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The Gernsback Machine: Towards A Museum Of Possible Futures And Probable Pasts

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Abstract

Museums have traditionally used timelines as a means of creating narratives of historical, cultural, political, geographical and social change. However, such timelines are only one aspect of a potential infinity of semantic continua, and fail to exploit fully the possibilities implicit in the objects that exemplify them. In this paper we describe the 'Gernsback Machine', a novel categorisation and navigation model based on principles of facet analysis that enables descriptive metadata terms to be located within a fully navigable universal facet tree. The navigation potential of 'step, flip or zoom' inherent in the GM permits exploration through all semantic continua, and, by allowing the users to follow their own particular threads, enables complex narrative structures to be created. We describe how the Gernsback Machine can be used to create a virtual museum space for new or existing collections, using a series of recursively defined 'bento' containers to define the museum content. We describe how our prototype illustrates the potential of the GM in exploring different aspects of the time facet, in a 'museum of the history of possible futures and probable pasts'.

Keywords: timeline, navigation, facet, virtual museum, bento, Gernsback Machine, search engines, retrieval, time concepts, space concepts, matter concepts, OAI, TGN, ULAN, CRM

Introduction

History is the science and art of the plausible construction of narratives out of such fragments as we have been left by the havoc wrought by time. Museums have traditionally used devices such as timelines to create these narratives. The simplest timeline may illustrate only a single theme, with historical events or occasions mapped against a chronology; more complex ones weave together parallel streams to produce a rich network of explicative narration (e.g. Rock+Roll Hall of Fame Museum, http://www.rockhall.com/; Metropolitan Museum of Art Timeline of Art History, http://www.metmuseum.org/toah/splash.htm; Natural History Museum's Dino Directory, http://flood.nhm.ac.uk/cgi-bin/dino/index.dsml). The history of the human race may be represented through a superimposition of the facts of fashions, reigns, civilisations, lives of famous people, culture, and technology on a common linear axis, with parallel streams sometimes representing these different threads of narrative for the same locale, and sometimes different physical or geopolitical locations for the same time-display.

Underlying all timeline displays is a set of presumptions that go overlooked and mainly unchallenged: these are to do with the commensurability of events, the correspondence between narrative structures, and the implicit assumption of the universal subjective temporal standpoint which McTaggart (1908) called 'the unreality of time': the 'God's-eye-view' that permits such temporal arrays to be strung together like beads on an abacus, each with its own measure but each in its role in the greater system. Fraser (1975) draws on Uexkull (1934) to show that such constructs are necessary subjective knowledge structures created by our sense of time, which belongs in a noetic umwelt overlaying the physical. Luce (1972) shows how our time-sense and hence our co-ordination of time's passage are necessarily embodied, and how the very selection of scale for time recording takes for granted much that must be considered in presenting a succession of events tied to a series of circadian-based sense impressions.

It is not that such systems are inaccurate or inappropriate, but rather that their use implicitly entails continuously ascending and descending a tree of interoperability to work (Figure 1). Any use of a timeline will always involve this reinterpretive nature, and this is especially significant whenever different term-sets (e.g. 1620s, 17th century, Jacobean, Renaissance) are used to describe the same moment in time.

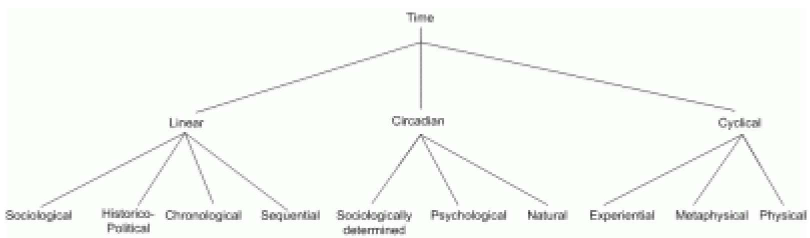

Figure 1. Tree showing organisation of time concepts.

Every comparison between a *sociological* view of history (reign, lifespan, generation) and a *chronological* one (century, decade, year) involves backtracking up this tree to the nearest common point and down again to the desired scale. As we see from Figure 1, the common ancestor for both sociological and chronological time is *linear* time. However, to move from a moment expressed as linear time to the same moment expressed as *circadian* time involves reference to the root node of the temporal tree.

Consider an example: a late summer day in England. We can determine the *linear* senses easily enough - *sequential*: 19:00/196/1911 CE; *chronological*: Saturday, 15 July 1911 AD; *historico-political*: Eventide, St Swithin's Day, Coronation Year of King George V; *sociological*: Edwardian/Georgian period - and we can move between them by common reference to the parent node of linear time. Similarly, we can move to the *circadian* sense (e.g. *natural*: early evening, midsummer; or *sociologically determined:* stumps, Saturday's cricket match) by drawing on the explicit alignment of the linear temporal with the circadian, an alignment inherent in temporality.

We can appreciate this concept more clearly if we make a small change to one of the received facts. If we change the *historico-political* value, so that we are now in the coronation year of George VI, rather than George V (but still Eventide on St Swithin's Day), then the only value that changes for the *sequential* is the year (1937 CE); the day of year (196) and time of day (19:00) will not alter. However, the *social* sense of the moment has gone from the golden dawn of a new century to the darkness of the Depression with the threat looming of a new European war. And the significance for the *circadian* values is considerable: while on a mundane level the day is now Thursday, and has all of the appropriate *sociologically-determined* circadian associations (workday, not half day), on a more sophisticated level it is unlikely to be an occasion for cricket, and much less likely to be a celebratory occasion (being further away from the Coronation date, and in a time of great austerity). On the other hand, the *natural* circadian sense (early evening, midsummer) remains untouched, as indeed it should.

If on the other hand the coronation were that of King George IV, while the change for the *sequential* would have had been similar (i.e. a change in year only), for the other senses of time the differences would be considerable. The s*ociological* sense of the moment would be placed in the turmoil of Georgian England, and while it again happens to be a Thursday, it would be the Thursday four days *before* the coronation, and the likelihood of celebration would have been high (although the prospect of cricket negligible).

We can see from these examples that, by having common ancestral terms, the inter-operation of the timescales can be guaranteed, and this is the mechanism that validates the parallelism that is involved in the multi-timeline display. As we shall discuss later, the tree structure in Figure 1 has all invocations of the temporal that are required in timeline displays, and any timeline display will always involve one or more of these categories.

Another way of examining the timeline is from the point of view of the signifiers marked along it: in other words, from the perspective of the *subject matter* that applies at the particular date. So our various interpretations of the point in time (19:00/196/1911 CE) become 'Sport, Edwardian, Cricket' or 'Harvesting, Early 20c, England' or any other combinations. The delineation on the line now becomes one of the interactions of several possible subjects of interest, and the secondary (i.e. *non*-temporal) significances are a matter of the implicit subject of display - to be in *this* timeline, it must have *this* feature. The problem of timeline representation then becomes one of multiple subject classification, one of which is always time.

The problem of classifying the temporal in determining the subject matter of documents is of course a constant problem for bibliography, and Ranganathan's (1959) distinction of a temporal 'facet' offers an insight for our timeline study. Time is only one of several continuously interacting facets of meaning operating in any high-level description of a set of facts, and to give meaning to the description must interact with other facets (space, matter, personality, etc) to give a clear understanding of the subject at hand. And every point in a timeline that has a spatial or material significance can also be represented as a point on a spatial or material continuum (effectively a 'space-line' or a 'matter-line') where the point has a temporal significance. We can then see that a timeline is a specific form of a generalised *facet continuum*, and that all such continua will have a primary facet which determines the nature of its contents, with secondary, tertiary, and so on facets qualifying the meanings of the labels used.

