A Recombinant Information Space

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ABSTRACT

The traditional web browsing paradigm is one of the most significant developments in the histories of publishing and human computer interaction. Yet clicking through links grows tedious, without affording dynamic knowledge building. What's needed is a partially ambient visualization mechanism that sifts through focused subsets of web space, with our occasional attention. CollageMachine supports fluid adaptive dynamic browsing. The granularity of browsing is shifted down from documents to their constituent media elements. As time passes, elements of interest stream continuously into a recombinant information space that helps us locate and arrange information, and generate connections. An interactive interface maps the expression of interest together with direct manipulation of visual design. This mapping enables the user to effect the same information space visualization that the program is developing, and express dis/interest, with a single gesture.

CollageMachine's generative approach to browsing extends experience beyond routine, to support creative experience. Stochastic decision-making enables the recombinant information space to develop in a way that is predictable on the average, and yet still open to the unexpected, as while browsing a physical library's stacks or store's racks. Hypermedia structure forms the basis for an associative model that interprets the participant's actions; like human memory, it learns through spreading activation.

A diverse set of techniques, that have evolved through several generations of development, make this work. *Seeds* are initial documents that are fed to the collaging engine. A document's HTML markup serves as a contextual guide for breaking it down into information elements. Image processing creates cohesion among the elements, and foreground/background relationships that make the collage easier to read.

Keywords

recombinant media, recombinant information, web reassemblage, granularity of browsing, compositing, metadocuments, navigation, recommender systems interfaces, creative cognition

1. INTRODUCTION

The traditional web browsing paradigm is one of the most significant developments in the histories of publishing and human computer interaction. With hundreds of millions of users accessing billions of hyperlinked documents [36], something is clearly working. Yet clicking through links can grow tedious, especially when you're not exactly sure what you're looking for, or where to find it. What's needed is a mechanism that lets us sift through focused subsets of web space, in a way that is stimulating and enjoyable, but not demanding. Such a mechanism can be directed when we want to interact with it, and can still work for us while we're busy with other activities. It creates visualizations that we focus our attention on sometimes, and leave in the peripherae at others. Links are traversed automatically, by a web crawling interface agent that models our interests, and acts accordingly. Using its model of user interests,

Figure 1. Two states from a recombinant knowledge space session, featuring research and student work in visualization and computer science at Texas A&M.

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CollageMachine automatically retrieves relevant information, and visualizes it in a mutable information space. This retrieval and visualization is a form of automatic browsing.

2. RECOMBINANT INFORMATION

Recombination is the process of taking existing coded compositions, breaking them down into constituent elements, and recombining those elements to form new codings. When practiced with and by living organisms, the constituent elements are genes, which contain essential information that defines an organism's makeup. Shuffling of base pairs, mutation, and splicing of subsequences are recombinatorial means that produce new gene configurations, and from them, new beings. Genes are the code of life, from which new organisms are created, and through which new species evolve. The information content of genes is so significant that the field of bioinformatics has emerged to focus the application of computational methods to gene composition and recombination.

Dada Information Collecting

In the information age, analogous processes of recombination are conducted with the units of meaning that we use to communicate, to express ourselves, and to represent ideas. The process began in the art world, in the Dada movement of the early 20th century. Marcel Duchamp, using the pseudonym R. Mutt, did the first creative work with found objects, or *readymades* [25]. He submitted "Fountain," an unadorned urinal, to the exhibition of the Society of Independent Artists Exhibition in 1917. The work created an uproar. People were outraged. Through this, he demonstrated the power of context in the interpretation of an object. Attention was brought to the object's semiotic makeup. Meaning was transformed by the shift from a bathroom to an art exhibit. The readymade *read* differently. The object's information content plays an essential role in its function.

According to an anonymous work attributed to Duchamp, "Mr. Mutt did not make the work. He CHOSE it [25]." This choosing is the act of collecting, reusing, and recontextualizing. It is the same choosing that contemporary D.J.s do when they assemble mixes. It is the same choosing that people do when they use file sharing services to swap musical tracks, and digital video recorders such as Tivo to collect video programming. Duchamp's work is not significant simply because of its effect on the art world. Duchamp asserted and demonstrated that "choosing," that is, collecting, is a creative act.

