially after we replaced the inter-tile connector from the original USB con-

[1] As discussed in Implementation, we have verified RFID-based cartouche sensing on the iPad and Bamboo platforms, but not yet stably integrated software or hardware for this function.

Figure 7. Ensemble of cartouches using slotted widgets on an iPad-backed casier. *Four DG7 cartouches describing different aspects of a scientific data flow are present within an FH7 casier on an iPad. Each cartouche – one data, one operation, and two parameter – makes different use of slotted widgets, illuminated and sensed by the iPad. Here, the iPad touchOSC app is the backing software.*

Figure 8. iPad-backed casier in use with a tiled display: *Six upper casier regions (illuminated and sensed by the integrated iPad tablet) are used to select presentation options upon the tiled display. A line of six lower casier regions allows selection of which screen is displayed (paralleling content on the tiled display's lower border). The tile display includes an integrated G8a-format (4.3"×33") casier, upon which cartouches expressing alternate screen content and behaviors can be placed.*

nectors to a dual-row rectangular header. (When early tiles were mechanically fixtured, the USB connectors were vulnerable to electrical noise.) The mechanical structure of Figure 3a was built around a Metro-like modular wireframe shelving system, with wooden substructure and a printed adhesive vinyl-coated Sintra (closed-cell PVC foamboard) façade. Graphics on the two VESA-mounted kiosk screens were generated with internally developed PyGame software, hosted by a low-end PC enclosed within the kiosk.

One of our group's broader goals is to help make tangibles more readily replicable and deployable beyond their home laboratory context. As our realization of casiers progressed, we felt our exclusive use of blades could impose impediments to replication by other groups. We were also interested in exploiting properties of several newly-developed commercial platforms, especially those easing the economical integration of dynamic mediating graphics.

We have designed a three-layer lasercut implementation of the three-wheeled parameter casier. We are releasing the mechanical aspects of the casier for open-source download, modification, and non-commercial use (cc-by-nc). For those with access to a laser cutter, the mechanical source files for the casier pictured in Figure 2 can be accessed at [3]. For others, this can be purchased from vendors listed at [3].

From a software perspective, our current casier implementation is ad-hoc. The Surface implementation is written in C# using WPF; the iPad, upon touchOSC (with remote parsing via Python in SimpleOSC); and on the Bamboo, via TUIO 1.1 and Python + pyTUIO. We are in the process of porting all code to a unified API provided by the tuikit middleware [23]. In the case of Surface, no supporting electronics are required – only placement of Surface visual tags to the underside of the casier and cartouches. As described in [24], we envision an ensemble of visual and electromagnetic tags allowing interoperability between different platforms.

The Bamboo and iPad require custom electronics to sense both casiers and cartouches. The Bamboo chassis and internals contain relatively little metal. As a result, in all but the center of the tablet, 125 kHz RFID readers on the rear of the unit are able to read RFID tags present on or slightly above the Bamboo's surface. This includes RFID tags embedded within casiers, as well as more vertically-offset cartouches. The Bamboo's sensing antenna appears to prevent multiple RFID readers from *simultaneously* employing this technique on a given tablet. However, the time-multiplexing strategy employed by (e.g.) the RFID blade of [20] allows multi-point RFID reading without antenna interference.

The iPad's aluminum chassis electromagnetically obstructs the Bamboo through-tablet RFID sensing strategy. This leaves several alternatives. We have found that 125 kHz RFID reader antenna with roughly 2mm horizontal offset from the iPad chassis are able to function with proximal RFID tags. This is the approach we are currently employing. In addition, placing the RFID antennas on or under the iPad's surface glass (as in [19]), or using front- or rear-facing computer vision provide additional strategies. We have tested both of these Bamboo and iPad strategies in prototype form, and are now implementing stable integrated prototypes.

DISCUSSION AND FUTURE WORK

In the history of graphical user interfaces, "real estate" has been a persistent technical and conceptual theme and challenge. The advent first of tiled windows, then of overlapping windows, are seen as important enabling landmarks in GUI evolution [16]. We feel casiers also have implications for real estate within a variety of physically-situated interactive systems. Figure 6 illustrates a clear example where casiers realize an "overlapping windows" analogue. We have also discussed casiers both "on and off the surface," an extension that resonates with [18] and broader ubicomp efforts.

Our casier example of Figures 1 and 6 builds directly on the earlier "parameter interaction tray" examples of [20,30], while the examples of Figures 3b, 5, 7, and 8 illustrate novel casier designs. We have also begun developing casiers embodying interactive maps, timelines, system diagrams, and other examples ranging from the general to the specific. Most of these casiers employ slotted widgets. Some are relatively "flat;" others engage 2.5D and three-dimensional relief; and others intended for rendering in multiple physical mediums. Thus, while this paper has illustrated a few narrow examples, we see the casier concept as generalizing more broadly.

Figure 7 raises another important question. Here, the screen real estate of the underlying tablet is almost fully occluded by cartouches. Conversely, from a real estate perspective, one could advance an opposite design decision: occluding as little screen real estate with tangibles as possible, thus leveraging representational qualities and freeing screen real estate for alternate uses. In practice, we suspect both heuristics are valuable and complementary, with many tangibles migrating frequently between more and less heavily mediated spaces.

The future of physical and electronic books is today a heavily discussed topic. We see casier and cartouches as having resonances and implications for these conversations. We have designed most of our casiers to include three-ring binder holes. Using these, we have begun to use and store binders of multiple casiers – some empty, others containing cartouches – in ways comparable to physical books. Per [24], an interesting way of viewing cartouches and casiers is as legible, actionable physical embodiments of online content. Moreover, cartouches' and casiers' use of (often cryptographically-secure) RFID gives them powerful properties as license tokens. Borrowing both from the history of tool lending libraries and the future of personal fabrication, we see personal and organizational libraries of casiers, cartouches, and other tangibles as promising prospects for TEI and beyond.

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