We can see equivalent semantic organisational hierarchies for facets other than time. The facet-tree in Figure 2 describes extension in *space*, showing, for example, *political* features (empires, nations, alliances in time) or *ecological* features (marshlands and beaches in recent history indicating global warming).

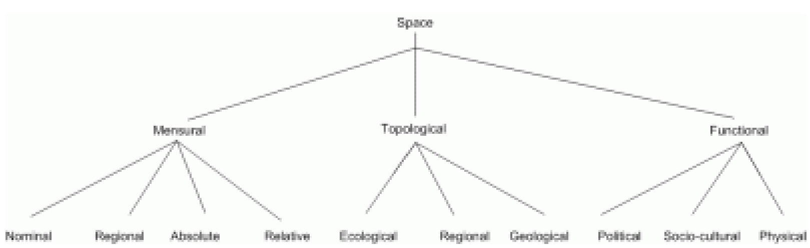

Figure 2. Tree showing organisation of space concepts.

In a similar way, we can describe a *matter* tree, for examining the instantiation of the agent and background for depicting historical events (Figure 3).

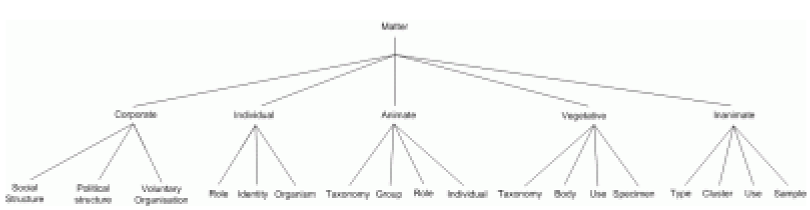

Figure 3. Tree showing organisation of matter concepts.

Beyond the root nodes of these individual facets there can be conceived a single facet tree which informs all these continua. The richness and evocative power of this tree lies in the large amount of symbolic content that can be placed within its framework. This is why timelines *per se* are so popular and ubiquitous: they have great psychological appeal, as if one had a glimpse into the engine of history, and could see the effects of causality embedded in its fabric.

Let us now return to the idea of timeline as narrative. When such timeline-based displays are conceived, their designers are effectively creating a narrative to convey a sense of time's passing to the intended audience. The events, occurrences or periods chosen for display (and perhaps more significantly, the artefacts chosen to exemplify them) are drawn from the designer's world-view, for all that they invoke the universal objective that McTaggart criticized. And when we place a series of artefacts in a line like beads on a wire, they are made into a pattern that conveys an idea of temporality, but their essentially quantal nature might equally well tell another story that fitted them.

This multiple interpretation is of serious concern to the exhibition designer - the effect of revisionism on older exhibits is to make them exposed to ridicule, for all that they had serious intention in their design. A review of art histories by Elkins (2002) shows a dangerous reliance on the European Leonardo to Picasso period, with a distorted view of the rest of human creativity. When Gould analyses historical timelines (Gould, 1987), trees of life (Gould, 1989) and categorization of race (Gould, 1981) he shows how much the designer serves as an unconscious interpreter for their audience.

Paradoxically, however, this polysemy is also of great potential benefit to the designer of such exhibitions. Given the multiplicity of potential interpretations for any point in the timeline, and for any artefacts instantiating that point, the question becomes one not of designing a timeline, but rather of selecting an interesting one from the myriad narratives implicit in the artefacts themselves.

The act of collecting and preserving that is the raison d'etre of museums cannot predict what will end up being important, nor can it say with any surety what was once important. But when making an exhibition, a pathway can always be drawn to connect and explain certain objects within a hypothesised narrative structure. This applies not only to the curator, but also to the museum visitors, who can select their own paths through an exhibition from the many possible ones that may be of interest. And the power of such narratives as educational and research tools is obvious: by creating time- and space-lines to record the contents of a collection, the users can create their own information matrix in that collection's holospace.

However, not all exhibitions will be coherent merely from the happenstance of their conjunctive orthogonality - there must be an intelligible rationale if the entire system is not to be become chaotic or anarchic in its presentation. So the challenge for the designer of such a museological information system is to try to restrict the potential to the plausible and interesting, without imposing too fixed a view onto the process of timeline creation. This leads to the establishment of a possible framework, not only for classifying objects in a collection, and for displaying them in timeline-based tours, but also for a systematic subject/facet-based interaction between collections that are geographically distinct, either within a multi-homed collection, or between different members of the museums community.

Bearman and Trant (2002) in a recent critique of museum Web practices, observed that increased access to independent sources of knowledge has not yet led to an emergent unified museum-based knowledge resource, as the Web currently 'takes little advantage of the interrelationships between and among disparately located museum objects'. They go on to state that 'museums' collective knowledge can only be identified, navigated, explored and integrated if its structure is explicitly declared (Bearman and Trant, 2002, 5).

In this paper we present a prototype for a virtual on-line museum that permits visitor-constructed narratives for museum exhibitions within a multifaceted, interrelated information space. The categorisation and navigation model at the heart of this system - the Gernsback Machine - permits novel types of exploration along all facets of meaning for any object or grouping of objects, and the system itself can draw on both local and Internetworked resources.

The Gernsback Machine

At the heart of the Gernsback Machine is a set of facet categorisations that determine the applicability of values to all of the objects within a collection. It is this commonly determined yet distinct categorisation system that enables the Gernsback Machine to perform its twin roles of cataloguing and navigation. The selection of different faceted termsets is an integral part of the process of accession and curation, and of the virtual museum's tour experience.

Our framework draws on Ranganathan's facets, but recognises the need for rich cultural (and more significantly non-book) materials to be represented in the multiple dimensioned trees that we have already described above. Each facet has a matching branch of a single unified facet tree, and the four levels of the branch give an invariant framework for scaling the appropriate continua and enable the collection objects to be located and navigated.

The Facet Tree

Despite a preponderance of metadata schemes and schemas for organizing metadata and encouraging metadata interchange, there remains (Doerr, Hunter, & Lagoze, 2003) a cultural relation aspect to most metadata use. When use has been made of traditional library science organizing principles such as Dewey (OCLC, 2004) and LCSH (Library of Congress, 2004), the tendency has often been to map the most likely occurrence of an artefact (i.e. to facilitate retrieval), rather than use them to indicate the semantic richness of an artefact.

Rather than take this approach, we have drawn on the Facet Analysis system's ability to represent the knowledge embodied in objects with the maximum amount of polysemy, and so make the consultation process much more informative. By maximising the points of access into a system, we maximise the likelihood of an inquiry being successful, not the case with single mode classification systems.

Facet analysis can be seen as an attempt to get a unified location of 'slot/descriptor' pairs within an intellectual universe of discourse. In this it presages the frame model of knowledge representation (e.g. Minsky, 1981), and it can be used to inform a frame-based media/collection description system. In drawing on the facets to organise our metadata-rich media artefacts and the objects for which they are proxy, we are proposing a new organising principle based on the facet classification system and applicable not only to existing metadata stores, but also to existing metadata schemas.

