Ice-Bound: Combining Richly-Realized Story with Expressive Gameplay

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ABSTRACT

This paper describes the design and implementation of *Ice-Bound*, an indie game that uses dynamic story techniques. Storygames with high narrative process intensity (where story is generated or recombined in algorithmically interesting ways, rather than being simply pre-authored) are still rare, in part because story creators are hesitant to cede control over output quality to a system. As a result, most readers still encounter digital fiction in the form of linear e-books or simple branching-path models of interactive story. Getting more dynamic models into the public consciousness requires exploring new frontiers of design space driven by the twin concerns of fiction authors (for high-quality story realization) and game designers (for frequent, high-impact player decisions). Our design for *Ice-Bound* rejects both branching-path models of interactive story as well as overly simulationist approaches, targeting a middle-road aesthetic of sculptural construction that marries a focus on quality output with the player's exploration of both an emergent expressive space and an AR-enabled art book.

Through implementing *Ice-Bound*, we developed design strategies and practical lessons useful to other interactive narrative designers, including three high-level lessons. First, quantifiable metrics and tools for content authoring for a combinatorial system are essential to maintain control over such a system. Second, authors should consider embedding highly dynamic but less narratively cohesive mechanics within layers of less dynamic but more tightly authored storytelling, so each part of the story can be told within a framework to which it is best suited. Finally, iterating the design of all story layers at once leads to tighter coupling between ludic and narrative levels and a stronger narrative experience overall.

Categories and Subject Descriptors

K.8.0 [**Personal Computing**]: Games

General Terms

Design, Theory

Keywords

interactive narrative, augmented reality, game design

1. INTRODUCTION

This paper describes the design and implementation of *Ice-Bound*, an indie game that uses dynamic story techniques. As both fiction writers and game designers, we wanted to create a literary game inspired by complex fictions like *Pale Fire* and *House of Leaves* with professional-quality surface text, while also allowing players meaningful expression and agency within our story world. Our challenge was to create an experience as engaging as a good book while moving beyond the simple models of interactive structure that drive most released games in this design space.

We believe this challenge is important because most readers still encounter digital fiction in the form of static e-books or simple branching path narratives, despite the increasing sophistication of the devices we read on. While more complex narrative systems are starting to appear, most games billed as interactive stories still have low narrative "process intensity"[1]; the code governing the assembly of the story is trivial. Much experimental research into more complex generative models of narrative has either failed to mature into systems that can be used in releasable games, or is unable to produce surface text on par with readers' expectations for well-written prose and compelling stories. We believe getting more dynamic models of storytelling into the public consciousness requires an exploration of new frontiers of design space driven by the twin concerns of fiction authors (for high-quality story realization) and game designers (for frequent, high-impact player decisions). Bringing such design exploration full circle into a releasable game demonstrates that such designs are feasible and raises the bar beyond branching-path models.

We used two key strategies to achieve this goal. Our core experience targets an aesthetic of sculptural construction (defined more fully in Section 3) that attempts to marry the high output quality of more traditional interactive stories with the best elements of simulationist approaches, such as

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[1]Crawford [5] defines process intensity as the ratio of computation to the size of media assets being processed. A game which procedurally generates landscape, terrain, and music has much higher process intensity than one which loads textures, soundfonts, and 3D models; which in turn has higher process intensity than a game that simply plays a movie file.
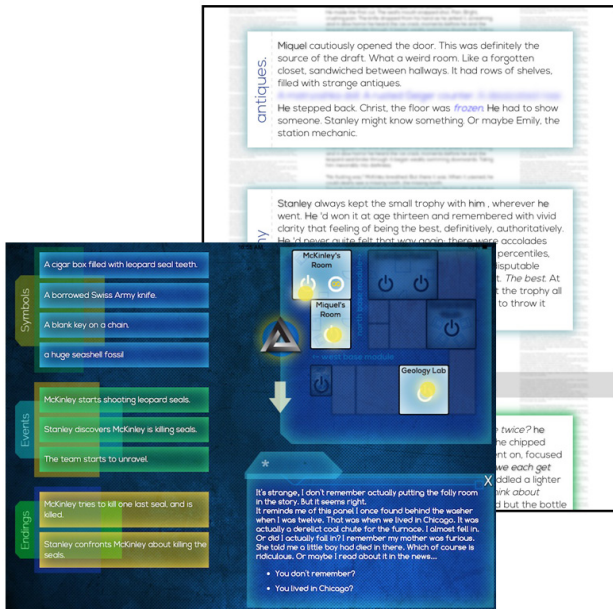
Figure 1: A screenshot of *Ice-Bound*'s landscape and portrait modes, described in Section 4.3.