Duchamp's Dada associate, Max Ernst, used found objects as the genes of new visual semiotic forms. In his collages and overpaintings, found elements are combined with new ones. Collage literally means, 'put together with glue." Ernst's work followed that of *papier colle* artists such as Picasso, who, in one work, substituted a physical spool of thread for a painted one. Yet their contemporaries, Tristan Tzara and Louis Aragon [3], asserted that Ernst invented collage several years later. This was, again, because of semiotics, because of the emphasis on meaning and concept in the construction of Ernst's works, and the way that found objects are used to produce new meanings. For example, as Krauss so clearly analyzes [23], *The Master's Bedroom* is an overpainting of a page from a catalog of high school teaching aids. Ernst overpainted most of the sheet with a simple plank floor and walls. He leaves an oversized bear in the distant back of the room, where the walls are converging, and a tiny whale in the front. A paradox is created, in which the rules of perspective are contradicted. Thus, he uses the catalogue in a commentary that challenges modernism, through its alignment with perspective. The precise choosing and the overpainting combine to a create an evocative new species of meaning.

Practices of Authoring by Reference

As the information age has developed, similar recombinant practices have been conducted in spheres of art, entertainment, and information systems. Duchamp's friend, John Cage, used found objects in music composition. For example, in Imaginary Landscapes #4, the settings of the dials of radios are scored for live players (1954) [33]. A few years later, Stockhausen's *music concrete* was the first work in which tape recordings of environmental sounds played an essential role in compositions [39]. In the conceptual art movement that began in the sixties, ideas themselves are considered to be an artistic medium [26]. Now, in popular music, hip hop artists quote sounds iconographically. For example, in the early nineties, Public Enemy utilized clearly quoted samples from television and Malcolm X, as well as James Brown [32]. They are among legions of practitioners. Knowledge of art history is not a prerequisite for engagement in recombinant practices of cut and paste transformational remixing.

With the proliferation of the networked personal computer, collecting becomes an everyday process that permeates work, communication, and browsing. Vanevar Bush foresaw the potential for this in information systems in 1945 [6], thirty years after Duchamp and Ernst began the practice with mass-produced objects. The trails of the Memex are based on an associative process of collecting and annotating. These annotations, which represent the collecting individual's responses to found elements, have the same creative potential as Ernst's overpainting activities. Bush foresaw that trails, themselves, would function as a medium, and that authoring of them would be an important activity. Soon after the onset of digital computation and communication, Ted Nelson formulated the concept of hypertext, a mechanism for non-linear writing, based on the reuse of found textual objects, and the power of random access memory to support the structure of the reference [29]. With the advent of the Internet, and WWW technology, a form of hypertext authoring and browsing became the fastest growing publishing medium in history. Thus, we experience a convergence of practices of *authoring by reference*. Explicitly named information systems intersect with information-based art and entertainment.

The work of Duchamp and Ernst is a beginning of the information age, because it focused attention on the meanings of objects. It brought focus onto how they *read*. This work started the postmodern era, because it brought production in the art world away from the creation of new masterpieces. Instead, work is created through the recombination of existing objects, based on their semiotic and sensory functions, through choosing, annotating, and assembling.

Media are sensory forms that information takes. By recombinant media, then, we mean media that is created through the combination and composition of preexisting readymade media elements. One definition of information is *data that communicates*, and a definition of communication is the *transmission of meaning*. We use media to convey meaning. Thus, notions of information and media are inherently connected. The distinctions lie only in emphasis on sensory

Figure 2. Snapshot from a 9-11 recombinant information space browsing session.

forms or communicated ideas, which cannot be essentially separated. By recombinant information, we mean meanings created through composition with readymade information elements.

Deep in the information age, we are deluged with information, and wading through it. There is a shift in the experiences of a broader segment of the population. We have a growing need to collect, arrange, organize, and assemble readymades. We need to make sense of these collections, to keep track of things, to understand interrelationships. The forms include bookmarks, email attachments, and more explicit *metadocuments* [11]. The contexts of signifying acts of choosing move from the public art exhibition to the personal computer and the Internet..

Recombinant Metadocuments

Metadocuments are authored by reference. That is, they are documents that consist primarily of references to other documents, including elements from those documents, and annotations. Users of hypertext often need to collect references to significant places that they encounter while browsing. These collections are metadocuments. They consist both of references by name, such as `<img` tags and hyperlinks, and by value, in the form of textual quotations. We call the image references and quotations *information elements*. For each information element, in addition to any embedded hyperlinks, there is always an implicit reference back to the original document, which we call its *container*. Schraefel articulates the importance to metadocument authors of the connection between an information element and its container [35]; when we collect information elements from the web, we want to be able to easily return to the sources of the quotations. Each information element can be thought of as a fat bookmark. When they include information elements, and the ability to navigate back to containers, as well as over to hyperlinks, metadocuments make referential structure functionally explicit.