(It is important to note that in some knowledge management and information retrieval literature we find a different use of the term 'facet', to describe a common system of headings for metadata, and to group lists of descriptors under those headings: in contrast to our usage, they present a faceted information space as one partaking of the grouped slot/term pairs, rather than the systematic that informs them.)

We have already introduced three of the facet trees in the Introduction: those for *time*, *space* and *matter*. There are corresponding trees for the remaining Ranganathan concepts (*personality* and *energy*), and to these we also add one for *ontology* and one for *causality*. These two additional facets are necessary because of the nature of the museum exhibitions that are to be supported: ontology because we are drawing comparisons between objects and sets of objects, and need to show how they fit together in relation to each other and the world, and causality because part of what we are trying to establish is a way of depicting the relations between the objects, especially when trying to illustrate complex object relationships in an historical setting.

We describe the facet trees in general terms here, and defer a complete discussion of their structures to another paper. Each facet tree has four levels - facet, domain, quality and measure - with each level considered a *dimension* of the termset that is used to determine the value of the object (Figure 4). These four levels are the minimum to get a necessary and sufficient set of terms to clearly define a termset. The application of a term to an object results in a value: to reconstruct that value, the full termset must be recreated as an enfolding context. Each path down a facet tree from node to measure represents distinct categorisations of values that cannot be mixed or translated without losing information or (worse) committing category errors. This is a significant point, as it is the manner in which we can underwrite the intelligibility of the classification practices involved from facet to value.

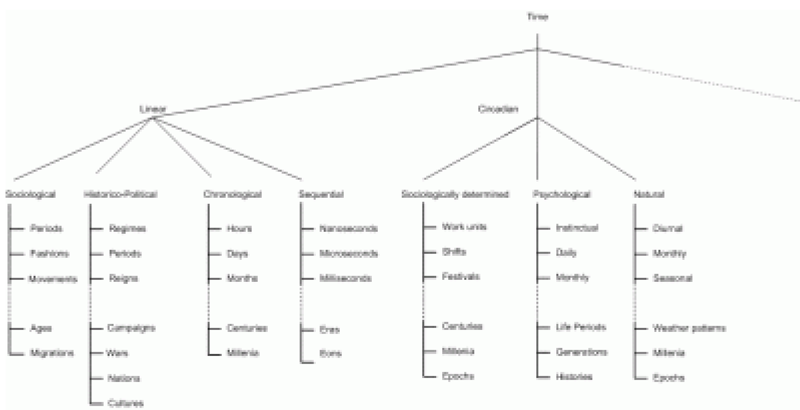

Figure 4. Part of the facet tree for Time showing (from top) dimensions of domain, quality and measure.

At the top of the facet tree is the root node, which corresponds to the facet itself. Below the root node is a dimension that represents the universe of discourse or *domain* within which the term operates. Although domains partake of the same facet, generally they are incompatible with each other - they are describing different experiences of the same facet. In the example of the time facet, the three domains (linear, circadian, and cyclical) are actually incommensurate - there are no one-for-one equivalences possible between them. Of course, some values (such as linear chronological values) will have components that may be translatable by reference to an absolute table of correspondence, but generally to consider one domain's value from the perspective of another is to commit a category error.

The dimension below the domain, *quality*, does however permit inter-translation. Here the ways in which the value can be applied to the object are regularised. The qualities within a domain are compatible with one another, but operate within different terms of reference. In our example in the introduction, we showed the different ways in which a point of time could take linear values.

Below the quality dimension is *measure*. This is the level at which the mechanism for description for the subject is determined: it can be selection of a units system, it can indicate a preference for vocabulary or customary use, or it can be indexical to an external authority that will act as a source for terms. In Figure 4 some of the measures for linear and circadian time are indicated. Here the examples elaborated in the introduction can be mapped out, and the correspondences clearly seen.

Thus, when we have the four reference points of facet, domain, quality and measure set, then the domain of application of the termset is established. The termset determines a value for the object, and that value is uniquely defined by that termset.

Navigation

The facet tree is used to retrieve objects within a collection by choosing a termset from the facet tree, and selecting values within that termset to use as search terms for the objects. Each selection of termset +values makes a constraint set (or *heuristic*), and application of an heuristic results in a set of objects that satisfy its being returned (the *ambit* of the heuristic). Repeated application of heuristics and movement within an ambit are what enables navigation through the museum space. Several constraints may be applied concurrently, permitting complex heuristics to be developed.

There are three types of operation possible within the collection space. We can move from one object to another either within or between ambits; we can change the heuristic so that it includes more or fewer objects in its ambit; or we can shift the focus of the system to another ambit entirely. It is these three core operations that determine our systems navigation: *stepping* between objects, *zooming* the heuristic (increasing range or increasing detail) and *flipping* the view (shifting the path) between ambits.

Stepping is the main navigation mode in the Gernsback Machine. It is how we proceed from one object (or composite object) to another. With step, we move in a direction from one object to the next in the currently selected continuum. Alternatively, movement can be in graded measures along a continuum (when there do not have to be objects present for those gradations), e.g. moving along a timeline one decade at a time, or synchronizing several sparsely populated timelines.

Zooming involves either changing the measure at which the ambit is viewed (e.g. from century to decade), or else changing the range of the heuristic to take in more or fewer features on the same measure (e.g. viewing one, three or five centuries on the displayed continuum). Generally, increasing the range of ambit increases the overview of the continuum, while increasing the measure increases the resolution (the detail visible). The zoom feature is also useful for orienting the Gernsback Machine when there are no objects visible. Zooming out to maximum range enables the entire collection space to be seen as a whole, and the user can then home in on the regions that are populated. Zooming in on the areas that are densely populated can enable the user to see the object disposition in finer detail.

Flipping is the least familiar of the GM navigation modes. It serves to re-ordinate the ambit through the use of shared metadata that is not related to the current heuristic. To understand this, it is necessary to remember that the metadata which is *not* responsible for placing the object being viewed within the current ambit will share potential heuristics with other objects that are also not in that ambit. In flipping, any given term from an object's metadata set can serve as a query-by-example navigation system to show other potential heuristics the object may exemplify, and those other objects which either share common or adjoining values with the current object in alternate continua. The user can then flip from the current continuum to one of the alternate continua, with the current object still the centre of focus.

As an example of flipping in action, consider a meeting of several captains of the fleet in the wardroom of a galleon in 1625. If it were a meeting of different nationalities, then the heuristic that the meeting exemplified (say of chronological time and nominal space) could serve as the pivot to enable the user to flip around to the maritime activities of any one of the nations (but only one of them) present. However, the situation could also pivot on the designer of the wardroom, or the writer of the report being read, or any other such metadata.

The significance of this feature is that it is a *navigation by network* - by the very interconnectedness of the elements of data - and this is the type of connection in an information space that is the most difficult to explore (it is incredibly costly in processor resources) yet the most intuitive to experience. What is more, a navigable graph is the only form of pathing through an information space that is guaranteed to cover every object.

After each navigation operation, the new continuum is itself the subject of stepping, zooming and yet more flipping.