continuous player agency and a focus on playful exploration of a possibility space. Players interact with a story until they've arranged it into a satisfactory state, rather than until they reach a leaf node on a tree. This more exploratory play style is embedded in multiple storytelling layers with differing affordances (Section 3, "Parallel channels of story"), letting us tell each part of the story within a framework to which it is best suited. These layers include a printed book enhanced with augmented reality (AR) and a choice-based conversation with a central character. The player can move freely between these different layers as they explore the narrative. By putting these different storytelling mechanisms in dialogue with each other, we create a composite experience that can be either more expressive or more responsive, at moments when either quality is most desirable.

Few finished and released games include nontrivial process intensity in construction of an interactive story. The remainder of this paper details the design and construction of one such game, *Ice-Bound*, as well as some key lessons learned about techniques and compromises necessary to bring a game driven by a dynamic story system to market.

2. PREVIOUS WORK

We position our novel design and technology approach in *Ice-Bound* relative to four major branches of work: AI approaches to story generation, multi-character social simulation, hypertext systems where lexia are conditionally activated, and our own prior explorations in sculptural fiction.

Experimental story-generation research. Many planning-based approaches to emergent story [24] or systems using analogical reasoning to create surprising artistic output [8] have been explored in academia, but these systems have rarely been released for designers to use or readers at large to encounter. Dan Benmergui's *Storyteller* [3], for example, is based around exploring a narrative possibility space driven

by logical story reasoning rules, but had not been finished or released as of the publication of this paper. Such complex systems are troubling both for designers and authors: there are no clear road maps to creating a successful play experience based around complex narrative systems, and the burden of authoring for them often remains immense [13]. In addition, because of their experimental nature, many of these systems do not produce output on par with the quality expected by literary audiences.

Multi-character social simulation. Two examples of released games with both high-quality surface text and considerable narrative process intensity are *Prom Week* [15] and stories released under the *Versu* brand [11]. Both systems use a complex simulation of character and social relations to determine what actions are appropriate in an evolving narrative situation. *Ice-Bound* differs from these systems in several significant respects. First, these systems are designed to tell stories driven by social politics and character interactions. Our goal was to tell a story primarily centered around a single character, with a dense, labyrinthine literary texture inspired by the fiction of authors like Borges and Nabokov. A social simulator was not useful in this context. Second, these systems take a simulationist approach of presenting a model world which moves forward with each action taken. Our design suggested a simpler model focusing on easier, reversible changes rather than long-term and cumulative effects. Finally, the flexibility of these systems can require huge amounts of content to cover all the emergent situations in a wide narrative possibility space: *Prom Week*, for instance, needed a thousand individual scenes to give the system enough leverage to perform adequately [20], and took several years to create. We would like a more agile, targeted system that offers less wide-open emergence, instead focusing more on providing interesting exploration within the particulars of our specific story.

Systems based on recombinable content. Some released text-based interactive narratives work with simpler models. The StoryNexus platform (which drives the successful browser game *Fallen London*) is based on giving the player decks of event cards limited by preconditions relating to the current state. Each card describes a situation and offers a set of possible actions, each changing the state in some way [2]. Structurally, StoryNexus is similar to a hypothetical system described by Bernstein and Greco [4] that is also based around cards with pre- and post-conditions. *Ice-Bound* uses a variation of this metaphor as the foundation of its story permutation system, and is informed by several other ideas from Bernstein's paper, including de-emphasizing the player as an embedded primary actor within the story. We also take inspiration from the minimalist aesthetic of Nick Montfort's "small-scale systems" for interactive narrative [16].

Evolution of previous work. Our aesthetic of sculptural construction is an evolution of our own previous work [19]. *18 Cadence* [21] lets the player explore a set of narrative fragments and gives them a workbench to freely arrange and combine them, with the implied goal of assembling them into a satisfying story. By changing the player's role from an actor to an editor, the piece suggests a different mode of relating to an interactive story. Another project, *From Closed Rooms, Soft Whispers* [6], encouraged playful exploration of a body of potential text through augmented reality and an interplay of printed imagery and digital words. *Ice-Bound* follows up on the ideas in these projects both by embedding

the notion of sculptural construction and free exploration within a frame story providing narrative context and momentum, and by adding a more formal system of dynamic story construction to connect the different pieces via cause and effect relationships, leading to more coherent assembled stories.

