Automatic Retargeting of Web Page Content

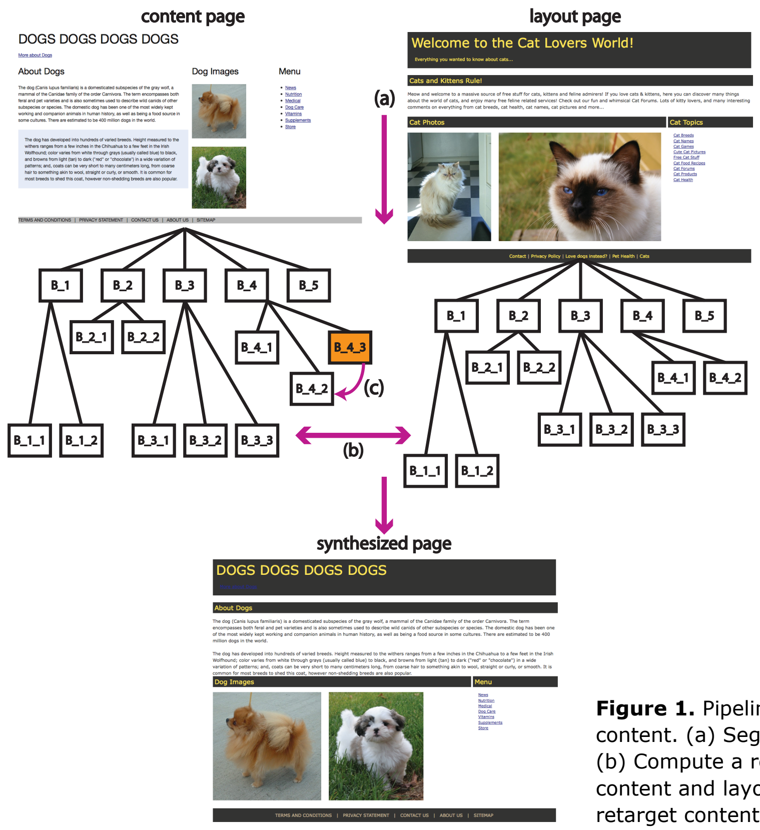

Figure 1. Pipeline for retargeting web page content. (a) Segment pages into perceptual trees. (b) Compute a reasonable mapping between content and layout trees. (c) Use mapping to retarget content onto the new layout.

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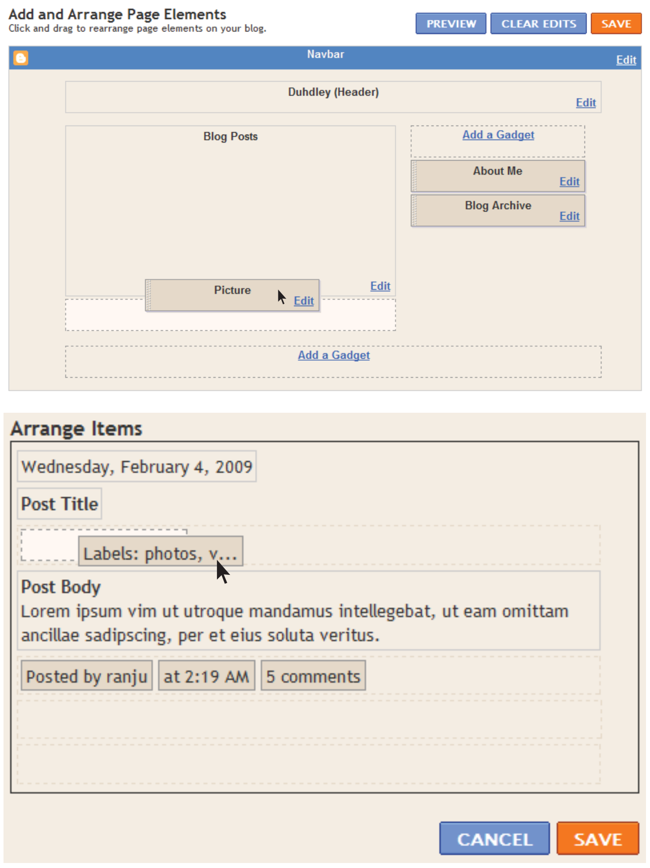
Abstract
We present a novel technique for automatically retargeting content from one web page onto the layout of another. Web pages are decomposed into their perceptual hierarchical representations. We then use a structured-prediction algorithm to learn reasonable mappings between the perceptual trees. Using the mappings, we are able to merge the content of one page with the layout of another.

