TwinList:
Visualizing List Differences

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ABSTRACT

We present a novel tool, TWINLIST, for the purpose of list visualization and matching. Leveraging Adobe's Flex platform and the Prefuse Flare toolbox, we created a rich internet application (RIA) with dynamic animated effects. These animated transitions lead the user through the procedure of matching two lists, using color coding to highlight the similarities and differences between the two. List items can be grouped, sorted and filtered according to their attribute values, to enhance workflow. To illustrate the efficacy of the application, we conduct usability testing for different applications with several domain experts and peers.

Author Keywords
list visualization

ACM Classification Keywords
H.5.2 Information Interfaces and Presentation: Miscellaneous

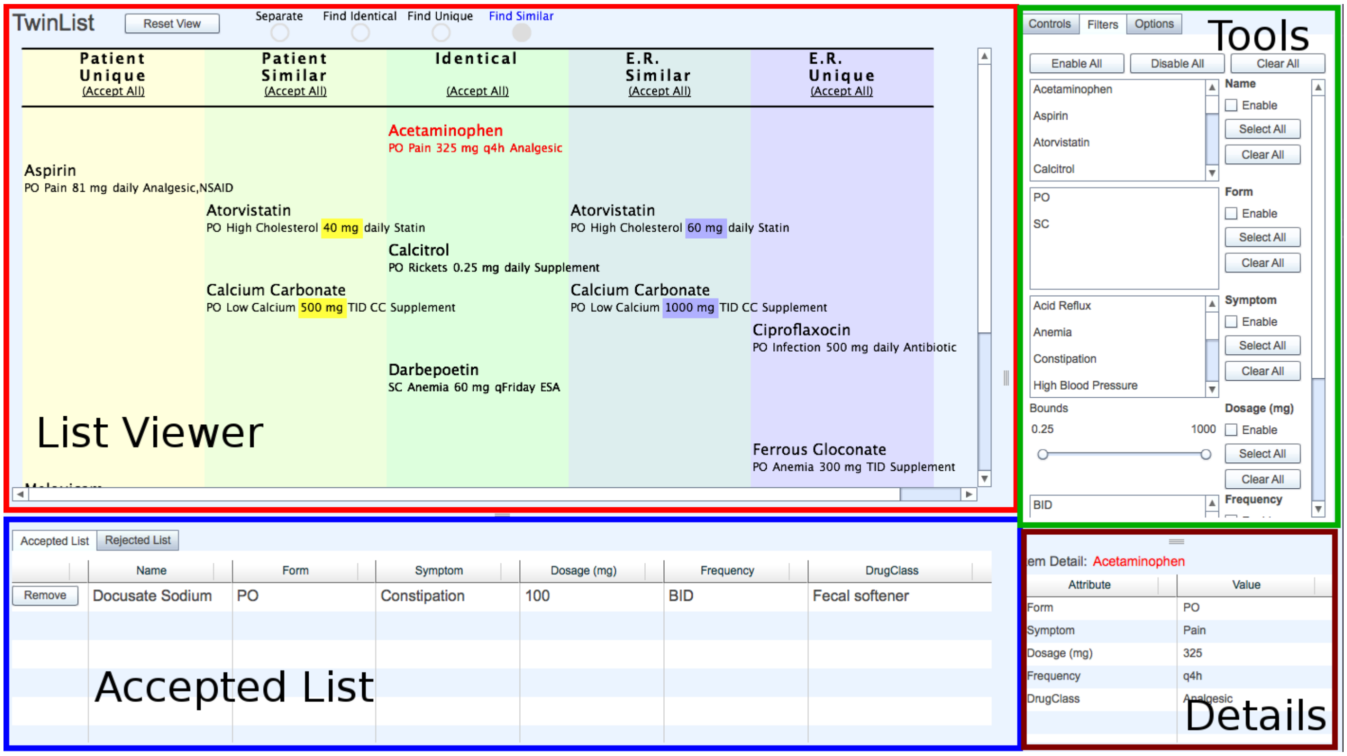
INTRODUCTION

A common task in data analysis is comparing list-based information from multiple sources or entities. This problem occurs in everyday life as well as in specialized applications. For example, a consumer interested in making a purchase may wish to compare the features of two products. A newspaper could compare the rhetoric used in various campaign speeches. Or, as a more specialized example, doctors perform the task of medication reconciliation. In medication reconciliation, a hospital physician must create a treatment plan for a patient prior to discharge. This involves reconciling multiple medication regimes the patient was taking before admission with the medications administered during hospitalization.

A core problem shared by these applications is that data is in the form of two lists, and a decision is reached by comparing the constituent items of these lists in a structured way. One element of the list structure is that items have some similarity or correspondence between lists, such as specific medications used to treat a particular symptom. The logic necessary to compare these items can be complicated, such as resolving a brand-name drug and its generic equivalent as the same item in two different lists. Each item may have attributes that must be taken into consideration when assessing similarity, such as the dosage of a medication prescribed. Attributes may also be used to segment list items into categories, such as different classes of drugs. Finally, list comparison should help reach a conclusion, such as a purchasing decision or a final list of medications to prescribe a patient. In this case, the doctor wishes to "reject" medications from the list that are no longer necessary, and "accept" medications that remain part of the patient's treatment plan.