3. DESIGN IDEALS

To meet our goal of producing an experience with high-quality surface text that still involved meaningful narrative process intensity, we needed a core mechanic that relied neither on static branching nor overly simulationist approaches. We will explore the limitations of both approaches below and then offer sculptural fiction as an alternative approach.

Limitations of branching as structural model. Most commercial games that advertise interactive narrative do so through offering fixed choice points as branches in a tree. Because of the problem of a combinatorial explosion for authoring, these choice points are a) minimized, and b) frequently inconsequential (resulting in either a premature end to the story or a merge with another branch). If choices seem to be frequently ignored, the player feels less agency, which can be a source of intense frustration (see the recent angry reaction to the ending of the game *Mass Effect 3*, in part caused by a perception that the player's choices were made inconsequential [22]). Conversely if choices lead to genuinely different branches, some players will wonder what alternative content they're missing out on, especially if there is no easy way to return and try other branches. Branching structures are also problematic for replay, since much of the same content must be progressed through again to return to a previous branch point. While branching stories offer a high amount of authorial control, with all text being hand-authored, they are highly problematic for interactive narratives hoping to offer real choices and for players hoping to appreciate the full multiformed complexity of such a narrative.

Limitations of simulationist approaches. An alternative to branching is to simulate some aspect of the story world, such as its spatiality (as in parser-based interactive fiction) or social relations between characters (as in *Prom Week* or *Versu*, both discussed in Section 2). Simulationist approaches are appealing since they offer more space for playful expression within a story world and suggest the possibility of emergent behavior. Such approaches can be difficult to enact in practice, however, since sensibly describing an emergent possibility space of narrative touches on unsolved natural language generation problems. If the state of the simulation is described artifically, the player's immersion is lost; however, if its interesting aspects are not communicated, the player might fail to see what is compelling about the simulation [23].

Sculptural fiction. For *Ice-Bound*, we wanted to find a core mechanic that gave us the best of both approaches: the focused, quality surface text offered by branching paths, with the sense of playful exploration allowed by simulationist works. In [19], one author proposed the notion of "sculptural fiction" to identify works that involve frequent small but reversible decisions, to create a play aesthetic closer to a sculptor constantly refining a work than a rat navigating a maze. The focus should be on continuous, small, reversible choices, creating a playful and exploratory feel. Sculptural fiction also implies a work that is structured more like a play session of varying duration, rather than the fixed-length

interaction associated with linear time media like film: ideally, the experience should last as long as the player is interested. While some of our earlier work had explored these concepts, until *Ice-Bound* we had not designed a system from scratch around this aesthetic.

Two key design decisions helped us produce a game exploring ideas of sculptural construction. The first was to base our system around fragments of narrative that fit together only approximately instead of exactly. The creators of StoryNexus describe a similar approach as "fires in the desert" design [2]: they provide a series of interesting dramatic episodes and rules for sequencing them, and let the player imagine the less interesting connective tissue linking these key points together. Another similar concept is Scott McCloud's "blood in the gutter" term [14] to refer to action that happens "between" the panels of a comic, which the reader fills in with invented detail; this elision has also been called dramatic compression [18].

These ideas helped us evolve a system based on three chronological categories of story content, with fragments written such that internal ordering within a category is flexible: any set within a group could plausibly make sense in any order. The fragments are then presented to the player as "extracts" from a final story, implying a coherence not explicitly modeled by the system. This let us focus on the core of the experience we wanted to create—letting the player explore hundreds of permutations of stories without needing to make each one have complete internal coherence—and freed our design from getting bogged down in implementing uninteresting details. While a danger of this approach is that the fragments can seem too disconnected, we make extensive use of templating (discussed in Section 4.5) to soften edges between fragments and create more narrative continuity from one piece to the next.

4. DESCRIPTION OF SYSTEM

Ice-Bound combines an iPad app with a printed artist's book that work together to tell a full story. Each can be encountered in isolation, but the full story cannot be experienced without both; the book serves as an input mechanism to the story, and also a canvas on which additional content can be displayed (via the use of markerless tracking augmented reality). The story concerns an unfinished novel of polar exploration by long-dead author Kristopher Holmquist, and the player's attempts to help an AI recreation of him (called KRIS) to write its ending. We will describe the system at some length in this section so the design lessons in Section 5 are contextualized.