Keywords
Web design, automatically generated alternatives

ACM Classification Keywords
D.2.2 [Software Engineering]: Design Tools and Techniques.

Introduction
Enumerating multiple alternatives is critical to good design [1] but is often tedious and time consuming. On the web, templates can be used to efficiently generate design alternatives. However, this limits designers to the corpus of pre-constructed templates. What if users could use *any* web page as a template? This paper presents a technique for borrowing the layout and style from any web page and applying it to your own.

The remainder of the paper is structured as follows. We describe the relationship of this paper to prior work. We



Lorem ipsum vim ut utroque mandamus intellegebat, ut eam omittam ancillae sadipscing, per et eius soluta veritus.

Figure 2. To edit layouts in Blogger, move around labeled content blocks.

then present the pipeline and algorithms used to synthesize alternatives. Finally, we discuss results and future work pertaining to building a graphical interface leveraging our technique to aid web design.

Related Work

This work draws on two main areas of prior work: web design tools that aid in producing higher quality designs and techniques for generating design alternatives.

Template-based systems (*e.g.*, Blogger) operate on the principle that pre-existing content can aid design. These systems allow users to quickly create many cookie-cutter web sites, but they greatly limit expressivity. Prior work has also explored using web pages with authentic content as starting templates. Lee *et al*.'s Adaptive Ideas [6] enables users to parametrically browse through a corpus of actual web pages, use the example pages as starting templates, and borrow style attributes (limited to font and colors) from them. With Adaptive Ideas, users must manually adapt content to the example designs in the corpus. The system introduced here performs this step automatically. Ivory *et al.*'s system [4] uses learned statistical profiles of good sites to suggest improvements to existing designs to increase their quality. These changes, however, must be manually implemented by the user, and the system provides no assistance for designers in the tabula rasa stage of development.

Prior work has explored two main approaches to generating alternatives. One is to represent the design as a set of parameters, which are manipulated to explore the space of alternatives [7, 9]. The other is to synthesize alternatives by adapting and merging past solutions to fit the current context: a common expert practice and the keystone of case-based design literature [5, 6]. Our framework provides an explicit mechanism for borrowing layouts and styles from other web pages to synthesize alternatives.

Synthesizing Alternatives

Automatically adapting content to different design layouts poses two significant technical challenges. First, given a pair of web pages, both must be segmented into their constituent perceptual blocks. Second, a mapping between the blocks of the two pages must be computed. Current template-based systems that support automatic layout changes require pages to be composed of labeled content blocks (Figure 2). Different template layouts are simply different arrangements of the same content blocks, making retargeting straightforward. We present a new method for merging content and layout between any two arbitrary HTML pages without imposing restrictions on content.

Perceptual Tree Construction

To merge content and layout of arbitrary HTML pages, it is necessary to codify the visual structure of web pages. We implemented a modified version of Cai *et al.*'s "VIsion based Page Segmentation" (VIPS) algorithm [2], an iterative, top-down method for building a tree representation of a web page's content structure.

