

# Augmenting Faceted Exploration with ResultMaps

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## ABSTRACT

*ResultMaps* are a treemap-based [5] search visualization concept for online digital repositories, designed to leverage hierarchical metadata often already present in digital libraries. We have previously reported our application of *ResultMaps* to a digital library's keyword search engine result pages (SERPs) [3]. Here we discuss the use of *ResultMaps* in the more interesting context of faceted metadata and plans for their formal evaluation. *ResultMaps* perform several useful functions in that environment: placing items within a consistent visual context; provide a mechanism for outlier, cluster and correlation detection; and act as a visual medium for previewing prospective selections.

## 1. INTRODUCTION

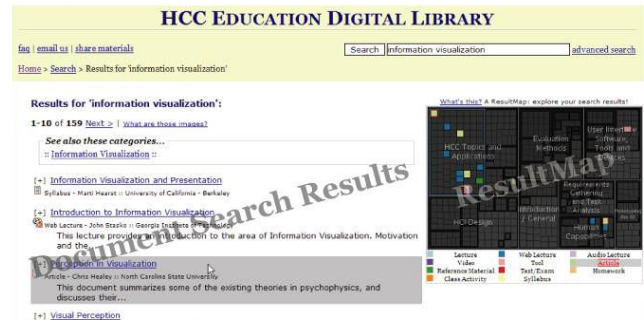
We developed *ResultMaps*, a treemap-based [5] search visualization system, as a way of leveraging hierarchical data often already available in digital library metadata. The Treemap is a well-known tree layout method in information visualization (*infovis*); *ResultMaps* use hierarchical metadata (e.g., a subject classification) to map repository documents into a treemap and highlight items that correspond to the current query. Interactive effects link those nodes to conventional text listings.

The text listing leverages users' familiarity with that environment and provides a connection to the more sophisticated *ResultMap* representation of the same data. *ResultMaps* always encode the full contents of a dataset, preserving inter-query visual consistency. Linking and brushing lets users identify items of interest with rapid access to their details. Moreover, the treemap representation provides a view into lower levels that is lost by flattening the hierarchy, and glanceable representation of the data which makes clusters and outliers visually apparent.

We have previously reported our application of *ResultMaps* to conventional keyword search engine result pages (SERPs) [3]. Here, we discuss their extension to faceted metadata, in which multiple facets may have *ResultMap* components. That addition allows visual comparison of item distributions (e.g., detecting correlations between facets), and a visual substrate for representing previews of prospective actions. We also summarize the results of lab evaluations of SERP *ResultMaps*, which have shown limited support of our hypothesized benefits, and discuss our thoughts on evaluating our current faceted work in that light.

## 2. RELATED WORK

Search visualization for the global search context (vs. within individual documents) requires a structured information space to relate search results to one another and to the overall space. Creation of such a structured space can be manual or automatic. Kules' dissertation [8] focuses on features to use for automatic categorization of WWW search results, but also reports a study of a treemap-based overview of search results, finding them comparable to outline-form overviews (and more effective than no



**Figure 1. A *ResultMap*-enhanced search engine results page (SERP). Brushing links items in the result listing (left) with the *ResultMap* nodes and color legend (right) and vice versa.**

overview). Lin has applied Kohonen maps [7] as a way of contextualizing digital library search results [9] in a manner that is similar to our SERP application. The scatter plot-like feature in the Envision [11], CitiViz [6] and EtanaViz [14] systems has some similarity to our approach as well.