The app lets readers encounter a series of procedurally assembled stories, each framed as an unfinished chapter of Holmquist's novel. Each story is initially a possibility space, with a number of different narrative elements that can be activated or left dormant by the player. The player explores the possible stories that could result from each combination of elements, and eventually selects one they feel is the best version. This decision alters the generator such that the next story assembled contains more elements similar to those in the player's selection. As players progress through the series of stories, the novel moves closer and closer to their own aesthetic, and through interactions with KRIS players uncover more details about both the outer and inner levels of narrative.
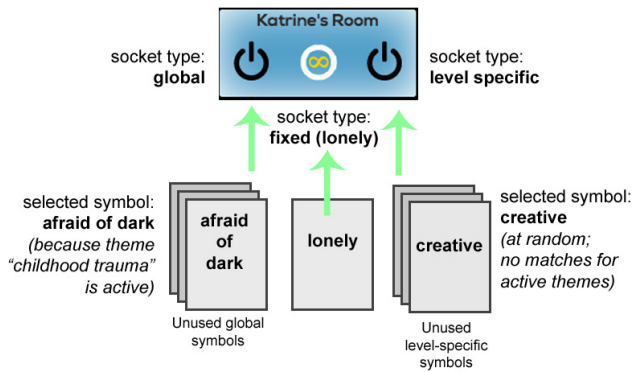
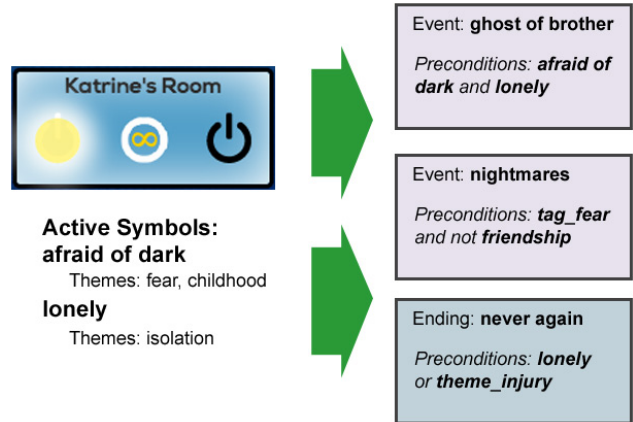Figure 2: Assigning symbols to sockets during level construction.

Figure 3: Events and endings triggered from a set of active symbols. The user has placed a light in the socket on the left, activating the symbol "afraid of the dark"; in combination with other active symbols this triggers the events and endings on the right.

4.1 System Structure

Each story is built around a map with a set of initially unfilled **sockets**. When the story is first constructed, each socket is filled in from a library of **symbols**, lexias[2] with associated metadata specifying what kind of sockets they might fit into (Figure 2). Each symbol corresponds to a potential component of the story, either a trait a character might have or the introduction of a dramatically loaded narrative element (such as a locked door or a loaded gun). Symbols have both a short summary and a longer "excerpt" containing a paragraph or two of templated text narrating a fragment of story connected to that symbol.

The system also has a library of **events** and **endings**, with similar textual content to symbols but an additional constraint of preconditions specifying when they might appear. Preconditions are usually logical combinations of active symbols. All three kinds of lexias can be tagged with **themes** that connect them with recurring thematic touchstones in the overall story. Preconditions can use themes instead of specific symbols to match broader situations. For instance, an event describing a violent argument might have as a precondition the symbol "angry" (a character trait) and "tag dark" (matching any lexia with a tag indicating something disturbing is active).

4.2 Symbol Selection

A story is defined with a set of unfilled, typed sockets positioned on a map; a cast of characters for this story; and a limited stock of **lights** which the player can put in sockets to activate them. The map is used to orient the player: each story is set on a different level of a fictional polar research station, and the position of sockets on the map indicates whether they relate to a specific character (by being placed in that character's living quarters) or a more general narrative element (for those positioned in other rooms of the station).