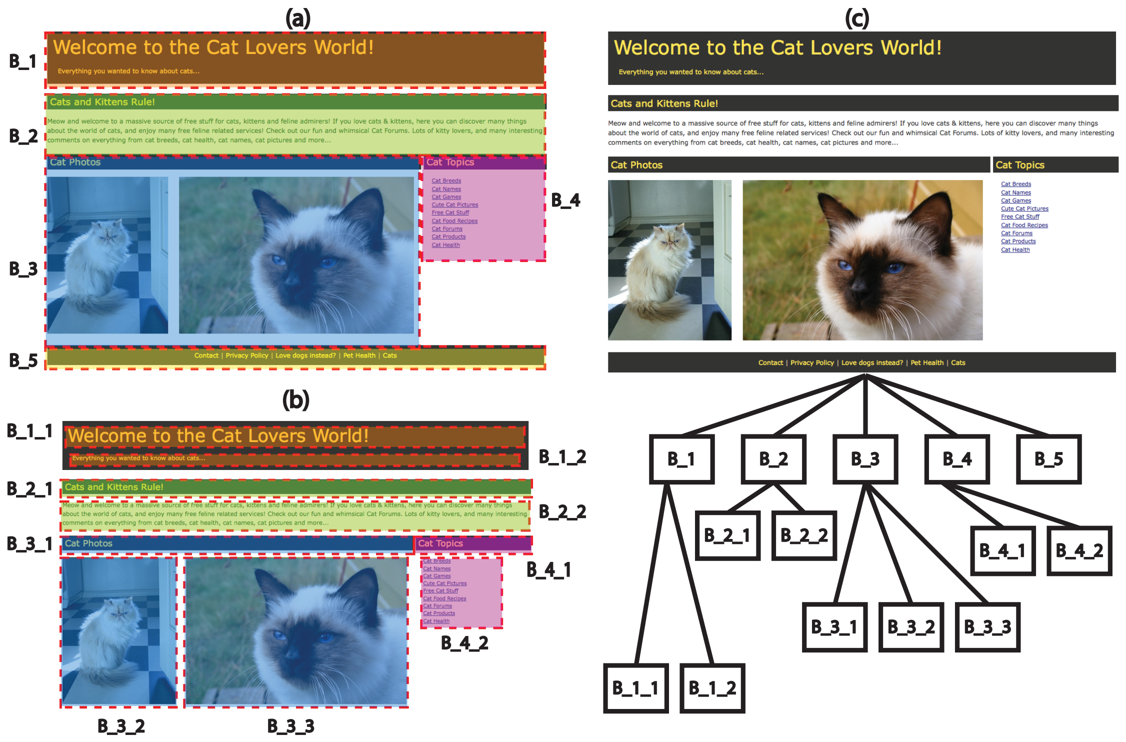


Figure 3. A web page segmented using our implementation of the VIPS algorithm [2]. (a) Blocks extracted after the first iteration. (b) Blocks extracted after the second iteration. (c) Resulting perceptual tree structure.

Each iteration of the algorithm has three phases. In the visual-block extraction phase, the system recursively traverses the DOM tree of the page and extracts DOM nodes which correspond to visually dominant blocks. The heuristics for determining perceptual importance are based on visual cues such as background color, size, and content type. In the next phase, vertical and horizontal separators are detected between the extracted blocks. These separators are assigned weights according to the visual difference between the blocks that they separate. In the final step, the extracted blocks are merged together into new blocks to form the hierarchical representation of the content structure. Merging starts with the blocks separated by minimally-weighted separators and iterates until the blocks separated by the maximally-weighted separators are merged.

At the end of an iteration, the leaf nodes of the tree (*i.e.*, the extracted blocks from that iteration) are fed back into the next iteration of the algorithm unless they exceed a granularity threshold (Figure 3). It is important that both the page containing the content and the page containing the layout have been broken down to the same level of granularity for our mapping algorithm to perform well.

Tree Mapping
Given this perceptual tree representation of web pages, the mapping between the visual structures of a pair of web pages can be computed. In general, a mapping between two trees specifies a sequence of edit operations that should be applied to each node in order to transform one tree into the other (Figure 4).

Suppose we impose an ordering on the nodes of a given tree. Let $T[i]$ represent the ith node of tree T in the given ordering. Formally, a mapping M from T to $\hat{T}$ is a set of pairs of integers $\{(i,j)\}$ satisfying the following constraints:

1. $1 \le i \le |T|$, $1 \le j \le |\hat{T}|$, where $|T|$ is the number of nodes in T.