A session with our hypothetical maritime museum would include all these navigation modes seamlessly. The user would search for a value ('La Perouse in Sydney Harbour'), find adjoining information by stepping (the First Fleet) and then see where one of the First Fleet ships went next (flip). From that ship's next flotilla engagement (step) we could zoom out to the entire fleet, then flip to the Admiral in charge. Following a letter home from the Admiral (flip) might lead to a discovery of 17^{th} Century child illness (flip), thence to 17^{th} Century medicine (flip), and so on.

Building A Gernsback Machine Virtual Museum

In this section we describe the architecture required for our museum, and how we have implemented the prototype. We then describe the process of constructing a virtual museum based on this architecture.

Architecture

The virtual museum space is a digital domain that represents the collections within a museum or group of museums, but which is separate from it. In essence it provides on request annotated displays of media artefacts that represent either the objects in the collections or associated material. In the context of exhibitions the museum will also include reference material and navigational aids (maps, lists etc) so that within the museum space there is a universe of information that is complete in itself.

Practically, the museum is a combination of a database, a metadata system and a media-server, working through an application facilitated by a Web-server.

The base level unit in the museum space is a containerised media resource with a metadata halo, which we term the 'bento'. (A bento is a Japanese tray or compartmented lunch box, designed to hold different items of food. Apple used the term to define their 'Bento Specification' in 1993 for a platform- and content-neutral data wrapper. However we use the term here in its more general descriptive sense and do not make use of the Apple specification, or any other implementation, in our project.)

The bento has three characteristics that are important for the GM: it contains standard 'media slots' that can be filled with simple or complex media artefacts; it is completely self-descriptive with metadata (subject, technical, structural and administrative); and, importantly, each bento is potentially linkable with any other, constrained only in a semantic, not a technical, sense.

Formally the bento is a *frame*: it contains data to describe itself, contains a dictionary of values, and maintains details of links with other bentos. The frame is a standard knowledge modelling format which has had great success in knowledge management, and the bento, by maintaining both the media artefacts and the pertinent metadata, serves doubly as cataloguing and navigating instrument. Since the bento can store media artefacts and access their metadata transparently, it follows that it can contain other bentos as well, and this mechanism can be as recursive as is necessary.

In Figure 5(A), the bento is laid out like the components of the lunchbox. As it is a frame, it has its own identifying metadata (including ownership, copyright, purpose, accession or creation details), references to related bentos (as a means of organising the bentos in sequences and modules) and can also identify media artefacts for which it is the parent. The AVI component in (A) is in fact itself a bento, and the blow-up in part (B) of the same diagram shows how it internally has its own metadata component.

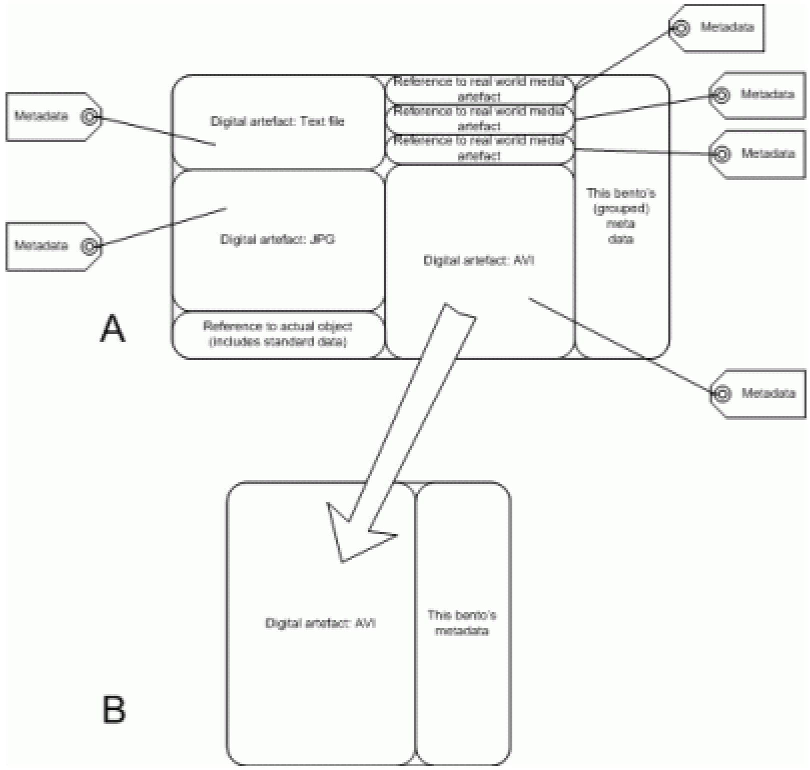

Figure 5 - Bento architecture

This structure makes the bento the ideal vehicle for recording the sequences of media artefacts necessary to instantiate a virtual tour of the museum, and by an ordered mechanism for creation and display, a single bento becomes all that is necessary to contain the entirety of the tour and its accompanying metadata. The lower order bentos in the hierarchy will then be self-organising, and an instruction to the top level tour bento to display next component, previous component, restart, time left in tour or even print/export will be dealt with at the top level.

Such a tour will consist of two types of bentos: those that contain artefact bentos with rich descriptions, and those that act as segues, standing in between other bentos and providing any necessary semantic buffering. The annotated bentos could then serve as building blocks to many other tours as well as the tour in which they are being included.

Since the bento provides both the content for the museum and its navigation potential, it is designed to enable the objects' information also to be retrieved from the system for the purpose of aligning the object with the continua, as part of a visitor's querying the GM. This means it can not only display the media artefacts as they occur within a tour or query result set, but each one can also display potentiality for further digressive navigation options, in the explorative manner outlined above.

In terms of guarding intellectual capital, bentos can also ensure that no object or representative artefact is ever displayed without the context of copyright, watermarking and precedent details, and can mediate these when the exhibition is derived from many different real-world institutions.

Figure 6 shows the recursive nature of the bento, and defines some terms that we shall use later in describing our museum space.

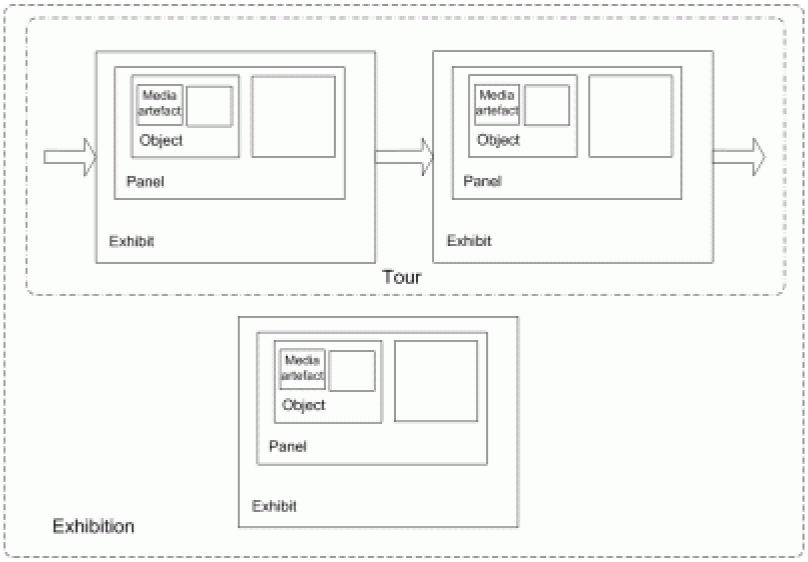

Figure 6 Recursive bentos forming museum structures.