Sockets are filled by symbols when the story is constructed. Each socket has a type, which limits what kinds of symbols may be assigned to it. Sockets may take a) a specific symbol, b) any symbol authored for this particular story, or c) any symbol in the whole content library. Authoring a story involves creating a set of story-specific content (symbols, events and endings), but also including global sockets on the

map that can be filled with symbols written for any story.

Some sockets can be designated as fixed: permanently active, rather than switchable by the player. These sockets usually take a specific symbol and establish fixed components of a story or character. For example, in the second story of *Ice-Bound*, the character of Katrine always has the trait "determined"; this is a fixed part of her personality the player cannot change. Through this, the combination of fixed sockets with specific symbols provides the authorial affordance to highlight certain key story components to the player, making them an explicitly visible component in a system rather than simply implied through authored text.

When the first story of the game is built, symbols are assigned to sockets randomly assuming all other restrictions are met. As play continues, however, selection begins to favor symbols tagged with themes the player has expressed interest in (see Section 4.6 below).

4.3 Player Interaction

Once the story has been constructed, the player may explore it by reconfiguring their limited stock of lights (Figure 3). Placing a light in a socket makes its corresponding symbol active and visible to the player. As different combinations of symbols[3] become active, they in turn can activate one or more events and endings based on their preconditions, and these also become visible to the player. Preconditions can include any logical clause, including negation or nested conditions. Events narrate situations that happen during the story, while each ending posits a possible conclusion based on a subset of active symbols and events. The interface presents the whole story from a single view as a series of causes and effects, rather than moving through it from an embedded position.

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[2]The term "lexia" is used in hypertext theory to signify a block of text of arbitrary size [10].

[3]Mathematically, a set of active sockets for a particular build of a story is an unordered combination without repetition. If a story has k sockets and provides n lights, there are k choose n possible combinations for that story. For most of *Ice-Bound*'s stories, there are roughly 30 to 70 possible combinations *for a given build* of a level; the number of possible builds is larger.

The number of events and endings shown to a player at a given time are restricted by a ceiling of five and three, respectively, to allow a whole story to fit on one screen and avoid overwhelming the player with too many story elements at a time. Without such a culling mechanism, authors would need to worry about whether each new global event or ending might overload an existing level, which would reintroduce some of the combinatorial authoring burden we were hoping to avoid. Excess events and endings are trimmed to favor themes either the player or KRIS has deemed important for the given story.

The player can also get another view of the story by rotating the iPad from landscape to portrait mode (both views are shown in Figure 1). The portrait view (which more closely resembles the page of a printed book) shows the active symbols, events and endings as a linear series of "extracts" from a (fictional) complete story resulting from this configuration. An inline syntax for specifying alternate words or phrases lets us present these excerpts with pieces of shimmering text that morph from one word to another, to create the aesthetic effect that KRIS is constantly considering many tiny variations on the story as the player reconfigures it.

The player chooses when to switch between the two modes: landscape, which focuses on assembly, and portrait, which focuses more on passive reading. This is the first of several parts of the design that give the player multiple channels of information they can freely move between. We discuss the importance of this further in Section 5 below.

4.4 Conversations with KRIS

Another channel is provided by a window in the lower right of the interface, displaying a running commentary by KRIS, the AI author-surrogate. Each action the player can take, or any effects produced by those actions, can serve as a trigger for a large library of possible comments, which are similar to the other lexias (they can have preconditions, use templates, and so on). Some comments are passive, while others provide a button labelled "Discuss This" which opens a full-screen window offering a dialogue-tree conversation. These comments serve an artistic role similar to the extra-textual footnotes in works like Nabokov's *Pale Fire* or Mark Danielewski's *House of Leaves*: they embed the interior story within a larger narrative frame, and problematize the reader's relationship to the text. From a game design standpoint, the KRIS comments are another channel of story the player can choose to focus their attention on, one with less free-form interaction but more authorial control over the narrative arc.

While interactions with KRIS do not usually directly affect the generated story, they interact with the overall experience, both providing backstory and altering a simple state machine tracking the player's relationship with KRIS. Answers to questions and triggered comments are stored by the system, and can be referenced by KRIS in later comments: he might begin a conversation by saying "I was thinking about what we were discussing earlier..." and reference a recently-discussed comment. KRIS lexias are hand-tagged with summary metadata to support this functionality.