Our goal was to design a visualization that allows users to quickly answer the dual questions "What is the same between these two lists?" and "What is different between these two lists?", quickly, accurately and effortlessly. We address these aspects of the list comparison problem in our visualization tool, TWINLIST. Using a spatial organization of data, we provide an intuitive way for users to quickly differentiate between items that are the same and those that differ in two lists of data. We abstract complicated similarity logic by categorizing items as "identical" when they are the same in both lists, "unique" when they appear in only one list, and "similar" when the same item has different attributes in each list. We map these three categories to a workflow and use animation to help users understand each step of the list comparison process. In addition, TWINLISTprovides sorting, filtering, and grouping functionality to allow users to explore different aspects of the data. Finally, the application supports accepting items that are relevant or rejecting irrelevant items, helping users reach a strong conclusion.

Submitted for CMSC 734 Information Visualization.



Patient Unique (Accept All)	Patient Similar (Accept All)	Identical (Accept All)	E.R. Similar (Accept All)	E.R. Unique (Accept All)
		Acetaminophen PO Pain 325 mg q4h Analgesic		
Aspirin PO Pain 81 mg daily Analgesic,NSAID				
	Atorvistatin PO High Cholesterol 40 mg daily Statin		Atorvistatin PO High Cholesterol 60 mg daily Statin	
		Calcitrol PO Rickets 0.25 mg daily Supplement		
	Calcium Carbonate PO Low Calcium 500 mg TID CC Supplement		Calcium Carbonate PO Low Calcium 1000 mg TID CC Supplement	
				Ciproflaxocin PO Infection 500 mg daily Antibiotic
		Darbepoetin SC Anemia 60 mg qFriday ESA		
				Ferrous Gloconate PO Anemia 300 mg TID Supplement

Enable All Disable All Clear All

Acetaminophen
Aspirin
Atorvistatin
Calcitrol

Name ☐ Enable Select All Clear All

PO
SC

Form ☐ Enable Select All Clear All

Acid Reflux
Anemia
Constipation
High Blood Pressure

Symptom ☐ Enable Select All Clear All

Bounds 0.25 1000

Dosage (mg) ☐ Enable Select All Clear All

BID

Frequency

	Name	Form	Symptom	Dosage (mg)	Frequency	DrugClass
Remove	Docusate Sodium	PO	Constipation	100	BID	Fecal softener

em Detail: Acetaminophen

Attribute	Value
Form	PO
Symptom	Pain
Dosage (mg)	325
Frequency	q4h
DrugClass	Analgesic

Figure 1. The TwinList interface: In this screen capture, the lists have been matched, displaying identical items in the center column, unique items in the outer columns and similar items in between. Color highlighting is used to indicate similar attribute values. In the bottom left panel is the *Accepted* list; in the upper right panel, the *Filter Panel*; and in the lower right, the *Details Panel*, which displays all attributes for the selected item (highlighted in red).

Related Work

The specific problem of list comparison as we have framed has relatively little research. Research in areas such as visualizing text corpora and set membership have resulted in relevant work that provided a basis for extending visualization techniques to novel problem areas. Collins et al.[4] use tag clouds drawn from text to compare several lists, using size to indicate frequency and giving a good overview of each document. Subsequent work also extends this approach to use spatial positioning to make it easier to find unique values[5]. One drawback of such approaches is that they are less relevant when comparing specific list items, particularly when attributes are important for comparison.

Other related work was useful when exploring different designs for our project. One well-studied area is the comparison of sets of data. For example, Venn Diagrams have long been used to show areas of similarity and difference, and provide a way to query for a specific group of similarities and differences[6]. While we prototyped a solution using Venn Diagrams, they ultimately did not fulfil all the needs of our target applications. Similarity matrices [?] are well-suited to situations where the similarity of one item to all other items is important, but this was not a common cirumstance in the problem domains we considered. Since the attributes of each item were important, approaches to show and quickly navigate through list attributes, such as [3] and [9] were part of our initial designs, but ultimately were not implemented, as we focused on the core problem of list comparison. Finally, we relied on work such as Chevalier et al. [2] where animation and highlighting show differences between document revisions, which draws visual attention to differences between documents. Extending the use of animation allowed us to demonstrate differences between lists similarities in a more interactive way.

Medical research on the medication reconciliation task has shown it to be an important problem[10]. Preventable Adverse Drug Events (PADE) are involved in 19% of post-treatment complications. Trials of medication reconciliation policies show dramatic results. In one study, 94% of patients had medication errors, and a medication reconciliation process nearly eliminated medication errors[10]. Although medication reconciliation shows such great success, visualization tools for this procedure are still in their infancy. Discussions with physicians suggest that many do not have tools or a well-specified workflow for medication reconciliation.

TWINLIST

TwinList is a novel list visualization tool for the purpose of illustrating the similarities and differences between two lists. It can be used in many cases where the comparison of two lists of items is required. The primary application that TwinList supports is that of medication list reconciliation: comparing and reconciling multiple medications that have been prescribed to a patient from multiple sources[?]. However, TwinList is equally adept in other applications, such as comparing bag-of-words lists or visualizing gene activity in different types of human tissue, such as normal brain tissue and brain tumor tissue. The design guideline we used is Eight Golden Rules of Interface Design proposed by Ben Shneiderman and Catherine Plaisant [**?**].