Implementation

The prototype museum database is a hybrid structure of authority tables, hierarchical metadata sets and standard data records. The challenge was to develop a design for a bento structure that permitted the maximum freedom for the content developers, while permitting the full potential of the GM navigation structure to be available, and to provide as seamless a way of cataloguing as possible to provide the full metadata description.

It was decided to make the GM's own native data format XML, and although the actual XML data is stored in a relational database, it is viewed and edited in XML form. There are two main XML trees involved in its implementation. Primarily there is the bento-space for recording the details of the bento material. This is done in our own XML dialect, as a KRL (frames are usually recorded with a KRL). The namespace is established with reference to knowledge management and expert system current practices, to ensure adaptability.

The secondary XML tree is the facet tree, which is made from the original Ranganathan set, with our own isolates extended via the three lower dimensions. The facet tree is based on general principles of faceted classification systems and the various compound classification systems and metadata ordering systems currently in use in the museums and library communities, such as AAT, ULAN, and TGN (Getty Vocabulary Program, 2004). This tree serves as the basis for the interoperability between the user and the museum - informing the dialogs and organising the material. Extensive term lists are not included in the tree, as (apart from reasons of efficiency) the actual values are either resident in other systems or are derived from the bento-space. The entire tree (about 300 termsets) plus candidate values (from the trial set and the external lists - about 4,000 terms) are extracted from the system in various XML metadata standards such as XFML (XFML, 2004), Topic maps (ISO/IEC, 2002) etc, and analysed for full coverage of the facets and their domains.

The result sets are created by an X-PATH match between the two XML systems, and the results displayed using an XSLT transform. This was done to make the solution as universally acceptable as possible.

An initial bento dataset (about 50 items) was populated by hand, with a view to seeing the architecture populated as soon as possible to test the interactive aspect of the GM. Media artefacts were created, together with appropriate metadata, and these were used to build up tours and exhibits. Although minimal curation was done, sufficient words were entered for the segue bentos to build up appropriate bento tour sets.

The bentos themselves were drawn from several different sources, and identified primarily by the space and time facet metadata. Multiple continua for time and place were established and explored.

Process

The museum when operating works by presenting a common interface to acccessioner, curator and visitor: they are all effectively different levels of user. This is necessary because when the Gernsback Machine is being used, the various controls that establish the presence of termsets represent the context for the value being applied. Therefore a matching dataset must be in place when retrieving it.

The initial contact between the museum and an object intended for the collection is at the stage of accession when a user describes the object, and creates artefacts to represent it, by use of the context-representation mechanism of the GM. This consists of selecting a termset via the facet tree, and then (depending on whether the termset wants a descriptor, a term picked from a restricted list, a referent to an external table, a date, or a numeric value) entering a matching term.

Cataloguing an item for inclusion in the virtual museum involves selecting an optimum number of terms to serve as retrieval keys. This would be in conformity to pre-existing practice in the parent institution, or if the virtual museum is a stand-alone concern, in conformance with the best-practice museum cataloguing standards. These terms are linked back to the termset when accessioned (i.e. the termset + value is stored as a key in the bento).

This is where the GM comes into its own: to perform such a task comprehensively is normally beyond the capabilities of the museum staff (in terms of time and resources), but the metadata components can be easily engaged either singly or as sets of metadata, while the action of placing an object within a continuum can present a set of suitable values to the user.

When curating an exhibition or tour, the same process repeats itself - the material can be gathered by a faceted search, and the items retrieved, and then the objects are lodged within the tour, with a new metadata set pertaining to their proposed new role in the tour. This process can reveal even more material as the collection grows in size, and fully documented and annotated bentos become available for inclusion.

This is the same for all levels of the exhibition - each time the same process of selection enables the curator to draw on more and more semantically rich material, all of which is deemed to fit the same faceted semantic halo (Figure 7). At each point in the selection process, the material from the level of complexity below is retrieved by the search, and that is the raw material for yet another bento layer.

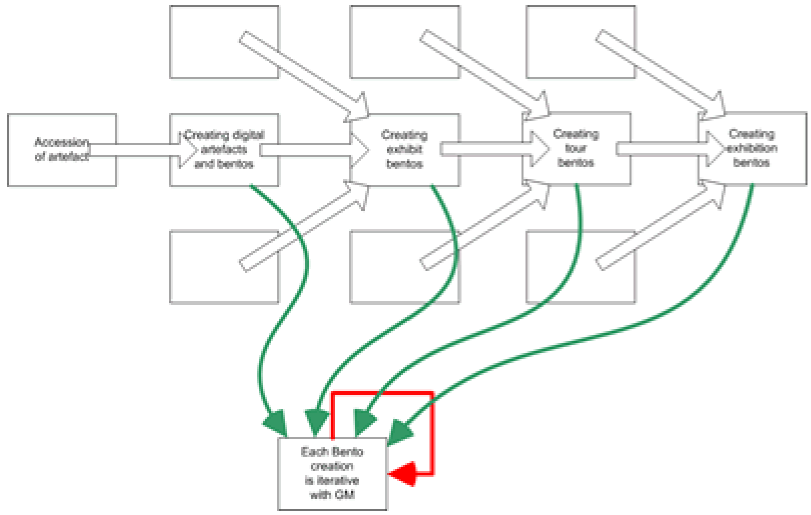

Figure 7 Accession and curation process forming composite structures

In retrieving material from the museum, and therefore indirectly finding potential tours of interest, the visitor to the museum repeats this process. The difference between the visitor's displays and those to which the staff have access is that the searches the visitor conducts are to an extent managed. Not all material will be visible, and not all metadata will be available for searching.

The collection is of course firmly grounded in the museo-informatic community of practice, and so it is not only appropriate, but also necessary to enable the virtual museum to partake in the common metadata initiatives that are being developed at the moment. Because the facet tree is an organising rather than an enumerating system, it is possible for the administrator to make the system fully co-operative with on-line open systems initiatives like the OAI (Open Archives Initiative, 2004). By having a hermeneutic layer built into the system as a dictionary, either all or part of the OAI interface can be implemented.

The public/private distinction that enables differentiation between the scholar's access to a collection and that of the ordinary visitor, or between the private access afforded an owner or curator and the public generic interface, serves to make a distinction also between the local and remote forms of the collection material. In the prototype, there is an ability to have a 'second shot' approach at finding material - the user can request that the search include remote material in addition to the local resources. This approach has already been trialed successfully with the NCSTRL (Networked Computer Science Technical Reference Library, 2004) repositories, and in the end it is more a question of reliability and certainty in making the mappings than a question of technological limitations. And from this point it is a small step - albeit one requiring a fair degree of co-ordination - to Bearman and Trant's (2002) metadata-controlled collection interoperability. The use of a public/private metadata distinction permits the GM interface to pick up on a distributed and decentralised set of objects displayed upon a series of continua.

Design issues

The problems of disappointment and letdown from a visit to a virtual, rather than an actual, museum are well known. The haptic and kinetic experiences of realia are part and parcel of the curator's art, and the design for the computer experience is a greater challenge than the recreation of the experience of cinema for television. Over and above this problem is the challenge of designing the system for the principle of least surprise, of not stopping a visitor to the virtual museum because of an unfamiliar interface.