Prior systems for metadocument authoring, such as Walden's Paths [11] and VKB [37], have focused attention on work practice. With its support for *spatial hypertext*, VKB even addresses the work practices in which people use color and font characteristics to group information elements. Still, these programs have not focused on the creative recombinant potential of collections of visual semiotic elements. Our senses of creative and work-based properties and uses of collections of information elements may come from different spheres of human activity, and different processes of production. Yet, they are essentially compatible. People tend to collect stuff that is interesting to them. We expect that for the collections, themselves, to be interesting to look at, will be beneficial. Metadocuments can transform their constituent elements through the recombination of information. Users do not have to compose with the same degree of precision as Ernst, in order to create compositions *they* find meaningful. Recombinant metadocuments are rich potential

sources of evocative, expressive new media. CollageMachine is a process-oriented art work, and a creatively motivated tool, in which the activities of browsing the web and authoring metadocuments are integrated.

Constructive Operations of Recombination

Assemblages connect found elements. They build relationships between the elements, and invite processes of interpretation. In this way, they form information spaces. As recombination moves from physical to digital forms, the potential grows for recombinant information spaces to be built procedurally, and to evolve dynamically. Whether compositions are single state and static or procedural and dynamic, whether they are composed with physical objects, or digital ones, certain underlying mechanics remain consistent. Whether it is performed by a human, by a computer program, or by a combination thereof, the process of creating recombinant media consists of four fundamental constructive operations:

Selection – Choosing material is typically a two pass process. First, one or more sets of candidate media elements are collected. In Max Ernst's work, this involved identifying scientific and popular catalogues (documents), and then selecting images from them (cutting). In CollageMachine, it means downloading and parsing documents, and building one set of candidate document references and another of media elements. Then a second pass of selection decides, periodically, which candidate web document references to crawl via recursive re-invocation of pass 1, and which candidate media elements to include in the current visualization.

Spatial Arrangement – deciding where to place elements spatially, in relationship to each other. In the digital realm, we can scale images and text, so this also includes determining elements' sizes.

Treatments – processing of individual elements in the recombinant composition. Rauschenberg, for example, sometimes puts a layer of varnish or glue over an image, so as to dull or brighten its appearance [15]. In *His Master's Bedroom*, Ernst's overpainting only partially obscures the material underneath it, leaving a murky echo of the obscured elements, that suggests the process of memories drifting into the unconscious [23].

Digital treatments include filters like blur, down-sampling, hue, saturation, and value re-mapping, and Fourier resynthesis. In CollageMachine, images are normally placed without initial treatments. Over time, as the age on screen, they are desaturated. They may be blurred as a reflection of the user's expression of negative interaction. The exception to this is when the model of the participant's interests maps negative interest to an element before it is placed. In such cases, the elements is blurred to begin with.

Fastening – the means of assembly; processing that pastes, blends, morphs, composites, or otherwise connects elements. We must answer such questions as: are elements simply juxtaposed, or are they blended further? Are lines of attachment softened, or do they stick out? In *Reves et Hallucinations*, Max Ernst leaves visible pasting lines [1]. In *His Master's Bedroom*, he makes them invisible [23].

One digital means of fastening, which is invoked particularly in the world of video, is the alpha channel. Alpha affects transparency, and, through intermediate values, translucence. When layers of bits overlap, the alpha channel becomes a fastening technology. A technique, known sometimes as alpha masking, uses intermediate alpha values in the border region of an image. Implemented in CollageMachine in 2002, such alpha masks are used to create a sense of visual flow between elements. They are implemented through the procedural generation of an alpha gradient that runs from an extreme alpha value at or near transparent at the image's edges, to absolute opacity, as the mask area ends toward the center of the image. The resulting sense of visual integration is palpable. The conceptual tensions between elements are often strengthened by their visual integration. Other elements are fastened opaquely, retaining separation. Prior versions of the program, which relied exclusively on juxtaposition, were less effective in conveying semiotic sense. The addition of image processing algorithms, of which alpha gradients are one, and buffering techniques which allow these computationally expensive operations to be performed gradually, without slowing the program down too much, did not require rewriting the entire program. They are modules in the CollageMachine recombinant framework.

Manovich focuses on the properties of fastening technologies [27]. Because montage and collage leave hard lines between composed elements, where alpha masking and morphing create continuity, he calls compositing "anti-montage." At the same time, he identifies montage as a device for creating conceptual tension, through juxtaposition between disparate elements. This makes sense semiotically. Yet this is not inherent in the media of fastening. It is a property of information composition. Manovich's examples of how actors are shot in front of blue screens, and then seamlessly composited into archival or computer generated backgrounds, clearly describe typical uses of digital compositing capabilities. Yet, as current versions of CollageMachine demonstrate, the same technology can be used to create conceptual juxtaposition. Collage, montage, alpha blending, remixing, and morphing are genuses of recombinant fastening operations. The compositional dimension of selecting such techniques is relatively independent of the dimensions in which visual and semiotic choices are made to create more or less cohesion instead of heterogeneity, in a composition, In a generative recombinant system, there is a whole space of options for how to integrate modules which perform semantic and visual analysis, with those that generate visual composition.