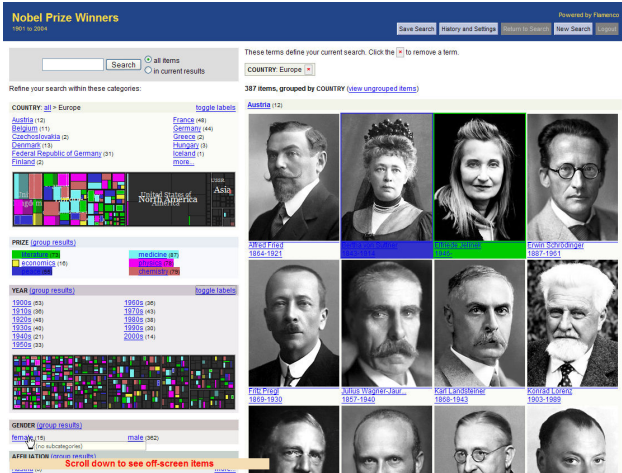
Faceted metadata browsers have been found to be effective in a variety of usage contexts [10] [13] [16]. But most faceted browsers include little [10] or no visualization component, and do little to contextualize remaining items within the dataset as a whole. Microsoft Research's *FacetMap* system [15] is more closely related to *ResultMaps*. *FacetMap* is a treemap-inspired exploratory tool for faceted data stores. Each facet is represented in a treemap, and user selections or queries interactively prune the information space within all of the treemap views.

The difference between *ResultMaps* and this sampling of the related work is indicative of the larger research space: treemap or map-like approaches [7] [8] [9] [11] are similar in some cases, but those works that actually present evaluations address relatively few non-performance measures (e.g., engagement). The *FacetMap* system [15] is conceptually similar to *ResultMaps*, but renders only part of a facet hierarchy and removes non-matching documents from the view (losing the context of the global document space). The text-based systems likewise have few mechanisms for showing what data has been filtered out. Thus, we view faceted *ResultMaps* as an interesting development, and evaluations of *ResultMaps*—a context-preserving visualization system applicable to digital repositories with (perhaps faceted) hierarchical classifications—as a contribution to understanding how visualization can support information-seeking behavior.

## 3. RESULTMAP DESIGN

We define a *ResultMap* as a treemap that:

- encodes a digital repository's contents according to pre-existing hierarchical metadata,
- accentuates certain nodes indicated by a query engine, and



**Figure 2. A ResultMap-enhanced Flamenco faceted browser showing Nobel Prize data. Users add facet value constraints from links in the area at left; list items matching the criteria are at right. Brushing links list items, ResultMap nodes, and key facet values. Similar behavior also previews the result of clicking on any facet value link (shown here).**

- is interactively paired with a text listing of query responses.

We refer to the metadata attribute used in a ResultMap layout as the *mapped attribute* or *mapped variable*. The attribute used for any color encoding is the *key attribute/variable*, or *key facet* in a faceted setting. Encoding the entire repository (rather than only items relevant to a query) provides a stable context in which to accentuate query responses. Our previous work [3] provides more details on an earlier version of SERP ResultMaps. We briefly update that account here before moving to our main discussion of our faceted ResultMap design and implementation.

### 3.1 SERP ResultMaps

Figure 1 shows a SERP ResultMap implementation running on a digital library we have developed for HCI/HCC teachers and students: the Human-Centered Computing Education Digital Library<sup>1</sup> (HCC EDL). HCC EDL content is classified into a hierarchical taxonomy of HCI/HCC topics, which the ResultMap uses for a squarified [2] layout. Each leaf node represents a specific document in the library, and all library documents—regardless of their match to the query—are drawn so that the treemap remains stable between queries.

We use document type (e.g., lecture slides, video) as the key attribute, and show the color mapping in a legend below the ResultMap. Categories matching the query are outlined in white. The legend entries, list items, and ResultMap nodes are all linked to each other; hovering over any of them brushes (using color changes and animation) all corresponding linked nodes, items or legend entries. In Figure 1, the user is hovering over the 3<sup>rd</sup> item in the result list, which brushes a legend item and two ResultMap nodes.

### 3.2 Faceted ResultMaps

We observe that using ResultMaps in a SERP context is merely a degenerate case of a more generalized application to hierarchical

faceted metadata. In this general case, we propose that the introduction of multiple ResultMaps could make relationships between facets (e.g., correlations) more apparent. We have augmented the open-source Flamenco faceted browsing framework [16] with our ResultMap engine. Our implementation uses the *prefuse* toolkit [4] to generate and cache layout coordinates for each ResultMap. Our extended Flamenco framework uses the cached results to produce DHTML markup that client browsers render into the ResultMap visualizations and interactive behavior.