The challenge for the user interface design is to ensure that the visitor's three fundamental concerns of *Where am I? What's here?* and *Where can I go?* (Veen,

2001) are addressed; while making available (but not overwhelming) the unusual navigation potential of the Gernsback Machine, based as it is on an unimaginably large information space that has no physical analog, and possessing a navigation operation (flip) that is unlike anything normally encountered.

It is well know that since users are only ever presented with a single screen, there is no inherent sense of the larger structure that sits behind that single page. Therefore, enough information needs to be conveyed within the page to invite further interaction. However, if this involves a high degree of computer literacy, or following detailed instructions, then a user without a compelling reason for exploring the site is unlikely to persist with the interaction.

A particular challenge is how to represent the potential of the 'step, flip, zoom' navigation in an intuitive manner. The default set of interface controls that we have developed are similar to the slider controls on a graphic equalizer, but they each have an informatic property to match a dimension of the GM. The four sliders correspond (left-to-right) to Facet, Domain, Quality and Measure, and the option to select a value from a pick list, enter a number, or retrieve a match is given to the user.

As the constraints are cumulative and additive, it follows that there can be a potentially infinite number of such slider sets combined to make for quite detailed searches. The interface enables these cumulative queries to be created, and the individual constraints removed one at a time from a running list of elements. If the display sliders are altered, then the labels on the 2nd, 3rd, and 4th are reset to blank, until a movement at a higher level re-enables them.

Of course, the slider sets that we have used here are only some of many possibilities, including virtual reality interfaces, that would be possible. Part of the designer's challenge is to create different consoles to match different purposes.

Another challenge for the designer is to create exhibitions out of the simple but raw outputs of the GM in making bento sets, which as we have noted form the basis for the museum exhibition. By default they produce an unsophisticated narrative told in terms of artefacts alone, with simple labels derived from the metadata. Before the exhibition is ready for the visitor, some additional design work will normally be necessary to ensure the exhibition is coherent and attractive. Here the GM and the virtual museum can help the curator and designer prepare a series of displays for an exhibition.

Examples

16th Century Ships

Our first example demonstrates the use of the Gernsback Machine within a relatively conventional subject setting. This hypothetical on-line museum provides a variety of virtual exhibitions, which include both guided tours and free exploration. The museum home page is shown in Figure 8, with three exhibitions, *Ancient Eastern Dances*, *16th Century Ships* and *Korean Dynasties*.

Figure 8. Home page for on-line museum, showing three available exhibitions

Guided tours

The visitor selects a desired exhibition and enters its start page (Figure 9). This page shows the narrative structure of the 16^{th} *Century Ships* tour, set out as thumbnails along a narrative line. The visitor may begin at any point within the tour. In Figure 9, the main narrative consists of the exhibits Navigation and Maps, Trade Routes, Life on Board and Ship Building. Trade Routes also branches to other related exhibits, Shipwrecks and Re-enactments of Voyages.

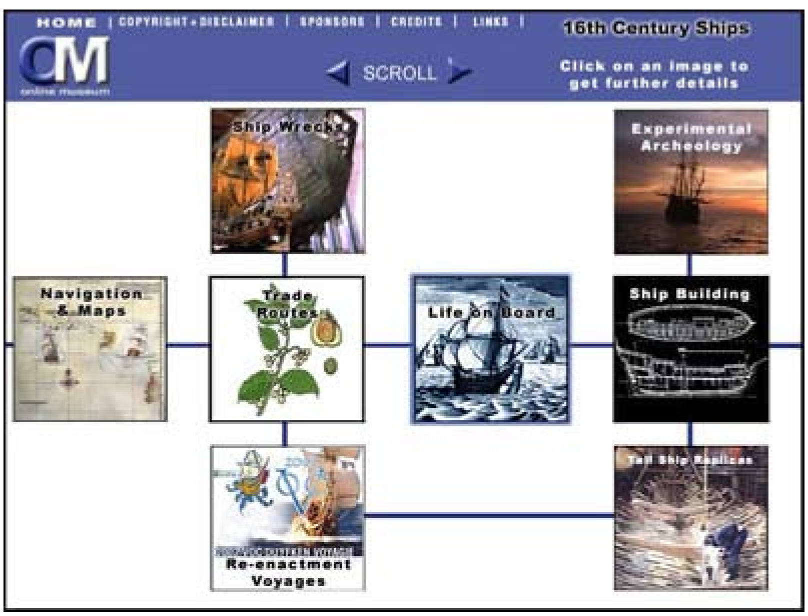

Figure 9: 16^{th} Century Ships Tour, showing narrative structure between exhibits.

The visitor clicks the 'Life on Board' thumbnail and is taken to the Life on Board exhibit (Figure 10). The position of the Life on Board exhibit within the main narrative of the tour is indicated at the top of the page, and the alternative narrative pathways on the left. The topics that make up the exhibit are shown as a navigable list at the top of the page.

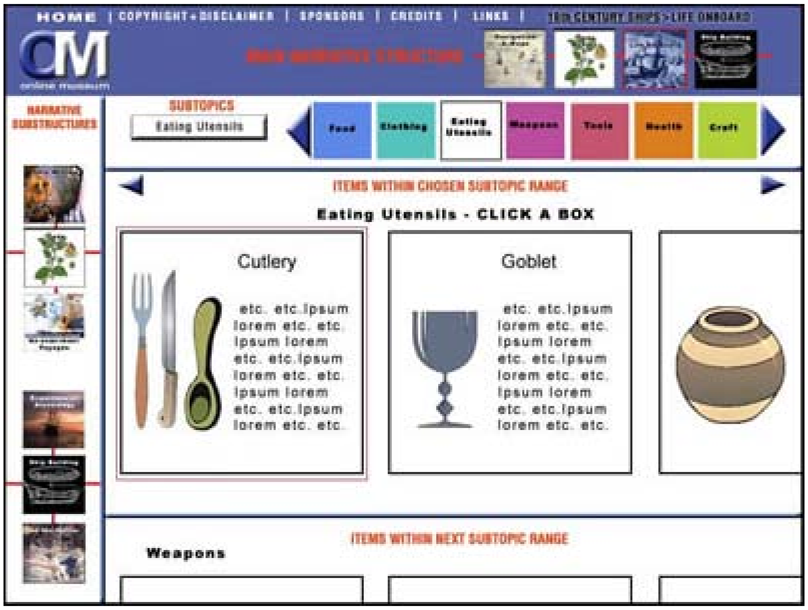

Figure 10. The Life On Board exhibit page, showing the visitor's current location within tour (top and left), and topic panels within exhibit (centre).

The visitor now has the options of exploring the topics within Life on Board, or continuing to the next exhibit in the *16th Century Ships* tour by using the top menu, or calling up more detail on any of the individual objects in the exhibit. To view more details about a particular museum object, the visitor clicks on the object (e.g. Cutlery) and is taken to the object page (Figure 11).