As *Ice-Bound* progresses, the boundary between the two levels of narrative begins to break down. Elements from Holmquist's life begin appearing as symbols in the interior stories, and events and endings might begin to refer to extradiegetic elements (such as recent conversation topics with KRIS). The fact that the conversation system and story mechanic share several core systems (such as the templating language and the processing of logical preconditions) allows this diegetic blurring to take place with a minimum of technical difficulty.

4.5 Templates

Our experience writing content for prior interactive narratives convinced us of both the importance of using templating with procedurally assembled text to reestablish context [20] and the necessity of tools to minimize authoring frustrations [19]. Because global content could be used with a wide variety of characters and time periods, it needed to be authored so that the system could deploy it correctly in a variety of narrative cirucmstances.

Easy authoring and robust error-checking. Templates that are evaluated only at runtime can cause hard-to-discover bugs, and an overly complicated template syntax can increase errors and pull authors out of a creative zone. For *Ice-Bound* we designed a template system based on expansion grammars, to let authors easily write content that could be used across many stories, but still feel specific. We designed the template syntax to be minimal and unobtrusive, removing unnecessary or hard-to-type characters such as quote marks and curly braces wherever possible. Among several ideas to simplify syntax, we allowed templates that take a single parameter to drop the parameter when it hasn't changed since the last template call. This let some template calls become as simple as adding an underscore in front of a pronoun. We also added compile-time verification that expansions were formatted properly.

Mixins for character specificity. Besides simple name and gender replacements, templates added some additional functionality, much of which was informed by our experience working with the templated text system on *Prom Week* [20]. Templates included mix-ins, generic utterances that could be filled in with a more character-specific version, if available. For instance, the mix-in "swearmodifier" has a generic value of "in the hell", so a character without this mixin defined might say "What in the hell are you up to?" However, we might give a more prudish character the value "in heaven's name" instead. A stock set of mix-ins is a simple but effective way to make a piece of dialogue feel like it was written for a specific character, especially important in a context where the sample piece of dialogue might need to work for characters coming from different historical periods. Another mix-in helping with this problem lets us provide different snippets of text based on what year the current story is set in, changing a laptop to a television to a radio, for instance, based on different time periods. Mix-ins also allow for more complicated references to the current story state, such as requesting an adjective that applies to a certain character (based on which personal sockets for that character are active), or providing different text based on what other lexias are active.

Matching dynamically changing characters to thematic content. When a lexia is made active, the system casts[4] it from a dynamically assembled pool of characters. Characters are defined for specific stories and represented as a set of sockets on the map corresponding to that character's quarters. As players reconfigure a story's lights, they can move the focus more towards specific characters by associat-

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[4]In the sense of a Hollywood casting director, not the programming term *casting*.

Figure 4: Interaction with the printed book using markerless tracking augmented reality.

ing more lights (and thereby activating more symbols) for that character. The casting of lexias can also change as the player reconfigures the level. For instance, one event might try to cast a character who has a specific symbol trait active; if the player deactivates the socket with that symbol, it must be re-cast. Themes can also be used in casting: an ending might have both a precondition and a casting request for a character who has a symbol active with the theme "fatal flaw." This lets us create an apparent continuity of characterization, chaining forward from symbols through events and endings, where paranoid characters are more likely to lash out irrationally, and brave characters are more likely to be cast as heroes.

4.6 Resolving Endings

To move on to the next story, the player must eventually conclude their exploration of the possibility space by resolving the current story to a particular combination and choosing an ending. *Ice-Bound* is not a puzzle game: there isn't a specific "right" answer to a story, and in fact all endings are written such that they could be dramatically satisfying conclusions. Instead, the players' own sense of aesthetics, as well as any information they've gleaned that seems relevant from their conversations with KRIS and interactions with the printed book, inform their decision of which ending to select.

Once an ending is selected, KRIS asks players to provide external evidence that this ending is "right" for the story. This is done by finding a page in the companion printed book that relates to the themes of the chosen ending, and holding the iPad camera up to to this page (Figure 4). The book contains fragments of textual stories alongside photographs and collages connecting to the interior narrative and the life of Kristopher Holmquist and his AI simulacrum. We use augmented reality with markerless tracking to identify individual book pages from the iPad's camera feed. Each ending and each book page are tagged with themes. If the reader shows the camera a book page that has at least one theme in common with the selected ending, KRIS will "agree" that the ending is valid, and unlock the next story for the player to explore. If no themes overlap, KRIS asks the player to try again with a different page. We also overlay images

and movies on the book page, as if the player is seeing its content filtered through KRIS's eyes and providing another channel of story information.