2. For any pair of (i_1, j_1) and (i_2, j_2) in M:

   - $i_1 = i_2 \Leftrightarrow j_1 = j_2$ (one-to-one),

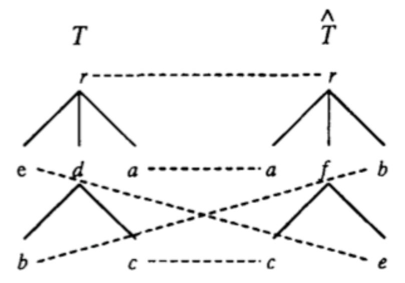


Figure 4. A mapping between two unordered trees, T and $\hat{T}$ [8]. A dotted line from a node in T to a node in $\hat{T}$ indicates a matching operation. A node in T and $\hat{T}$ that is not touched by a dotted line should be added and deleted, respectively.

- $T[i_1]$ is an ancestor of $T[i_2] \Leftrightarrow \hat{T}[j_1]$ is an ancestor of $\hat{T}[j_2]$ (ancestor relationship preserved) [8].

Then, the reward of a mapping M can be defined to be the sum of all individual rewards associated with each edit operation:

$$\gamma(M) = \sum_{(i,j)\in M} \gamma\left(t_1[i] \to t_2[j]\right) + \sum_{\{i \mid \nexists\, j \text{ s.t. } (i,j)\in M\}} \gamma\left(t_1[i] \to \lambda\right) + \sum_{\{j \mid \nexists\, i \text{ s.t. } (i,j)\in M\}} \gamma\left(\lambda \to t_2[j]\right),$$

where $\gamma\left(t_1[i] \to \lambda\right)$ and $\gamma\left(\lambda \to t_2[j]\right)$ represent insertion and deletion edit operations, respectively.

Predicting Mappings
Given this formalized notion of mapping between trees, we use the generalized perceptron algorithm for structured-prediction [3] to predict reasonable mappings between the visual structures of web pages. For this supervised learning algorithm, a training example is given by a pair $(x^{(i)}, y^{(i)})$, where the input variable $x^{(i)}$ represents a pair of perceptual trees and the target variable $y^{(i)}$ represents the mapping between them.

To predict good mappings, the algorithm learns how to weight (reward) shared features between a pair of perceptual blocks. Using these learned weights, the optimal mapping (that is, the mapping with the highest reward) can be calculated for a given tree pair. More formally, the algorithm learns a rewards-weight vector $\vec{w}$ such that $y^{(i)} = \arg\max_y \vec{w}^T F(x^{(i)}, y)$, where $F(x^{(i)}, y)$ is a feature-counts vector containing the number of appearances of each feature in a given mapping. The feature-counts vector we use has the form

$$F = \begin{pmatrix} \text{\# of inserts and deletes} \\ \text{\# of matchings with matching tags} \\ \text{\# of matchings with similar content} \\ \text{\# of matchings with similar dimensions} \\ \text{\# of matchings with similar positioning on page} \\ \text{\# of matchings meeting none of the above criteria} \end{pmatrix}.$$

Each iteration of stochastic gradient ascent executes the following sequence of operations until $\vec{w}$ converges:

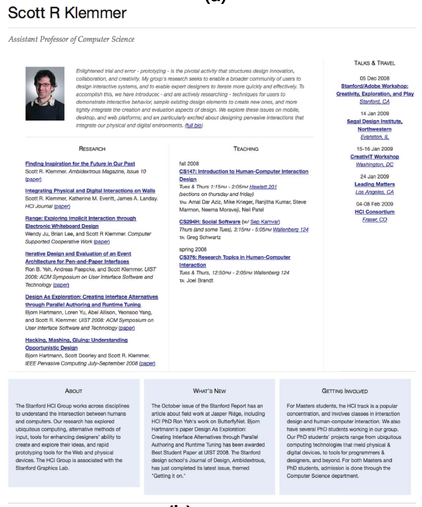
- Pick a random training example: $(x^{(i)}, y^{(i)})$.