TWINLIST's interface consists of four major components: the *List Viewer*, *Tools Dock*, *Accepted/Rejected* lists and *Details Panel*, as shown in (Figure 1). The *List Viewer*, located in the upper left corner of the interface, is where the list matching visualization will be performed. The initialized view displays two separated lists loaded from XML files. The *Tools Dock*, in the upper right corner, displays the *Control Panel*, *Options Panel* and *Filter Panel*, which can be made visible one at a time by selecting the appropriate tab. If an item in the *List Viewer* is selected, its detail information will be shown in the *Details Panel* in the lower right corner. TWINLIST is not merely meant for visualization; it also allows users to take action. List items can be accepted or rejected, whereupon they will appear in the *Accepted/Rejected* lists.

ListViewer

The *List Viewer* is the most important component in TWINLIST. The *List Viewer* presents the two lists the users are comparing. The layout of this component uses spatial placement and color to delineate identical, similar and unique items in the lists. To aid the users in understanding this layout, animation is used to provide a visual guide to the list comparison.

The five-column list placement

To visualize the similarities and differences between two lists, a five-column list placement is used in TWINLIST. Each item is shown with a name and attributes below. Identical items that occur in both lists are shown only once, and placed in the middle column. The extreme columns (one and five) contain items that are unique to a specific list. Items that are similar are duplicated and shown in both columns two and four. The attributes that differ between similar items are highlighted to allow users to quickly identify discrepancies between items.

Color is used to provide a visual cue to this organization. The extreme columns have background colors yellow and slate blue, respectively. The middle column is the combination of these colors, green. Finally, the columns for similar items are yellow-green and blue-green, respectively. The highlighting of similar attributes uses the color of the associated lists. We use pale background colors, to preserve the readability of the text. This palette does not pose problems for most colorblind users. By providing a constant visual cue to the user, we hope to ease the cognitive demand of identifying lists while matching.

To see the *List Viewer*in action, refer to Figure 1. Acetaminophen, Calcitrol and Darbepoetin appear on both lists, so they are placed in the center green column. Atorvistatin appears in both lists. However the dosage of the medication differs between the two lists, with 40mg on the patient list, and 60mg on the E.R. list. As a result, two instances of this item are shown in the second, yellow-green column and the fourth, blue-green column. The different dosages are highlighted in the attribute text. Aspirin is unique to the patient list, so it is placed in the leftmost, yellow, column.

Matching Animation

To emphasize the three different matching sets, the items move into their corresponding groups through an animation sequence. The animation sequence ends up matching the two lists through three steps:

1. The *Identical* items moving into the middle column, and the column is highlighted.
2. The *Unique* items move into the first and last columns, and the two columns are highlighted.
3. The *Similar* items move into the middle column with their differences highlighted, and the column is highlighted.

The animation sequence can be viewed step by step using the animation buttons at the top. The *Match Lists* button at the top runs the entire animation sequence, and clicking *Reset View* afterwards reverts the entire animation sequence to the original list with the two lists separated. The animation speed can be adjusted through the *Options Panel*.

Figure 2 shows how the three animation steps alter the view of the *List Viewer* and accentuate the *Identical*, *Unique*, and *Similar* items in each step.