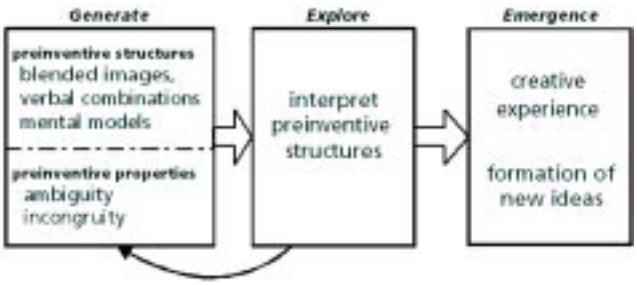

Figure 3. Creative cognition: the Geneplore model.

Cognition of Recombinant Information

Our cognitive processing of recombinant information is addressed by the *geneplore* model of creative cognition [10]. According to geneplore, creative experiences sometimes develop when phases of generative processes (e.g., memory retrieval, analogical transfer) alternate with exploratory

interpretive operations (e.g., attribute finding, hypothesis testing). Certain conditions increase the likelihood of creative experience. The generation of *preinventive structures*, which serve as the grist of creative process, makes the development of creative results more likely. Combinations of images and words, that is recombinant information, are a form of preinventive structure, as are visual patterns and mental models. The exploration phase consists of articulation, interpretation, and refinement. We play with the preinventive structures in search of understanding. We may iteratively cycle back and forth between phases of generate and explore.

Some preinventive structures are also characterized by *preinventive properties*. Examples of these include ambiguity and incongruity. That is, when information elements are recombined, if the combinations make sense immediately, the cognitive process is not likely to go anywhere. But, if there are potential relationships that are not immediately clear, the mind tends to work on making sense of them, to find new connections. Sometimes, configurations of preinventive structures don't lead anywhere. There are no guarantees. On the other occasions, we experience, "Ah-ha!" This is the emergence of new ideas.

In the case of a recombinant work with fixed form, such as a still collage, or a filmic montage, the creative process actually includes two phases of exploration. First, there is process of the artist, making the work. The artist is privileged by the ability to generate forms of the work, reflect on states as the work develops, and iterate back through more creative generation. Eventually, the work is presented to an audience. Here, again, there is a new process of interpretation. Typically, the conceptual relationships between elements of a provocative work, such as Ernst's collages, are not immediately apparent. They are preinventive structures with preinventive properties. The audience member has an opportunity to engage in interpretation that may lead to emergent ideas. The audience member is not, in such cases, able to influence the generative phase.

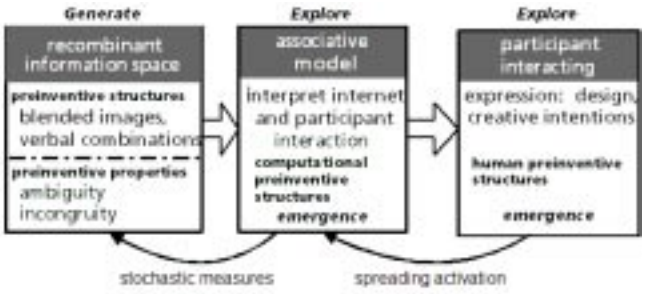

Figure 4. Creative cognition with CollageMachine.

CollageMachine is being designed to create a more actively *geneplorative* experience. The difference is that generation of recombinant forms, as well as their interpretation, continues once the participant user is involved.. The computer plays the generative role, by undertaking procedural dynamic retrieval of information elements, selection of them, and recombinant visual composition. Exploration is accomplished cooperatively both by the participant, and by the program. The participant can use the interface interactively to express interests. The program's goal is to translate this interaction into responsive automatic browsing, that is consistent with what the participant is actually expressing. That is, the goal is to retrieve related elements to those that s/he has expressed interest in. The program also seeks to recognize and respect the participant's design decisions as it makes spatial decisions about the placement of new elements. The program's mechanism for generative automatic browsing actions is its associative model of hypermedia content and user interests. Through this feedback mechanism, interactive exploration iteratively effects the generative phase.