- Compute $\hat{y} = \arg\max_y w^{(t)T} F(x^{(i)}, y)$, where t is the iteration variable.

- Update $\vec{w}^{(t+1)} = \vec{w}^{(t)} + \alpha^{(t)}(F(x^{(i)}, y^{(i)}) - F(x^{(i)}, \hat{y}))$, where $\alpha^{(t)} = 1/\sqrt{t+1}$ is the learning rate.

In each iteration, the optimal mapping $\hat{y}$ is computed for the given tree pair $x^{(i)}$, using the current rewards-weight vector $w^{(t)}$. The algorithm for computing the optimal mapping between two unordered trees is NP-complete. However, if we bound the number of leaves in even one tree, the exhaustive search algorithm runs in polynomial time [8]. The leaves of our trees correspond to the smallest perceptual blocks that are returned by our VIPS implementation. By controlling segmentation granularity, we generate trees that have fewer than 20 leaf nodes, giving a reasonable bound on the running time of the algorithm. Dynamic program-

(a)



Scott R Klemmer

Assistant Professor of Computer Science

Enlightened trial and error - prototyping - is the pivotal activity that structures design innovation, collaboration, and creativity. My group's research seeks to enable a broader community of users to design interactive systems, and to enable expert designers to iterate more quickly and effectively. To accomplish this, we have introduced - and are actively researching - techniques for users to demonstrate interactive behavior, sample existing design elements to create new ones, and more tightly integrate the creation and evaluation aspects of design. We explore these issues on mobile, desktop, and web platforms; and are particularly excited about designing pervasive interactions that integrate our physical and digital environments. (full bio)

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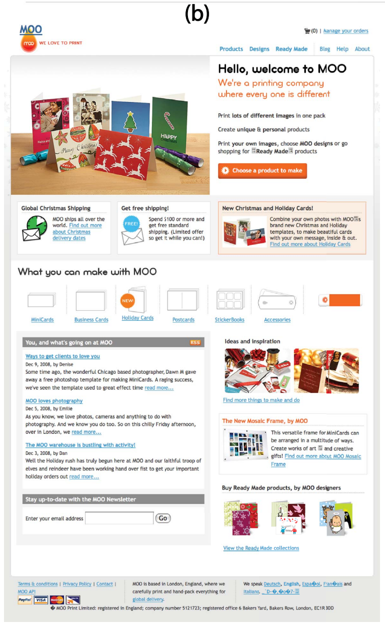

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ming solutions exist but introduce mapping constraints that greatly restrict the flexibility in choosing mappings between trees [10]. Furthermore, once we have learned a reward function that allows us to predict good mappings between perceptual trees, we can employ heuristic algorithms to predict mappings [8] instead of relying on exhaustive search.

We are still in the process of generating training data to produce better predictions. Manually constructing mappings between tree pairs is very tedious; therefore, we are designing a graphical interface to aid in the process. With such an interface, we can even crowd-source the task.

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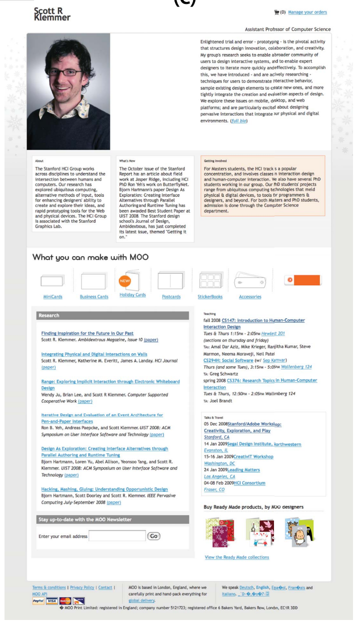

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Preliminary tests done with only a few mappings in the training set are promising. The reward weights corresponding to the various features are reasonable: the weight associated with "insertions and deletions" is negative, while the weights associated with matched pairs with "matching html tags", "similar content", and "similar dimensions" are large and positive.