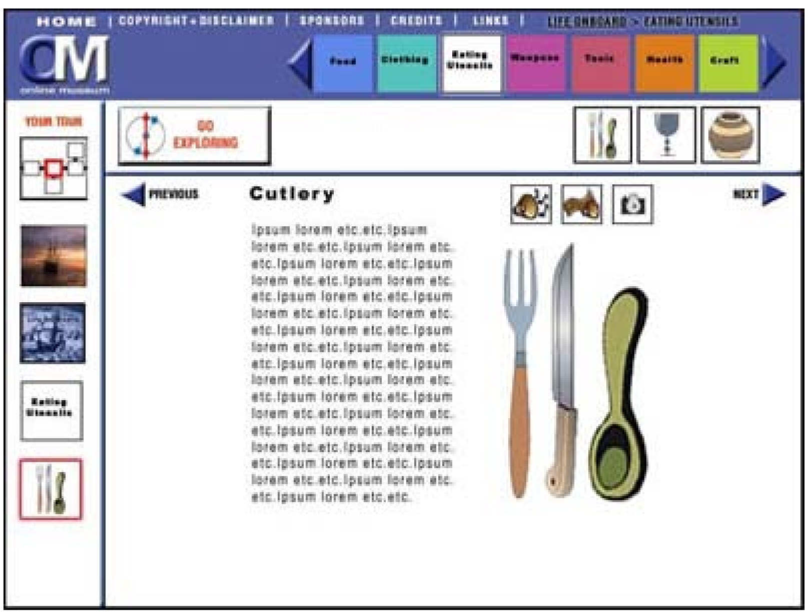

Figure 11. Object page in tour mode, showing descriptions and media artefacts about museum object.

The object page is the simplest level available to the visitor, and consists of a description and media artefacts (e.g. images, video) about the museum object, here a set of 16th Century cutlery. From here the visitor may view other object pages within Eating Utensils (Goblet, Bowl) or may return to the Eating Utensils panel in the Life On Board exhibit.

Another option available to the visitor at this point is to leave the guided tour, and embark on a free-form exploration of the exhibition space. This possibility is indicated by a Go Exploring button and is described next.

Exploration

To leave the tour, the visitor clicks on the Go Exploring button on the object page. The page changes to exploration mode (Figure 12), and the slider sets that permit the facet navigation about the selected object appear. (Note that three slider sets are shown here, but, as discussed earlier, the number is potentially infinite - in practice, the number of sets available depends on the judgment of the designer and the limitations of screen real estate.) The surrounding narrative structure disappears, as it is no longer applicable in the free exploration (although a return to tour icon enables the visitor to leave the exploration at any point and return to their last place in the guided tour).

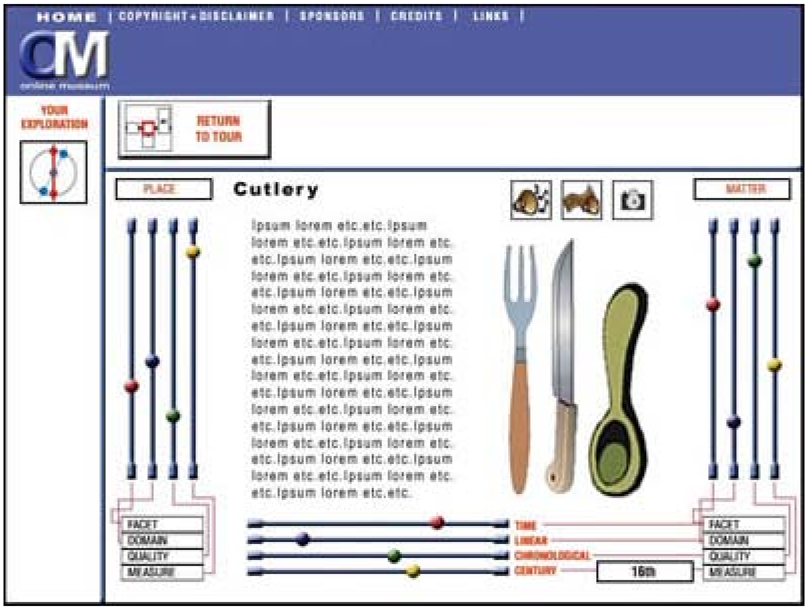

Figure 12. Object page in exploration mode, showing facet sliders

Exploration begins when the visitor selects a facet for exploration. It is important to remember that when considering the object outside the context of the original tour narrative, there is no single 'true' location of the object, and it is therefore up to the visitors to choose what facet(s) they are interested in seeing the object located in, and to continue navigating from that point.

For example, to see where the object was located in time, visitors would select the Time facet on one of the slider sets. They could then select to view where they were in Linear (rather than Circadian or Cyclical) time, and within Linear, Chronological. Within Chronological they might choose to view at a measure of Century, and the final value for the object, 16^{th} Century, would be displayed (Figure 12). The visitor now knows that in terms of linear, chronological time, the object is located in the 16^{th} Century on a measurement scale of centuries. Equally, they could have chosen to view the object in terms of Linear, Social time and found that the object was located in, say, the age of colonial expansion.

Leaving any of the parameters in a slider set unselected results in either arbitrary or default values being shown. For example, a designer might choose to set defaults for domain and quality to Linear and Chronological respectively, so that if only the Time facet was set by the visitor, the most common concept of time, that of chronology, would be displayed for the object.

The visitor may also set any of the other facets to constrain further the description of the museum object. Other values are not shown in Figure 12; however, possible values for Matter and Space could result in the Cutlery object being described by 'cutlery, Dutch merchant ships, 16^{th} Century'.

Although the visitors have now constrained the description of the original object within the parameters they are interested in, other objects within the collection will also fulfil this heuristic. Clicking a 'Show All' button at this point changes the display view to thumbnail, and the original object is shown along with others that are located in the same facet space.

The three types of navigation - step, flip and zoom - that characterize the Gernsback Machine are now available to the visitor.

Zoom navigation occurs by altering the Measure slider, for example from Century to Decade. Again, a different object set (but one that contains the original object) is displayed: e.g. 'cutlery, Dutch merchant ships, 1580s'. Alternatively, changing the measure of ship type could expand the view to 'all types of Dutch ships in the 16^{th} Century'.

Step navigation occurs by stepping to the next century on the timeline, to see what other objects are displayed, for say the 17^{th} or 15^{th} century. A new set of objects is displayed. Stepping to a different value on the Time/Linear/Sociological view of the timeline would permit a comparison with (e.g.) 'Post-Colonial', while concentrating on the Space/Functional/Political would permit different a narrative of comparison of nationality to be followed, and would retrieve 'cutlery, French merchant ships, 16^{th} Century'.

Flip navigation occurs by altering the quality or domain sliders. For example, to flip from chronological to social time would return anything relevant from the social age ('age of colonial expansion' or 'age of exploration') that the object being viewed exemplified. Another flip (say on space to 'Functional/Political/Nationality') would move to French or English maritime cutlery, and from there perhaps to medical implements from the age, or to food preparation. The power of the flipping mechanism is by its nature the most powerful for exploration.

The same principles of exploration apply to the self-guided exploration of the visitor as to the curator who constructs the guided tours: semantic coherence is best achieved by making only small changes from set to set, rather than altering several facets at the same time. Another factor that ensures the visitors are not overwhelmed by the vast number of navigation possibilities is that they are constrained to navigate within an exhibition, rather than the entire collection space of the museum. The options available to them (on the slider sets) will therefore be constrained accordingly (in our example, the visitors would still be exploring within 16^{th} Century Ships- space, not within the Korean Dynasties or Ancient Eastern Dances exhibitions).

As the exploration progresses, other tours in which the viewed object (or set of objects) is used are dynamically displayed, and visitors can then choose to jump to one of the tours and continue in a pre-written narrative again. A trail showing their exploration path is also generated (blank in Figure 12), with the option to save for returning to later.