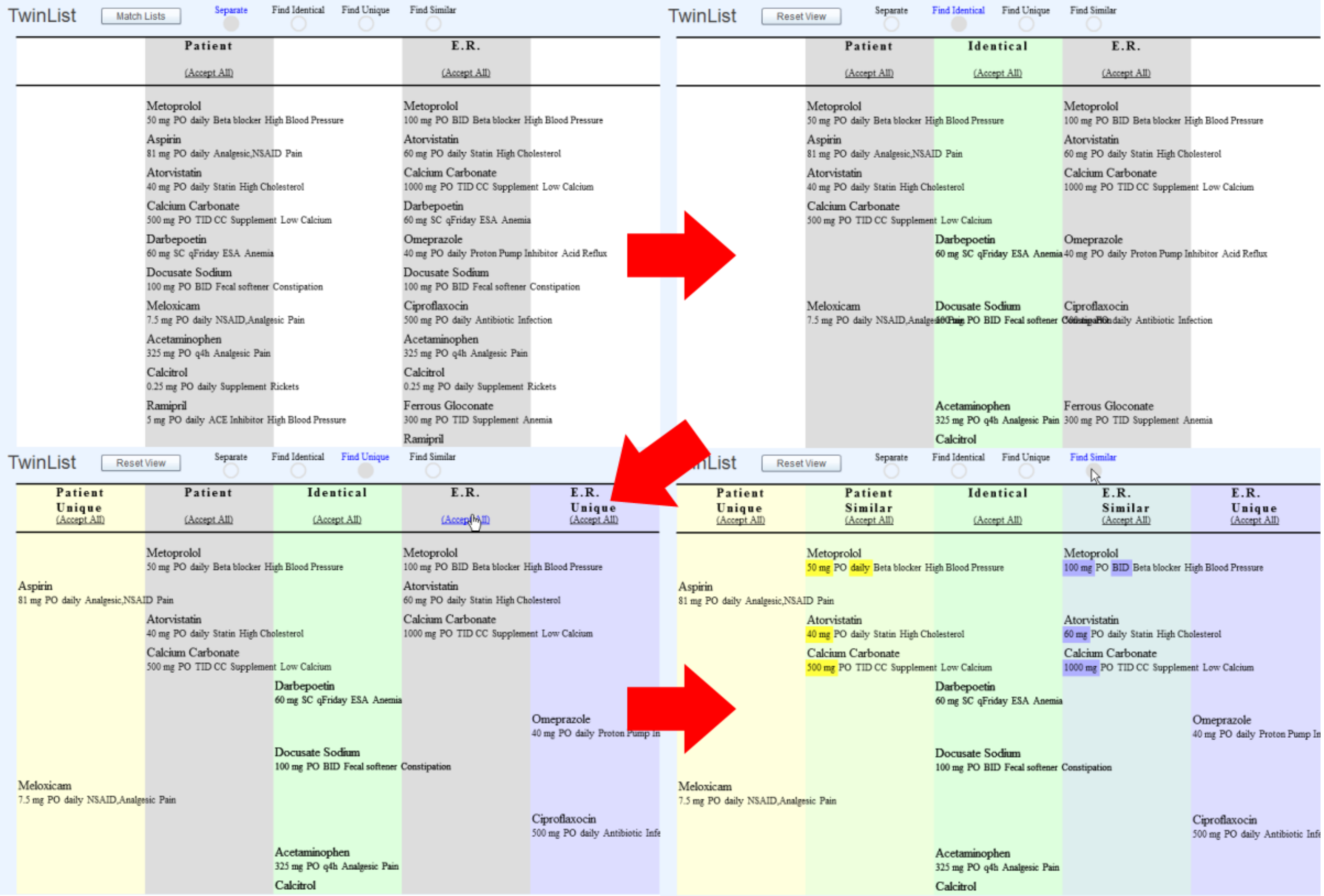
Details on demand

When the user click on an item, it's detail information will be shown in the *Details Panel* , shown in Figure 3. Although user can see every attribute value in the *List Viewer*, we still intend to have a separated *Details Panel*. This details panel give the potential of further edit the presentation of list items. For example, doctor can choose to only show the dosage, frequency and form of the medication and not to show drug class and symptom information, because they might be very familiar with most of the medications. They can still check the detail information on drug class and symptom in the *Details Panel* . We are not provide this feature in the current version.

Action taking

Once the list matching is performed, the users can see the similarities and differences clearly. TWINLISTprovides functionality that allows users to take actions about the list items. This feature is especially useful for medication reconciliation, since doctors will need to make decisions after examining the list items on both lists. When users click and hold the left mouse button, a menu with two options will show up and users can choose which action to take for that particular item (Figure 4).

Once users choose to accept or reject an item, that item is added to the top of the *Accept/Reject* List (Figure 5). Actions can be reversed by clicking on the "Remove" button next to each item in the *Accept/Reject*view. Items that have been accepted or rejected are either removed from the *List*



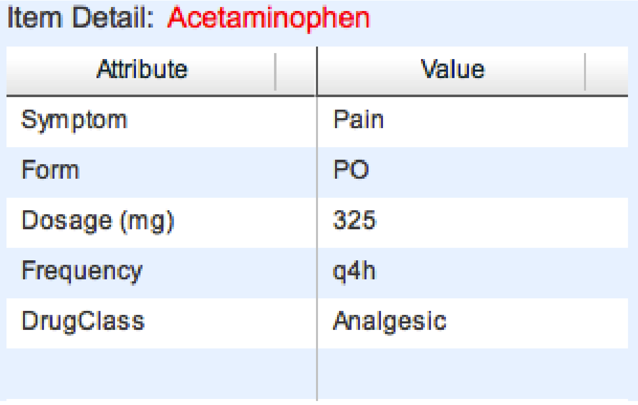
Patient (Accept All)	E.R. (Accept All)
Metoprolol 50 mg PO daily Beta blocker High Blood Pressure	Metoprolol 100 mg PO BID Beta blocker High Blood Pressure
Aspirin 81 mg PO daily Analgesic,NSAID Pain	Atorvistatin 60 mg PO daily Statin High Cholesterol
Atorvistatin 40 mg PO daily Statin High Cholesterol	Calcium Carbonate 1000 mg PO TID CC Supplement Low Calcium
Calcium Carbonate 500 mg PO TID CC Supplement Low Calcium	Darbepoetin 60 mg SC qFriday ESA Anemia
Darbepoetin 60 mg SC qFriday ESA Anemia	Omeprazole 40 mg PO daily Proton Pump Inhibitor Acid Reflux
Docusate Sodium 100 mg PO BID Fecal softener Constipation	Docusate Sodium 100 mg PO BID Fecal softener Constipation
Meloxicam 7.5 mg PO daily NSAID,Analgesic Pain	Ciprofloxacin 500 mg PO daily Antibiotic Infection
Acetaminophen 325 mg PO q4h Analgesic Pain	Acetaminophen 325 mg PO q4h Analgesic Pain
Calcitrol 0.25 mg PO daily Supplement Rickets	Calcitrol 0.25 mg PO daily Supplement Rickets
Ramipril 5 mg PO daily ACE Inhibitor High Blood Pressure	Ferrous Gloconate 300 mg PO TID Supplement Anemia
	Ramipril