Synthesizing a new page
Given a mapping between two page trees, we can synthesize a new page in which the content from one page has been adapted to the layout of another. Since all the graphical content of a page is contained within the leaf nodes of its tree, we consider only the image of the leaf nodes of the content page under the computed mapping. If these nodes are all mapped to blocks in the layout tree, we are finished. If some nodes are not mapped, we must determine approximate mappings in order to ensure that we transfer all of the content from our current design. We accomplish this by collapsing the unmatched blocks into their siblings or ancestors, depending upon which of these blocks have the best mappings; see Figure 1(c). The synthesized pages shown in Figure 5 were constructed using this method.

Conclusions

This work-in-progress introduced a novel technique for automatically retargeting the content of a web page onto the layout of any other web page. This technique allows users to quickly realize new alternative designs for their web pages without restrictions on content. We have observed that our algorithmic pipeline produces reasonable results when mappings are manually defined, and the results of the mapping predictor trained with only a few examples are likewise encouraging. We are currently collecting more training data to produce better predictions, which we hope will result in a fully automated retargeting pipeline.

After that, the next step is to build a graphical interface which leverages this technique. Since there could be many reasonable ways to actually retarget content onto different layouts, presenting the user with a gallery of options would allow for greater customization flexibility. By extending this pipeline, we could also support borrowing of style and layout separately. We plan to deploy this tool as a web application to do large-scale empirical studies on how these methods would effect the quality of designs produced.

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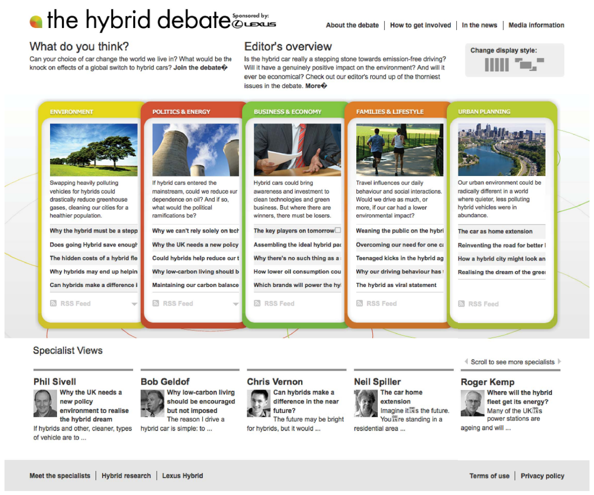

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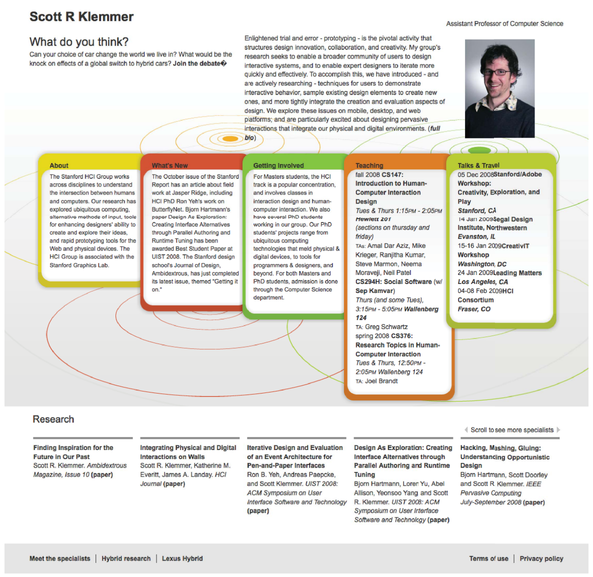

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What do you think?
Can your choice of car change the world we live in? What would be the knock on effects of a global switch to hybrid cars? **Join the debate�**