Personalized Web Recombination

The web continually grows as a vast hypermedia repository of size beyond human scale. A small, yet precious, subset of this media is of interest to an individual. Helping people discover and derive value from that interesting subset is the essential role played by an emerging field of programs that perform dynamic recombination of web content as a reflection of a participant's personal desires. In Bender's "Daily Me," [5] – exemplified by systems such as FishWrap [8] and Zwrap [13] – the presentation takes the form of a "personalized newspaper." Anderson and Horvitz's "My Montage" [2], composes a similar presentation based on "routine patterns of access." These programs are influenced by recommender systems, such as Letiza [24] and Fab [4]. The impetus for another track of web recombinators generators, such as The Impermanence Agent [41], and Netomat [42], has come from the art world. CollageMachine, an agent of streaming web recombination that integrates functional and artistic motivations, has been under development since 1996 [17-22]. A burst of development during the last year has improved the agent model, added visual compositing, image processing, a language for specifying seeding, new methods for text visualization, a new interface design, and many other features. Integrated approaches to content retrieval, interactivity, and visualization are iteratively developed. The current conceptual approach and functionality set is a product of many design/implementation iterations over that period of time, based on diverse feedback through usability studies [16, 18], informal demos, public presentations, and conceptual walkthroughs [22]. The program has been co-developed through and along with the concept-context-design interactivity development model [22].

3. GRANULARITY OF BROWSING

Granularity refers to the size of the fundamental units that browsers present. CollageMachine shifts the granularity of browsing down from documents to smaller units. It makes *information elements* essential. In the current implementation, supported information elements consist of images and chunks of text.[1] A study by Schraefel et al [35] confirms that users regularly need to deal with these finer grains. CollageMachine gives attention both to the ongoing retrieval of interesting information elements, and to their visual composition into a recombinant form that facilitates reading individual elements and relationships between elements. This process develops gradually and continuously: pages are automatically streamed into the browser every few seconds; media elements once per second.[2] Thus, temporally, the granularity of browsing is

1 Support for additional MIME types, such as video, audio, and Flash, is in progress.

[2] These are the default; the user can halt content streaming, and control its rate (See below). It is also interrupted automatically by interactive media element drag operations.

extended from a single static view that settles and waits for the user to click a hyperlink, to a dynamic one that evolves continuously.

4. RECOMBINANT BROWSING AGENT

Conceptual And Functional Approaches

CollageMachine integrates three essential components: an associative model that drives operations, a recombinant visualization that reflects the state of the model to the user, and an expressive interactive interface that enables the user to directly manipulate the visualization and effect the model. As the program runs continuously, the model evolves. The model connects the structure of the information elements, including their interrelationships, with the user's interests and intentions. The state of the model at any moment is stochastically applied in all recombinant information-making decisions, such as the selection of documents to retrieve, of media elements to display, their size, and location. This effects dynamic adaptive browsing. An operation-specific metric is applied to the set of attributes that adorns each content element structure: each candidate is assigned a floating point weight.

Decisions based on the model are made probabilistically, rather than deterministically. Rather than choose a minimum or maximum, a weighted random select operation is conducted, These procedures, on the one hand, faithfully reflect the model, on the average. At the same time, by retrieving and displaying content elements that are within the scope of the traversed space, but are not necessarily the ideal candidate, CollageMachine opens the process of browsing. Scientifically, this works in a manner that is analogous to simulated annealing [9]. Experientially, it is like going to the library with a list of books and call numbers, and finding an exciting book on a nearby shelf; or finding a really great hat while shopping for socks. From an artistic perspective, the use of indeterminacy to open the set of considered possibilities corresponds to methods employed by postmodern practitioners such as John Cage [7] and Marcel Duchamp [25]. This corresponds to the way memory and cognition work when the brain is in an intuitive state. "Flat activation" of a greater set of memories that participate in a cognitive moment increases the potential for new associations to emerge [12]. Cognitive models of creativity also utilize indeterminacy [10]. CollageMachine's generative approach to browsing extends experience beyond the routine to expand conceptual spaces and support brainstorming.

Associative Model

The associative model consists of the content elements and multiple referential structures that link them. This model is currently maintained only for the duration of a single session. Each content element includes a tuple of attributes. Information elements inherit attributes from their containers. Some of these attributes represent properties of the content. The *generation* attribute counts the number of links traversed from the session's origin; it is used to effect breadth-first, rather than depth-first, web space retrieval. The *numLinks* attribute counts hyperlinks to the element; as in the Google PageRank metric, [30] more links to a single content element means more importance. The mime attribute is used to give JPEG images priority, since they are usually photographs, and make for interesting recombinant compositions.

Other attributes represent properties of the user and the visual composition designer. *UserSignificance* can be positive or negative. It represents the intensity of the user's interest or disinterest with regard to the element. This field gets modified both by expressive direct manipulation of a visualized media element in the information space, and by inference. We also measure positive clicks, in order to keep track of direct manipulations separately from inference mechanisms. This enables CollageMachine to pay particular attention to the participant's design decisions.