Extending The Timeline: A Museum Of The History Of Possible Futures And Probable Pasts

Our second example illustrates the potential of the Gernsback Machine navigation by concentrating on manipulating aspects of a single facet, that of time. Our hypothetical virtual museum this time is a museum of 'the history of possible futures and probable pasts'. This museum draws on predictions of the future made at various times, both in the past and in the present, from different sources (such as science, science fiction, sociology), to create a media rich, interactive virtual space.

As we saw in the Introduction, a timeline as commonly seen often uses the same continuum to express many different aspects of facet-relative detail. However, a facet-line can convey token-reflexive information as well - for instance with time, by showing a date, and then pointing to the next day, the following year and so forth. Thus the next monarch of the United Kingdom can be placed on a timeline after Elizabeth II, even though the details are surmised (probably Charles III, but possibly William V).

An interesting notion arises here: of expressing the multiple possibilities of prediction (or with regard to the distant past, analysis) for the same point of time. Our current present is, as the saying goes, 'yesterday's tomorrow and tomorrow's yesterday'. We can see that there is an infinitude of token-reflexive expressions for any point in time with reference to any other point in time. It becomes a matter of selecting the interesting narratives from the many possible ones and comparing them. So, we can compare the futures of Swift, Bergerac, Verne, le Queux, Wells, Huxley, Orwell, Bradbury and so forth: it makes sense to speak of a series of denoted presents for these authors 2004 [Swift], 2004 [de Bergerac], 2004 [Verne], 2004 [Le Queux], 2004 [Wells] , 2004 [Orwell], 2004 [Huxley], 2004 [Bradbury]. We can envisage plotting these futures on axes leading from their time of writing to the present with a varying degree of detail. Within this context, it would be a simple matter to cross-reference these dates with other faceted axes, as shown in Table 1.

	Domestic transport	Communications	Entertainment	Society
Swift – Lunatic republic	Servants	By dispatch	The same	The same
de Bergerac – Voyage to the planets	Metallic horses	Mechanical	The same	The same
Verne – Earth to the moon	Aerial ships	Telegraph	The same	The same
Le Queux – The coming war in the air	Mini-dirigibles	Telegraph	The same	The same
Wells – The shape of things to come	Flying cars	Radio	Programmed radio	Repressive technocracy
Orwell – 1984	Walking/ bus	Pneumatic tubes	Programmed TV	Brutal socialist regime
Bradbury – Pedestrian/ F451	No pedestrians!	Telepathy	No books!/ Mindless soap opera	Repressive technocracy
Huxley – Brave new world	Aerial moving footpaths	Videophone	Contraception and its consequences	Subtly pervasive technocracy

Table 1. The future as imagined by various authors

Table 1 shows interesting contrasts in sharp relief — how the future was a means of satire, of lampooning the present for early writers, but a dystopian view, a means of warning for later ones; and how the means of expression of the futures reflected the technology of the time. The model can be extended further — it is possible to see how (say) Huxley versus Orwell saw the poor in the future (invisible vs. ubiquitous), or how foreign countries were seen, or how change was expected.

A prototype version of the museum has been implemented, and filled with some of the futurological and science fiction of England and France from the 19th and 20th Centuries. Using the Gernsback Machine, it is possible to present concurrently on a single display the relevant details and associated media artefacts of exactly such hypothetical futures as are discussed in Table 1. Such analyses permit comparisons of same time/place with different social strata for different authors, for instance comparing Orwell's Proles with the leisure class of Huxley.

In a fully-populated museum, we could also look at the 'pasts that never happened' - the 1965s of Orwell, Wells, Le Queux and Verne, say, and see if it would be possible to get to where we are now from there. We might also compare them with the 'pasts' that are the staple of social advocates (both optimistic and pessimistic) to see if they are any more plausible. At each stage of comparison the detail can be fleshed out with comparative illustrations from book and film - a sense of the continuous lives led by the different characters makes for a play of Pirandellan synchronicity unfolding before the visitor to the exhibitions.

In an interactive mode, the user could examine the different continua for reasonable hypotheses: given what we know about AIDS and global warming. How does that colour Huxley's gentle promiscuity, or Verne's coal-power technocracy? As the timelines diverge between predicted futures and our own past, comparisons can be made between the objects that the writers chose to symbolise their imagined futures, and those that were present in our past. We can imagine these metonymic tokens arrayed in their own continua, yet compared along axes of attitude and intention.

This all makes for a fascinating tool for research, enabling new methods, including statistical analysis of gaps in the literature, with targeted sites for further research, and identifying concentrations of influence between hitherto unrelated items. Enriched by the superabundance of illustrative media artefacts in sound, picture and moving image, it also draws one to think of Hesse's *Glasperlenspiel* (Hesse, 1943) and of the intellectual game of infinite comparison of the arts and sciences of the past and future.

Conclusion

The Gernsback Machine offers a new approach to the construction and exploration of virtual museums. By recognising that time is only one of several continuously interacting facets of meaning for any set of facts or objects, the conventional museum timeline is itself seen to be only one representation of a number of possible semantic continua that may be drawn through a collection. The GM is a categorisation framework based on a facet tree that provides both the definitions of the termsets used to describe objects, and the navigation potential through the collection space, enabling exploration of these alternate semantic continua in a way that opens up possibilities for new types of narrative structures.

The facet tree that provides the twin functions of cataloguing and navigating is indexical and integrates with existing metadata schemes and metadata sets, providing the potential for metadata-controlled interoperability of museum collections. The containerising and recursive nature of the bento, the base level unit of the GM museum space, enables existing digital collections and their metadata to be incorporated into new virtual exhibitions constructed from logically-defined sources.

The GM provides a powerful tool for museum curators and exhibition designers, and permits new visitor-constructed narratives of the museum space. It also has great potential as a research tool, and has been successfully applied in this manner in a separate project on the history of programming languages (D. Pigott, unpublished).

Our back end prototype has demonstrated the proof of concept of the cataloguing and navigation engine of the Gernsback Machine. Much exciting work remains to be done to develop interfaces to support the curatorial process and to explore appropriate metaphors and innovative interfaces for the visitor.

Note

We named our cataloguing and navigation model the Gernsback Machine after Gibson's short story, 'The Gernsback Continuum' (Gibson, 1981), in which a man who leaves the current space-time continuum after an extended period of photographing and analysing futuristic art-deco buildings finds himself to have slipped sideway through time into the Gernsback continuum. This is an alternate time continuum to our own, wherein the future envisaged by the science fiction illustrator Leo Gernsback has come to pass. The artefacts that are out of place and unimportant in our continuum have become the most significant, while the buildings of Louis Sullivan and Frank Lloyd Wright are marginalised. A subtext of the story is the notion that there may be an infinity of such continua, one step away: the essence of our Gernsback Machine.

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Other Sources

We acknowledge the following sources that were used in construction of the screen shots in Figures 8-12:

CorelDraw10 Clipart (CD) (cutlery, goblet, pot)

www.musicaustralia.org (sound and multimedia icons)

www.british-museum.ac.uk/compass (camera icon)

www.duyfken.com (all other images)

http://www.e-merl.com/pocom.htm (concept of displaying narrative structure as box-and-line)

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