Patient (Accept All)	Identical (Accept All)	E.R. (Accept All)
Metoprolol 50 mg PO daily Beta blocker High Blood Pressure		Metoprolol 100 mg PO BID Beta blocker High Blood Pressure
Aspirin 81 mg PO daily Analgesic,NSAID Pain		Atorvistatin 60 mg PO daily Statin High Cholesterol
Atorvistatin 40 mg PO daily Statin High Cholesterol		Calcium Carbonate 1000 mg PO TID CC Supplement Low Calcium
Calcium Carbonate 500 mg PO TID CC Supplement Low Calcium		
	Darbepoetin 60 mg SC qFriday ESA Anemia	Omeprazole 40 mg PO daily Proton Pump Inhibitor Acid Reflux
Meloxicam 7.5 mg PO daily NSAID,Analgesic Pain	Docusate Sodium 100 mg PO BID Fecal softener Constipation	Ciprofloxacin 500 mg PO daily Antibiotic Infection
	Acetaminophen 325 mg PO q4h Analgesic Pain	Ferrous Gloconate 300 mg PO TID Supplement Anemia
	Calcitrol	

Patient Unique (Accept All)	Patient (Accept All)	Identical (Accept All)	E.R. (Accept All)	E.R. Unique (Accept All)
	Metoprolol 50 mg PO daily Beta blocker High Blood Pressure		Metoprolol 100 mg PO BID Beta blocker High Blood Pressure	
Aspirin 81 mg PO daily Analgesic,NSAID Pain			Atorvistatin 60 mg PO daily Statin High Cholesterol	
	Atorvistatin 40 mg PO daily Statin High Cholesterol		Calcium Carbonate 1000 mg PO TID CC Supplement Low Calcium	
	Calcium Carbonate 500 mg PO TID CC Supplement Low Calcium			
		Darbepoetin 60 mg SC qFriday ESA Anemia		
				Omeprazole 40 mg PO daily Proton Pump In
		Docusate Sodium 100 mg PO BID Fecal softener Constipation		
Meloxicam 7.5 mg PO daily NSAID,Analgesic Pain				
				Ciprofloxacin 500 mg PO daily Antibiotic Infe
		Acetaminophen 325 mg PO q4h Analgesic Pain		
		Calcitrol		

Patient Unique (Accept All)	Patient Similar (Accept All)	Identical (Accept All)	E.R. Similar (Accept All)	E.R. Unique (Accept All)
	Metoprolol 50 mg PO daily Beta blocker High Blood Pressure		Metoprolol 100 mg PO BID Beta blocker High Blood Pressure	
Aspirin 81 mg PO daily Analgesic,NSAID Pain				
	Atorvistatin 40 mg PO daily Statin High Cholesterol		Atorvistatin 60 mg PO daily Statin High Cholesterol	
	Calcium Carbonate 500 mg PO TID CC Supplement Low Calcium		Calcium Carbonate 1000 mg PO TID CC Supplement Low Calcium	
		Darbepoetin 60 mg SC qFriday ESA Anemia		
				Omeprazole 40 mg PO daily Proton Pump In
		Docusate Sodium 100 mg PO BID Fecal softener Constipation		
Meloxicam 7.5 mg PO daily NSAID,Analgesic Pain				
				Ciprofloxacin 500 mg PO daily Antibiotic Infe
		Acetaminophen 325 mg PO q4h Analgesic Pain		
		Calcitrol		

Figure 2. An animation sequence matching two lists of prescription drugs. The original *List Viewer* is shown at the top left. In the top right, the *Identical* items were found. The *Unique* items are found next in the bottom left view. Finally, the *Similar* items are matched with their differences highlighted in the bottom right view.



Item Detail: Acetaminophen

Attribute	Value
Symptom	Pain
Form	PO
Dosage (mg)	325
Frequency	q4h
DrugClass	Analgesic

Figure 3. *Details Panel*.

Viewer or shown in a lightweight, gray font face. This option is user-configurable through the *Options Panel*panel.

Controls

The *Control Panel*, depicted in Figure 6, contains functionality for organizing and manipulating the the *List Viewer* visualization. This includes the following components:

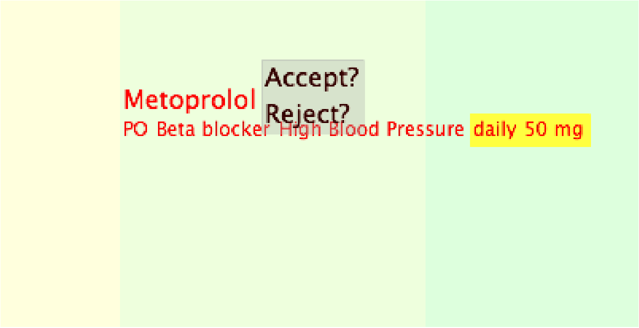
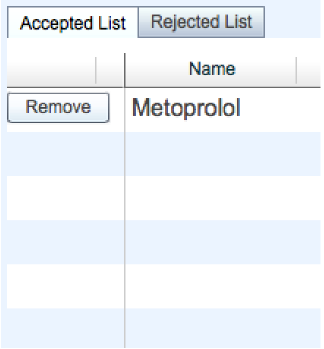


Figure 4. A detail of the action menu.

- *Size By*: scales item text by its value for the given attribute. This control only works with numerical-type attributes.
- *Color By*: colors item text by its value for the given categorical attribute. This control only works with categorical-type attributes.
- *Group By*: organizes items by their values for the given



Metoprolol

Figure 5. A detail of the added medicine in *Accept/Reject*.

attribute. This control works with either categorical- or general-type attributes (but not numerical).