An array structure for available containers – those that have not yet been downloaded – and one for available media elements is maintained for efficient weighted random select operations. Hashtables, with URLs as keys, allow for fast lookup to determine, during parsing of a new document, whether a referenced content element has been previously downloaded. The hyperlink structure of containers and media elements allows expressive interaction to be propagated by spreading activation [34] [31]. The links function as edges; the weights measure the flow capacity of the edges. Each interactive operation specifies an activation (positive values) or inhibition (negative values) energy multiplier for its particular flow. When a media element is altered, a lesser alteration is propagated to its associated container, and, if there is one, hyperlink. When a container's user significance is altered, this is propagated directly to the contained media elements.. Such procedures are invoked recursively, with a damping factor of 5/9. (The efficacy of this constant is based on adhoc tuning, tempered by evaluations.) Thus spreading dies out with a sort of half-life.

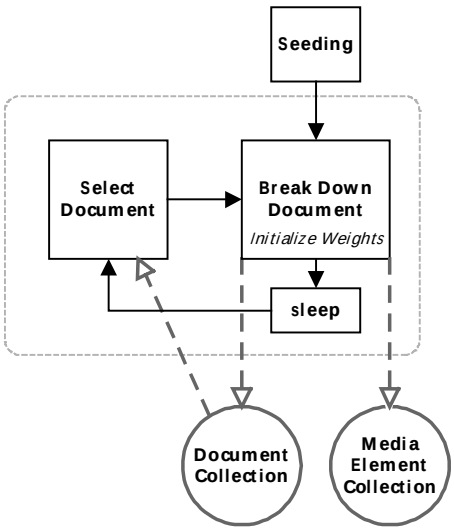

Figure 4. The flow of seeding and breaking down documents.

5. EXPERIENCE AND OPERATIONS

Seeding

The recombinant information space session begins with the specification of a set of initial web addresses, or *seeds* (See Figure 4.). These are the first documents that are fed to the collaging engine. They can be static or dynamic documents; all that matters to the program is that they are in the form of

HTML, and that they can be accessed over the network via the http or ftp protocols, or from a local file system.

The process of seeding is closely related to the context of deployment. As this tool can be used in different ways, the growing set of seeding mechanisms is diverse. Connection of seeding processes and content with activity contexts enables the generation of situated [40] knowledge spaces.

Seeding decisions themselves can be made dynamically, using a database and server-side logic, as in the JumboScope exhibition [22]. In that case, the seeds were samples that served as access points for the visualization of an evolving hypermedia repository, that represented the Tufts University community. This visualization was accessible in a central public space on a flat panel, and also via the web.

Static seeds could be fixed in advance, as part of web site authoring. In this case, CollageMachine functions as alternative metanavigation. This was done by the God Ist Ein DJ project at the Ars Electronica Center. The metanavigation approach would also be an effective means for presenting the contents of any digital library or electronic catalog, in which a substantial investment has been made in the production of high quality images. Art museum and clothing store web sites are examples.

In the standard, user-oriented interface [17], sessions can be seeded via 3 different pathways. In the first, the user types web addresses directly. This extends the paradigm of typing directly into the browser's location/address field; by providing multiple fields, allowing mixed browsing to multiple concurrent destinations. The search engine seeding mechanism works similarly, providing multiple fields that enable the collaging of multiple search engine requests. In this mode, CollageMachine functions as a front-end to Google, providing an alternative form of search results to the standard text listing. It would be interesting to integrate CollageMachine directly with Google. In that case, a persistent form of the CollageMachine associative model could be used by the search engine, as it forms query responses, to augment its understanding of the user's intentions. This would create a new kind of feedback.

The third seeding mechanism, collections, offers a set of pre-curated information space seeds. Popular cultural examples include news (BBC, New York Times, CNN, ABC), art museums (Louvre, Van Gough Museum, British Museum, MOMA, Metropolitan, National Gallery), and 911 (September 11th). Other pre-curated sets have corresponded to events. Ensembles of hypertext literature authors have seeded CollageMachine with their works to produce a dynamic composite information space in public presentation venues, such as the Guggenheim Museum, and the NYU Center for Digital Multimedia. Collections have also been created using the works of peer participants for symposia, such as at the Banff Centre New Media Institute. In these cases of live events, a social space is created by the dynamic reassemblage of digital works in conjunction with a community of participants who are also physically present.