Once a story has been resolved with a particular ending, the ending's themes are strengthened. When constructing the next story and assigning symbols to sockets, the system will prioritize symbols that have strengthened themes. As the user progresses through the stories, therefore, an increasing percentage of global sockets are filled by symbols with story elements similar to those they've scanned from the printed book. As an example, if a user resolves several stories with endings incorporating elements of fear and dread, they'll start to see more and more stories seeded with character traits or plot events related to those themes. The player is thus "completing" a version of the story that moves slowly towards his or her own preferences of what they think the story should become.

Another complexity involves the interplay between *Ice-Bound* as a ludic experience and a narrative one. Some pages may have themes that are useful to the player to get an ending they particularly want, but also contain information it might be narratively dangerous to show to KRIS. For instance, a certain page might contain the story revelation that the KRIS simulation project was a failure. If the user shows KRIS this page, they might get a story ending they want, but at the expense of damaging KRIS's sense of self-worth or the player's relationship with him. Technically, this effect is achieved by tagging pages with additional, hidden themes that KRIS can react to, both immediately or in the future. From a design perspective, this puts the player in the difficult position of needing to manage ludic strategies with narrative consequences: are you willing to potentially hurt a fictional character to "win" the game?

5. IMPLEMENTATION LESSONS

From building *Ice-Bound* and seeing the above design through to a playable game, we learned a number of lessons about our design ideals that may be of use to other interactive narrative designers.

Effectively authoring recombinable content requires high-level metrics and tools. Since an *Ice-Bound* story is formed from a combination of both level-specific and global lexias in three logically connected types (symbols, events, and endings), knowing how much content from each category was necessary to consider a particular story "finished" was an ongoing and difficult issue. While a game based on branching paths might be complete when all important nodes on a design tree are filled in, our nonlinear sculptural model meant it wasn't as easy to tell when a story had enough content. The question at times felt like asking "how many Legos are enough" to build something satisfying? How many global versus level-specific symbols did we need? How many events and endings were required to make adjusting symbols produce visible changes to the overall story? Significantly, what we were looking for was not a formal verification process that a story was logically completable. Since there aren't right and wrong solutions to *Ice-Bound* stories, the problem was framed more as one of aesthetics: how to ensure a majority of possible configurations of both symbols into sockets (by the system) and activated sockets (by the player) produced quality stories as output.

We could establish a basic lower bound for the number of needed symbols by thinking through the implications of how

Table 1: Channels of story information in *Ice-Bound.*

Interaction Channel	Agency	Authorial/Narrative Control
rearranging symbols to explore possible stories (app landscape)	high	low
reading stories based on current arrangement (app portrait); resolving shimmering words	medium-low	medium
reading and responding to KRIS comments in simple dialog trees	medium	medium
reading the printed book	low	high
using the printed book to resolve stories	medium	medium-low

themes are strengthened through interaction with the printed book (see Section 4.6 above). For the system to maintain an ability to choose new global symbols with strengthened themes, the pool of such symbols should grow faster than the rate at which global sockets appear in story definitions. Since our design called for a sequence of eight stories, an average of three global sockets per story, an average of three to five themes per ending, and approximately 25 total themes, this was in fact the case. Some arithmetic suggested authoring at least three global symbols per theme (around 75 total symbols) would be enough to provide adequate coverage that still allowed the system to respond to player theme selection.

Determining how many events and endings were needed for an optimal experience proved more difficult. While we could play an individual story build and see if it presented an interesting range of possible stories to explore, the feel of the same story could vary significantly depending on the global symbols chosen, and how they affected the set of events and endings available to explore. We needed two things: a metric to quantitatively separate optimal and suboptimal combinations within a story, and a means to locate problem areas in the complex potential space of all possible story builds and all possible combinations of active symbols within a built story. Through playing built levels multiple times, we evolved this metric for identifying an optimal story: most combinations of active symbols should produce between two and five events and between two to three endings. This meant as the player explored the possibility space, most configurations felt like traditional stories (with more than one event but not too many) and offered a choice of endings that was neither too overwhelming nor too minimal (a single ending removes the player's agency over resolving stories; zero endings breaks the game by preventing a story from being resolved). With this metric in hand, we could design visualization tools [7] to show both how many combinations of a given story build were problematic, and how many story builds overall produced too many problematic combinations.