In describing this work, we use examples from a Nobel Laureate dataset included with Flamenco. It contains metadata for 748 Nobel Prize winners from 1901 to 2004. It has facets for home country, prize won, year of prize, gender and affiliation. We added continents to the country facet to make it hierarchical.

#### 3.2.1 Scalability

Before continuing, we would be negligent not to discuss the representational limits of ResultMaps. In the SERP implementation, a ResultMap leaf node represents an individual document. Thus ResultMap scalability is inversely proportional to the number of items in a repository, and scales at most to a few tens of thousands of items (given reasonable browser and ResultMap sizes). While there are many interesting datasets within this constraint, broader applicability is obviously preferable. A more scalable approach is to relax the assumption of individual representation.

Instead, a ResultMap can collectively render all items of the same type within a single super-node. Figure 2 shows our implementation of this approach, which we refer to as a *collective treemap*: the completely opaque colored nodes represent the items on the current page with that category (i.e., country or year) and prize type; the partly-transparent nodes are those items meeting the same criteria but on another list page; any remaining gray space represents items filtered out. The advantage of this approach is evident with larger datasets—ResultMap scalability is now inversely proportional to the number of *categories*. Thus, our collective layout should scale to arbitrarily sized repositories. The interactive part of the visualization is only slightly altered—since one ResultMap node refers to multiple items, clicking on it cannot scroll to one particular list item.

#### 3.2.2 Interface

The basic operation of the Flamenco system is unchanged from the original. The system has three primary phases, which the Flamenco authors call the opening, middle and end games. The screenshots here are from the middle game—the opening phase shows only facet areas with no items listing. Adding a constraint via clicking on any facet value or entering a keyword search transfers the user to the middle game. Active constraints are shown in boxes at the top of the screen, where they can be modified or removed arbitrarily. Items meeting the constraints are shown in a list area at right, which is paginated when there are too many items for one page. Clicking on a link in the item listing transfers the user to the end game, which shows details about that specific item.

Figure 2 shows our modified Flamenco instance using the Nobel data and collective treemaps. The two hierarchical facets—home country and year—include ResultMaps. Prize type they key facet. The same principles from the SERP implementations apply: items

<sup>1</sup> See <http://hcc.cc.gatech.edu/hcc-search/>



Figure 3. Detail of facet area in Figure 2. The user is hovering over the female facet value (at bottom), which triggers a preview of the effects of that selection (see key facet highlights, white outlines of ResultMap nodes).

in the list are linked to their ResultMap nodes and the key legend (i.e., the prize facet box); hovering brushes all linked ResultMap nodes, list items and prize facet values. ResultMaps for facets that are inherently ordered can use the order-preserving strip treemap layout [1] (as with the year facet in Figure 2 and Figure 3). Users can also hide ResultMap labels to reduce clutter (as with the year ResultMap in the figures).

Note that the year ResultMap indicates a downward trend in the share of prize winners from Europe over time, as indicated by the increasing percentage of grayed-out area from left to right. Also note that this trend is not evident from the simple numerical counts per decade because the overall number of prizes per year has gone up over time (due to the addition of the economics prize in the 1960s and an increase in the number of dually-awarded prizes). The context of the entire dataset provided by ResultMaps is crucial in this instance to making this insight.

Hovering over any facet value link in *any* facet previews the effect of that selection by highlighting which items meet that constraint in the ResultMaps, key legend and item listing. In Figure 2, the user has selected the *Europe* facet value and is previewing the *female* from the gender facet. Two females are visible in the list area and are highlighted with their prize color; a message at lower left indicates the presence of others later in the list and out of the

viewport. The brushing effects also show that there are no European female winners of the Nobel Prize in economics and that there is a relative paucity of European female winners of any prize in the mid-20<sup>th</sup> century.

The interactive nature of the preview effects allows users to compare the effects of different prospective actions (similar to the Relation Browser bars [10]) with minimal effort. Previewing the effects in the visualizations also allows rudimentary analysis of the dataset. In the opening game, for example, previewing each of the decade facet values in succession and examining the country ResultMap shows the number of winners moving from majority European to majority North American. The benefit of the ResultMaps is a visual medium in which to present the preview information, a better alternative to updating and scanning a substantial amount of text and numerical indicators. ResultMap’s view into a facet hierarchy also allows the user in this case to see that the North American increase is driven by the United States.