- *Sort By*: sorts items (within groupings) by their values for the given attribute. This control works with any attribute. Note that the *Group By* control has precedence over this control.

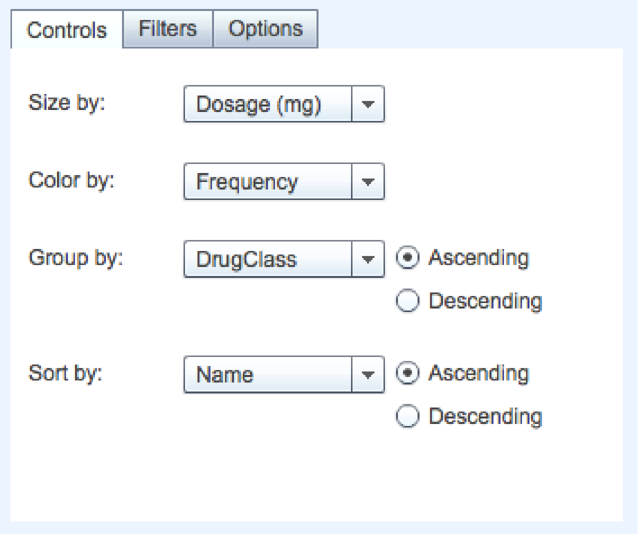
As of the submission of this paper, the *Size By* and *Color By* functionality is not operational, due to time constraints, though these features are planned for future iterations.

For an example of the usefulness of these features, consider the following scenario in the context of analyzing the State of the Union addresses. One might begin by grouping items (words) by their part of speech (assuming part of speech is an attribute). To further organize the display, one might then sort items by name (i.e. alphabetical ordering). The former lets the user analyze syntactical patterns, while the latter enables quick lookup of particular keywords. One can go even further, sizing words by their TF-IDF value, to reveal lexical patterns, similar to a Wordle[11]. In the context of medication list reconciliation, one might wish to group by drug class, size by dosage and color by frequency.

Filters

TwinList's *Filter Panel* were inspired by those of Spotfire[1]. The ability to perform realtime queries and see the changes propagate to the visualization augments data exploration and analysis. For example, in medication list reconciliation, one might wish to display only certain drug classes, or only dosages in excess of a certain amount.[1] Figure 7 depicts a detail of the *Filter Panel*.

Filters come in two classes: categorical and numerical. Categorical filters can be used to display only a specific set of attribute values, taken from a finite set of possible values. Numerical filters can be used to display only attribute values that fall within specified lower and upper bounds. Note that an item will only display it passes all filters, meaning its attribute values fall within the specified allowable sets or ranges.



Size by: Dosage (mg)

Color by: Frequency

Group by: DrugClass ● Ascending ○ Descending

Sort by: Name ● Ascending ○ Descending

Figure 6. A detail of the *Control Panel*.

A filter can be enabled and disabled via a checkbox displayed to the right of it. Enabling a filter implies that it is active. When a filter is disabled, it has no effect on the *List Viewer*, no matter which values or bounds are set. The *Select All* and *Clear All* buttons select or deselect all options in a categorical filter, where selection is demarcated by highlighting. A selected value is kept in the visualization. In a numerical filter, both *Select All* and *Clear All* simply reset the bounds.

Options

The *Options Panel* allows the user to control the following global application behavior:

- *Dataset*: selects and loads a dataset from the three demo sets.[2] Upon changing the dataset, the application will be reset, except for the *Options Panel*.

- *Font size*: sets the size of the font used to display item names in the *List Viewer*. Note that the attribute text font size is relative to that of the name, though slightly smaller to reduce clutter.

- *Animation speed*: controls the relative speed of the animations in the *List Viewer*. The speedup is defined as 2^α, where α is the slider value. Thus, a value of $\alpha = +1$ will double the speed and a value of $\alpha = -1$ will reduce it by $1/2$.

- *Link identical items*: determines how identical items are treated in the *List Viewer*. When linked (the default), highlighting affects both items and accepting/rejecting either will hide the other from the *List Viewer*. When unlinked, they are considered completely separate items.[3]

[1] While in practice dosages are typically given on multiple scales — e.g. 325 mg, 30 CCs — we require that all numerical attribute values be normalized to the same scale.

[2] In future versions, the user will be allowed to upload a dataset using our proprietary XML schema.

[3] Unlinking identical items implies that both items can be accepted or rejected, independent of the other.