Runtime Parameters

In the standard web incarnation, the user is afforded several other runtime parameter options. Choices for information space size include "full screen," "near full" (which leaves convenient space for the task bar at the bottom of the screen), "almost half," and "quarter" The "stay close" or "allow wandering" choice lets the user focus or limit the web space traversed by a session. If stay close is specified, then the web crawler will be limited to URLs beneath the web address directories specified by the seeds. For example, if the only seed is "www.nytimes.com," then having this string as a prefix is a requirement for traversal of hyperlinks. The set of seeds then defines a spanning space for hyperlink traversals during the course of the session. If an address within that spanning space turns out to refer to a server-side redirect, the redirect target will also be added to the spanning space of traversal. The need for this redirect mechanism was established through experiences with the CNN web site:, where, for example, cnn.com/sports is a server-side redirect to sportsillustrated.cnn.com.

Another runtime parameter, "as found," or "abstracted," maps to two internal parameters. Abstracted allows for the pixelation of smaller images into larger visuals. This creates a textural effect. Abstracted also allows increases the size of the largest possible images. While larger images may look quite interesting visually, they occlude a larger subset of the media elements one could see. When using CollageMachine in order to sift through quantities of elements, this may be considered undesirable.

Breaking Down Documents

When the user pushes the "Launch CollageMachine" button, the seeds are subjected to the same procedures as web pages that are subsequently chosen via the web crawling selection mechanism.[3] Each is downloaded, and parsed. The HTML serves as a guide for how to break the documents down into containers of constituent media elements and references to other containers. The treatment of the **`<img`** tag as a reference to an image element is obvious. Markup, such as the **`<p>`**, **`<div>`**, **`<td>`**, **`<li>`**, and **`<br>`** tags, is used as a first pass in the delimiting of text chunk elements. Text chunks are currently also parsed for sentence boundaries. Their size is thus currently on the order of a sentence, or smaller. Extremely long sentences are currently thrown away. This is one development process aspect with a collaging browser that recurs. Some features are not obliged to work perfectly – only reasonably well. Hyperlinks are translated into container structures, and references thereto, well before downloading. Or, if a referenced document or image is already known to the application, the reference counter attribute of the model, *numLinks*, is incremented.

Figure 5. Temporal controls.

Temporal Controls

The participant can effect temporal development through a subset of the tape recorder and automobile accelerator metaphors. A pause/play button allows the information space evolution to be temporarily stopped, and then resumed. A rate slider affords control over the rate at which documents are downloaded and media elements are added to the visual

[3] After seeding, a thread is started which loops forever. Each iteration selects a container reference from the currently available set, downloads and processes the web page, and sleeps briefly. This is the web crawler.

composition.[4] These controls play an important role in giving the participant control of the experience. In addition, with support for drag and drop, the paused recombinant information space, like Hunter Gatherer, [35] can function as a canvas for collection-building activities.

Building the Recombinant Visualization

Concurrent with the start of breaking down documents, a window appears. The recombinant visualization develops here. The visual composer thread iterates forever through these operations: 1) select a media element from the currently available set to add to the visualization; (2) update the weights for each information space element already onscreen, in case their attributes have changed, and including a history factor that measures how long each has been part of the session;[5] (3) sort the already on screen elements by their weights, so they can be displayed with z-stacking order corresponding to their relative importance;[6] (4) choose a size for the new media element; (5) choose a location on screen for placement of the element; (6) repaint the entire visual composition; and (7) sleep briefly.

Figure 6. CollageMachine Toolbar.

Expressive Interactive Interface

The goal for CollageMachine interactivity is to create an expressive interface, which enables the participant to: take an active role in designing the visual appearance of the information space; and to steer the directions the program takes in traversing web space, over the course of a session. The participant *creates* the experience of receiving information, instead of just passively receiving it in the precise form of someone else's design. In this way, the information space is mutable. The interactive interface maps together the participant's expression of intention with her/his direct manipulation of information space design. This mapping enables the participant to effect what the visual display looks like, and express dis/interest, with a single gesture. The isolated ranking interaction of the typical recommender system, [3] in which the user must perform the ranking task for the system, without immediate gratification, is eliminated by this fusion.

In the current implementation, CollageMachine presents a modal interface, utilizing the MacPaint paradigm, in which a set of tools is made available through a tool palette; one tool (or mode) at a time, is activated. Each tool can be utilized via click, and in some cases, drag and drop operations, with respect to a information space element. The tool acts upon the selected media element, on its container, and, if present, on the target container of a hyperlink. In the case of text elements, which may contain embedded hyperlinks, clicking on or off those links changes the effect. This set of targets forms the operand context for the tool's action. Operation is further propagated from the operand context to related elements by spreading activation, or in the case of negative expression tools, spreading inhibition, to related content elements, based on hyperlink and container relationships.