Enlightened trial and error - prototyping - is the pivotal activity that structures design innovation, collaboration, and creativity. My group's research seeks to enable a broader community of users to design interactive systems, and to enable expert designers to iterate more quickly and effectively. To accomplish this, we have introduced - and are actively researching - techniques for users to demonstrate interactive behavior, sample existing design elements to create new ones, and more tightly integrate the creation and evaluation aspects of design. We explore these issues on mobile, desktop, and web platforms; and are particularly excited about designing pervasive interactions that integrate our physical and digital environments. (***full bio***)

About
The Stanford HCI Group works across disciplines to understand the intersection between humans and computers. Our research has explored ubiquitous computing, alternative methods of input, tools for enhancing designers' ability to create and explore their ideas, and rapid prototyping tools for the Web and physical devices. The HCI Group is associated with the Stanford Graphics Lab.

What's New
The October issue of the Stanford Report has an article about field work at Jasper Ridge, including HCI PhD Ron Yeh's work on ButterflyNet. Bjorn Hartmann's paper Design As Exploration: Creating Interface Alternatives through Parallel Authoring and Runtime Tuning has been awarded Best Student Paper at UIST 2008. The Stanford design school's Journal of Design, Ambidextrous, has just completed its latest issue, themed "Getting it on."

Getting Involved
For Masters students, the HCI track is a popular concentration, and involves classes in interaction design and human-computer interaction. We also have several PhD students working in our group. Our PhD students' projects range from ubiquitous computing technologies that meld physical & digital devices, to tools for programmers & designers, and beyond. For both Masters and PhD students, admission is done through the Computer Science department.

Teaching
fall 2008 **CS147: Introduction to Human-Computer Interaction Design**
Tues & Thurs 1:15PM - 2:05PM ***Hewlett 201***
(sections on thursday and friday)
TAs: Amal Dar Aziz, Mike Krieger, Ranjitha Kumar, Steve Marmon, Neema Moraveji, Neil Patel
CS294H: Social Software (w/ **Sep Kamvar**)
Thurs (and some Tues), 3:15PM - 5:05PM ***Wallenberg 124***
TA: Greg Schwartz
spring 2008 **CS376: Research Topics in Human-Computer Interaction**
Tues & Thurs, 12:50PM - 2:05PM Wallenberg 124
TA: Joel Brandt

Talks & Travel
05 Dec 2008**Stanford/Adobe Workshop: Creativity, Exploration, and Play**
Stanford, CA
14 Jan 2009**Segal Design Institute, Northwestern**
Evanston, IL
15-16 Jan 2009**CreativIT Workshop**
Washington, DC
24 Jan 2009**Leading Matters**
Los Angeles, CA
04-08 Feb 2009**HCI Consortium**
Fraser, CO

Research

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Finding Inspiration for the Future in Our Past
Scott R. Klemmer. *Ambidextrous Magazine, Issue 10* **(paper)**

Integrating Physical and Digital Interactions on Walls
Scott R. Klemmer, Katherine M. Everitt, James A. Landay. *HCI Journal* **(paper)**

Iterative Design and Evaluation of an Event Architecture for Pen-and-Paper Interfaces
Ron B. Yeh, Andreas Paepcke, and Scott Klemmer. *UIST 2008: ACM Symposium on User Interface Software and Technology* **(paper)**

Design As Exploration: Creating Interface Alternatives through Parallel Authoring and Runtime Tuning
Bjorn Hartmann, Loren Yu, Abel Allison, Yeonsoo Yang and Scott R. Klemmer. *UIST 2008: ACM Symposium on User Interface Software and Technology* **(paper)**

Hacking, Mashing, Gluing: Understanding Opportunistic Design
Bjorn Hartmann, Scott Doorley and Scott R. Klemmer. *IEEE Pervasive Computing July-September 2008* **(paper)**

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Figure 5. Two synthesis results (continued from previous page). Mappings were manually defined. (a) Content page, (b) layout pages, (c) synthesized pages. **Zoom for more detail.**