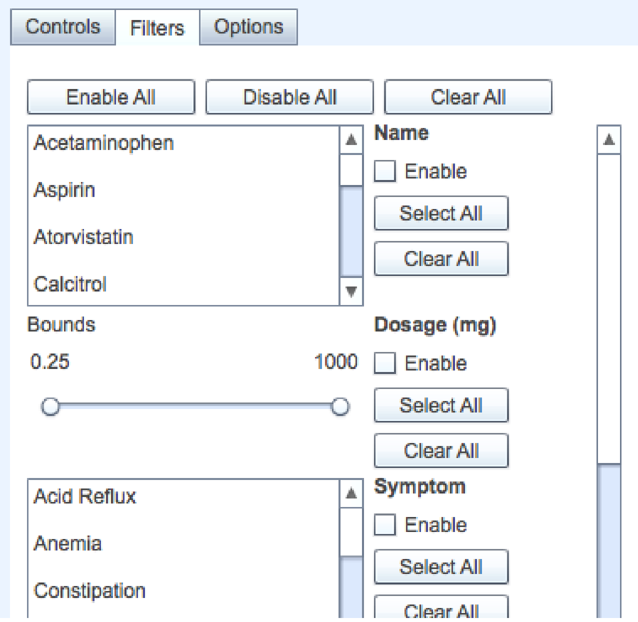
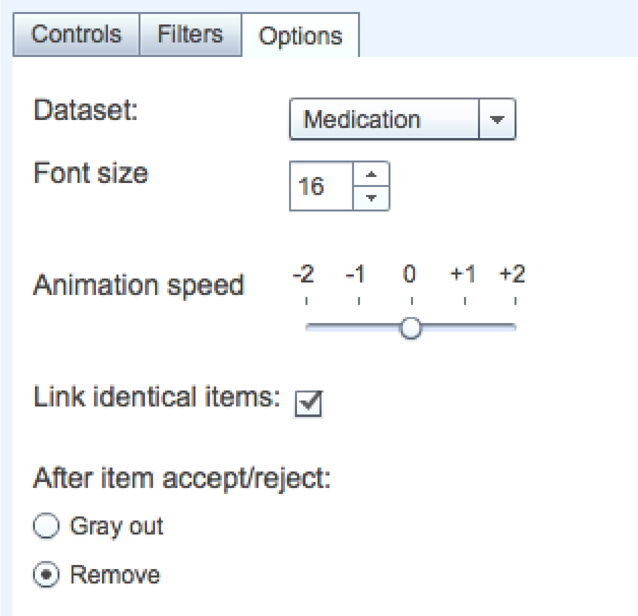


Figure 7. A detail of the *Filter Panel*.



Dataset: Medication

Font size 16

Link identical items: ☑

After item accept/reject:

○ Gray out

● Remove

Figure 8. A detail of the *Options Panel*.

- *After item accept/reject*: determines the behavior of the *List Viewer* after accepting or rejecting an item. *Gray out* will simply gray the text and disable mouse actions; *Remove* will hide the item from the *List Viewer*.

EVALUATION

Our goal was to deliver a working prototype, not a finished, fully-functional application. As such, we are more concerned with qualitative than quantitative feedback on the features of our visualization system at this point. According to the categorization proposed by Lam et al [7], the evaluation scenario best matching our present purposes is the *User Experience (UE)* test case. The goal of the following experiments is to observe how users react to the visualization and interaction features offered by TWINLIST. We will use their feedback to improve the system's design in future versions.

Experiment Design

Test subjects came from two populations: two physicians and two graduate students in Computer Science (CS), both in the field of Human-Computer Interaction (HCI). The former used TWINLISTto perform medication reconciliation. The latter was tested on the car data set (lists of features of two cars, one list per car). The testing protocol proceeded as follows: first, the user watched a 7-minute video demonstrating basic usage. Following this, the user was allowed to ask questions. Next, the user interacted with the system unaided, performing either specific tasks (medication reconciliation case studies) or general, free exploration ones (car data case studies). While using the system, subjects were encouraged to *think aloud* [8]. The entire experiment was recorded in both audio and screen capture video.

Case 1: Med. reconciliation, A. Z. H., male, 34 y. o.

Overall, the participant performed the tasks as expected and reported anticipated results. A. Z. H. purported to be very comfortable with computers. He does not perform medication reconciliation on a regular basis, except when doing inpatient aid and discharge from the hospital, for which he does not use any software. This is how he describes his TWINLIST experience: *"It's really impressive, the way you organize things is great. It's definitely a step in the right direction . . . "*. He was very enthusiastic and provided several suggestions, most of all worth including in this section.

Results

This is our reading of A. Z. H.'s experience:

- There is need for an indication that there are more items than what can be currently seen in a column. The scroll bar alone is insufficient.

- It is difficult to get to the *Accept/Reject* pop-up menu when accepting/rejecting an item. He had trouble with the click-and-hold behavior, wanting instead to use the mouse's right-click button.

- To send items from *Accepted/Rejected* lists back to the viewer one-by-one requires quite some effort when you have many items in those lists. A *Remove All* button would be desirable.

- Warning dialogs or undo may be needed when accepting and rejecting items, since it is a delicate operation in medication reconciliation.

- In the control panel, drop-down boxes should indicate what the default *Group By*/*Sort By* attributes are, instead of blank captions. (The default is actually the original ordering.)

- It would be desirable to shorten vertical empty spaces in between items to minimize the need of scrolling.

- The number of visible item attributes should be shortened in the *List Viewer*, since reconciliation is performed, in practice, based on only a few (e. g. the *Indication* feature).

- For items in the *Similar* columns, the item pop-up menu should have a third option, to automatically reject an item of a list if its counterpart at the other list was accepted. According to the participant, this would be the likely outcome in almost every such context.

- The participant suggested that we should change the way items are displayed so that, for each list, you have items sorted by some *uniqueness level*; for example, by vertically ranging from identical to unique. This would add more meaning to the vertical structure of the list, which is somewhat lost after lists are matched, but would represent a significant change in the concept.

- The participant felt that placing the *Accepted/Rejected* lists at the bottom of the interface may be suboptimal for tracking what happened to processed items, especially when the user gets distracted.