The *Web Page* tool is active on startup. This tool provides a mapping from recombinant information space browsing to the traditional web browsing paradigm. It opens the target document – either the hyperlinked document if there is one, otherwise the container – in a button-less web browser window. The same window is reused (and brought to the top) for subsequent Web Page tool invocations. This tool is initially active, because usability tests have indicated that this function is the one typically expected by naive users. When this tool is active, clicking works in a manner similar to that of conventional browsers.

The *Positive Grab* and *Negative Grab* tools operate similarly. They enable the user to express interest or disinterest in the operand context of an element. Positive Grab effects "Bring to Top" on click. Both tools enable dragging. Dragging is considered to be the strongest expression. Elements can be dragged within the recombinant space, or beyond its borders, to another program, such as a web browser, content authoring environment, or document editor. The Negative Grab tool was created in response to usability testing [20]. Tests indicated that users sometimes drag elements they like out of the way, so they no longer occlude desirable ones. This is true even though they could use the cut tool to eliminate the undesirable element. An unexpected side effect of this interaction design is that Negative Grab affords drag under. This creates an unusual tactile and visually stimulating experience.

The *Cut* tool's operation is more straightforward. It removes an element from the information space on click. Disinterest is expressed with regard to the tool's operand context.

The Text tool enables editing of existing text elements, and creation of new ones. Through this process, the user is able to annotate the information space, with her/his own conceptual glue. These annotations also enlarge the scope of the ongoing evolution of the space, in that they trigger the automatic synthesis of new Google queries.

Image Processing Techniques

CollageMachine uses image processing techniques to create visual layering. They effect treatments on and fastenings of information elements. These treatments are mapped to serve multiple functions: visual, cognitive, and operational. Blur and desaturation create foreground/background effects that aid the viewer in seeing the recombinant space's multiplicity of elements. As elements are progressively desaturated, reflecting their age on screen, their color seems to be gradually drained out of them. This mirrors the way human memory works; events fade over time. This is similar to Hollan and Hill's notion of edit wear [17]. Similarly, negative interaction effects blur on the elements in the operand context (See Figure 7.); this blur is propagated to "related" elements via spreading inhibition. The

[4] Work in progress will extend these temporal controls to include reverse, and will differentiate play and record.

[5] The history factor is only relative, based on an element's age compared to other elements in the collage. It does not absolutely account for elements that persist due to user significance measures in the model.

[6] Using a form of radix sort, the elements in each fat pixel are sorted as part of the same procedure that sorts the whole collage.

Figure 7. Successive states of disinterest expressed through blur, and propagated through spreading inhibition..

blurred and less colorful elements become less prominent visually, than those that are sharp and colorful. As these elements fall into the background, newer and more important elements grow easier to see. These effects occur automatically, based on the participant's perceptual + cognitive systems. Further, the participant who understands these mappings can use them more intentionally. As these imagistic mappings visualize the state of the program's model, so they inform the participant about how the program is working, and, therefore, about what it is likely to do. Positive interaction with an information element overrides the desaturation function, maintaining an element's visual state and prominence. This is one of the many ways in which CollageMachine works to respect and reinforce the participant's direct design decisions.

Rollover State

A number of fluid visual modifications are effected on rollover of an information element (See Figure 8.). Immediately, the unprocessed version is displayed, removing all effects, including blur, desaturation, and alpha blending. This reminds the participant about what the element looks like in its original context. The element is surrounded by a black selection box. Further, if the focus information element is partially occluded by other elements, the bounding regions of occlusion are drawn with a window shade horizontal hashing. This makes visible the area that the focus element would take in the information element if it was not occluded. Once rollover lasts long enough to be deemed an intentional exploration rather than an accidental or in-passing wave -- for 700 milliseconds – a bubble above the element displays metadata about it's operand context. For example, in what document is it contained? To what document is it perhaps hyperlinked? If it is an image, is there metadata in the HTML markup, via the `alt` text attribute? The participant does not need to invoke the web page tool to access this contextual information.

6. FUTURE WORK

The range of significant means for improvement, and applications of CollageMachine is surprisingly vast. We are currently working to extend the associative model of content to incorporate information retrieval's term vector model [34]. We also plan to extend the model of the participant beyond a simple measure of interest, to account for a range of feelings, interests, physical sensations, cognitive processes, and symbolic senses. An expanded set of interactive design capabilities will give the participant further ability both to effect the visualization and to express intention. We are beginning to work on integrating a computer vision system that will enable 3-D physical interaction via gesture. The relationship between physicality and expressivity will be explored. Ubiquitous displays and situated integration will relate the generation of digressive information brainstorm spaces more directly and automatically to participants' ongoing activities. Applications areas such as digital libraries, authoring, and local and remote collaboration will also be addressed.

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