### 3.2.3 Limitations

We should make note of several issues we have not fully addressed in our faceted RM work to date. The sizes of the ResultMaps here are arbitrary (400x100 pixels), picked to minimize vertical size. Initial formative testing suggests this size may result in uncomfortably small nodes, so increasing ResultMap areas may be advisable.

Increasing their size does present other problems: faceted ResultMaps benefit from close proximity to each other and to the key facet. Making them bigger moves them farther apart—especially problematic if it moves a ResultMap out of the browser viewport. Similarly, scrolling to look at items lower in the list area potentially moves all of the facet areas—and thus the ResultMaps and all the brushing effects—out of view. Moreover, it is quite possible for there to be too many facets—and potentially ResultMaps—to fit within the viewport. As a result, it might be impossible to see all the visualizations at once. Flamenco’s ability to reorder facet boxes can help, but scrolling remains a problem. Our proposed solution is to add the ability to pin facets boxes (i.e., keep them within the browser viewport).

We should also note that our use of DHTML—specifically JavaScript—introduces some practical constraints: only browsers with recent JavaScript engines (e.g., Firefox 3+; Safari 3.11+) execute the preview effects at interactive speeds (because they access the largest number of DOM elements). Time will mitigate this failing, but optimization of JavaScript DOM access and manipulation function calls should also make our implementation more palatable on older platforms.

## 4. EVALUATION AND FUTURE WORK

Evaluation of infovis applications is notoriously tricky [12]. Many systems are oriented towards browsing or exploring data—inherently open-ended activities—making performance-based metrics (e.g., task time) less important. Despite these complications, our research has a strong empirical testing bent. Rather than discuss the details of our findings, we take this opportunity to discuss our larger evaluation approach, its drawbacks and our plans for its improvement. We have conducted two lab studies (N=20, N=36) on our SERP ResultMap implementation. Our dependent measures have included task time and accuracy, subjective satisfaction and engagement and assessments of repository knowledge. Our results have been

marginally in favor of ResultMaps. We have found a few statistically significant results, a larger number of near-significant ones, and positive qualitative observations and comments—but not enough to substantiate our claims.

Our major practical conclusion from our lab studies is that we need larger sample sizes to detect the ResultMap effect size. Though our use of between-subjects comparisons reduces experimental sensitivity, we also suspect the combination of volunteer subjects, relatively dry data (lectures and other class materials), and little external motivation further dampens the ResultMap effect size. Our negative experience complements the Flamenco authors' (and others') positive experience with and recommendation for matching participant interests with data in studies of search systems; aligning interest and data predisposes users to motivated effort on experimental tasks.

We have also found lab study convention to exacerbate the problem of experimental tedium. The overall tone of many experimental procedures (including ours) is very similar to test-taking, driven by strict agendas demanded for experimental control. It also leaves little room for impromptu interest in the data—an activity at the heart of infovis.

Our plans for evaluating faceted ResultMaps address these concerns. We are preparing a much larger dataset (10,000+) of architectural images for use with first-year architecture students at Georgia Tech. The dataset itself is presumably of some interest to the students, but more importantly experimental tasks will be a part of their course curriculum. We are also attempting to encourage more spontaneous exploration by framing experimental tasks in a less adversarial, test-taking manner. Instead, we present tasks as questions that the experimenter needs help answering cooperatively. We are not suggesting an uncontrolled think-aloud procedure—rather, a change in the way the experimental tasks are framed and presented to the subject.

We have conducted pilot testing of this procedure in our formative testing and found it relatively straightforward to implement without injecting the experimenter into the procedure. A wizard-of-oz style script (i.e., canned responses to user dialogue) is useful to retain experimental control while also conducting the procedure more cooperatively. Our pilot tests have found users—with little prompting—readily suggest new inquiries into the data apart from the prescribed tasks. The effects of ResultMap visualizations on this inclination are an important part of our upcoming work, along with facet relationship analysis, user engagement and satisfaction, etc. We also hope to report on the efficacy of this broader evaluation approach as a whole.

## 5. ACKNOWLEDGMENTS

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