We believe this kind of dynamic visualization of narrative possibility space is critical for authors creating content in a non-branching structure. Each author and project has its own set of often non-quantifiable aesthetics that nevertheless need to be optimized for. Tools that let creators intuitively feel their way towards a finished piece (such as visualizations, fast iteration/feedback loops, preparsers and syntax checkers to catch authoring bugs at compile rather than run time, and so on) are vital steps towards interactive narrative projects making artistic as well as technical advances.

Parallel channels of story allowed us to be both expressive and responsive. Another key design decision was to tell the story in parallel channels or layers, each offering different affordances to the player. This approach was in part designed to sidestep the question of where to position the player with respect to the narrative. Most choice-based narratives embed the player in the story world by casting him as a character within it making decisions, and encourage the player to become lost in the fantasy of becoming that character (a sensation Janet Murray calls immersion [17]). However, to gain full appreciation of an interactive story often requires replaying it multiple times [12], even though such repetition can produce a more detached perspective harmful to immersion [9].

Instead of choosing one extreme or the other, *Ice-Bound* is structured so as to simultaneously offer layers of immersion and layers of detached perspective to the player, who can move between them at will. (The different narrative channels present in *Ice-Bound* are summarized in Table 1.) The pleasure of understanding a potential story by replaying it multiple times is offered in parallel with other channels of narrative focusing on creating an immersive, ongoing narrative context. This lets different parts of the story be told in the medium which most suits them, and prevents having to build a single system that can be at all times both expressive and responsive.

Designing and iterating story layers in tandem was critical for a strong narrative experience. While some multi-channel stories are designed to be experienced sequentially without deep systemic interrelationships (as in many "transmedia" projects), in *Ice-Bound* each channel was a crucial and co-designed component of an integrated structure, with overlapping mechanisms and an ability to affect one another. While we initially thought some of the channels could be designed independently from others, we found in practice that iterating all layers together was both structurally necessary and more artistically successful.

One illustrative example was our use of the augmented reality framework Metaio to layer virtual content onto the pages of the physical book, which we at first assumed could be designed and printed in isolation. We found that Metaio's image recognition algorithms worked best with images that have a broad range of unique colors, which necessitated the use of colorful imagery on every page of the book, even those we at first envisioned as being mostly text. This moved our design aesthetic towards a heavily illustrated look where many pages are "glitched" with colorful image compression artifacts, and altered the fictional backstory to make the book a reconstruction of a hurried and partial transmission. Increasing recognition accuracy also pushed the book towards a smaller size (so the iPad could see whole pages while being held closer) and a rougher, less reflective paper stock (to reduce image-altering glare). These changes again shifted our conception of the book to something more like a 'zine than a carefully assembled art book, which in turn shifted the kinds of images we wanted to project onto it and, in turn, themes we wanted to explore. The evolution of the

printed book's design and the AR game component (as well as each other component of the overall experience) were in continual dialogue with each other throughout design and construction, leading to a more tightly integrated and holistic final artifact. We believe this approach will lead to a final experience that meets both of our primary goals: a story that is both meaningfully interactive but also narratively satisfying.

6. CONCLUSION

While much exciting research in story generation and computational narrative has and continues to be undertaken, there are still a disappointingly small number of released, playable experiences that leverage the expressive affordances such technology allows. The state of the art for story games is still static branching trees and little to no narrative process intensity. While there has been increasing recognition for the importance of narrative in games (including a new Narrative category in the 2013 Independent Games Festival, and the proliferation of new systems since 2011 for telling text-based interactive narratives) there are not enough playable experiences demonstrating that moving beyond old models is possible, especially ones that target a broad audience. Though there are over 100 million tablets and e-book readers in the USA alone [1], almost none of them are running complex interactive stories, despite the significant computational power of these devices.

With *Ice-Bound*, we designed a game that puts some of these tensions around the future of the book in the reader's hands, envisioning a future for textual narrative that goes beyond emulating paper in digital form, and a new direction for future work in non-textual forms of interactive narrative. We are still finishing the content for *Ice-Bound* at submission time, but plan to release it in summer 2014. We hope *Ice-Bound* helps demonstrate that producing work at high enough quality to reach a broad audience is possible, while still allowing for nontrivial player participation.

7. ACKNOWLEDGEMENTS

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