- The participant missed being able to interact on the spot with accepted/rejected items that are grayed out. In his words: *"If it is grayed out, what if (. . .) I really want to do the 100 mg, is there any way to click and have it re-instate (. . .) or un-reject/un-accept"*. He believes that if he could interact with grayed-out items on the viewer, the *Accepted/Rejected* lists might not even be necessary, thus allowing more room for the main visualization. As such, the list of rejected/accepted items could be output as the final product of the interactive process and would be activated by pressing a button. As he suggested: *". . . Here is your final list of medications, this is your rejected list over here, and when one finally accepts, export to (. . .) or put in patient's medical record . . . "*.

- The participant suggested an additional *Sort By* criteria: in his own words, *"medications that haven't been dealt with yet."* We translate this as a grouping of medications based on their accepted/rejected status. This is a useful, general concept applicable to other list matching problems.

- The participant mentioned the importance of filters, especially to filter by route (e.g. I.V. medications).

Case 2: Med. reconciliation, M. G., male, 62 y. o.

As opposed to the previous participant, M. G. had more trouble to perform his tasks. It was clear from his reactions that he was expecting the system's terminology to be more towards medication reconciliation (such as having *Match Lists* as the caption of the button that triggers list matching, instead of *Reconcile Lists*) than general list matching. As the matching animation began, he clearly expressed a feeling of overwhelm: *"Wow, what just happened there?"*. M. G. considers computers somewhat hard to use (he reported a difficulty score of 4 out 5). This subject does medication reconciliation every day.

Results

This is the summary of M. G.'s results:

- In his opinion, one item's list of attributes should not exceed the width of its column. He felt that the piece of the attribute list that slops over to the next column could be associated with another item in that column, which could lead to a serious confusion: for example, the dosage of one medication could be associated with another by mistake, as he pointed out himself.

- The user got confused by the step-wise animation buttons when told to accept all identical items. He clicked at *Find Identical* instead of *Accept All* at the *Identical* column of the viewer, when told to accept all identical items. The animation then went half-way through and he realized he did not do what was expected. He then tried to fix it and ended up clicking on *Find Unique*. Finally, when he tried to accept/reject items, he realized that similar items across both lists were not in the same row of the viewer. The reason was that he did not perform the list matching all the way, a sign that list matching should be performed as an atomic operation. That is also supported by the fact that the first physician has not even touched the step-wise matching feature.

- An unexpected outcome of this test was that the user somewhat associated temporal order from left to right, as if the first list represented an event that necessarily came before the second list. He compared the dosage of the drugs at the Patient's *Similar* column (left) with the corresponding drugs/dosages at the E.R. column (right), and tried to infer some sort of temporal pattern regarding how the patient was dealt with in emergency: *"Conceptually, I think it is a nice setup, actually. Because you can try to deduce what went on during the stay in the E. R. For these drugs, they decided that the patient needed more of that, because they increased the dose ..."*. Although this was not intended when the lists were fed to the system or however the data were displayed, to associate temporal meaning to lists might be an interesting path to explore in the future.

- The issue of having to unnecessarily reject a similar item after accepting its counterpart appeared again, particularly if dosage is the single attribute that changed across items: *"If it is absolutely the same in every respect, except for the dosage amounts, you can't give two dosage amounts simultaneously ..."*.

- Different from the other participant physician, M. G. thinks *Indication* is not a very descriptive attribute since a drug can be prescribed for several reasons. On the other hand, he likes the *Drug Class* feature and, after being asked about it, he agrees it could be a useful feature to group by.

Cases 3 and 4: Car data, T. L., male / A. N. S., female.

Both participants are doctoral student in CS/HCI. In particular, the first one has background experience in interaction design and is very familiar with usability testing. T. L. had trouble to grasp the list matching idea when first told about it, but after some explanation and with the provision of adequate background information, he understood the concept well. He had very few problems while interacting with TwinList, and was particularly impressed with the animation. A. N. S. went through the experiment very smoothly and had no problem to interpret the visualization. She immediately came up with a plan on how to find similar items and detect differences, and clearly described the steps she took to reach results. A minor difficulty she encountered was to operate the *Accept/Reject* pop-up menu. In fact, it is a recurring problem, since it also happened to the first participant of the medication reconciliation experiment. However, after A. N. S. was reminded on how to operate the feature, she was quickly able to make it work.

Results

The most prominent outcomes of these experiments were:

- T. L. complained about the size of the *List Viewer*. This brings back some suggestions of participant A. Z. H. (medication reconciliation test), who pointed to the lack of "vertical meaning" after matching is performed. In fact, when items are removed from the viewer, the panel is left with apparently unnecessary empty rows, potentially increasing the need of vertical scrolling.

- To perform list matching, T. L. seemed to prefer the stepwise matching buttons to the *Match List* button on the left. However, we believe that it was mostly due to the exploratory nature of this particular experiment, i. e., the user was encouraged to explore the interface as thoroughly as possible.

- While exploring the filters, A. N. S. was confused by the attribute descriptions in the drop down menu. To her, terms such as "priority ()" would appear more as a function call rather than an attribute name. She suggested that we should use more understandable wording for the attributes during the preprocessing the data.

- A. N. S. was very impressed with the filter options but did not like the fact that, the viewer changes size when filtering results are displayed.

CONCLUSIONS AND FURTHER DIRECTIONS

Our goal was to create a list comparison tool to assist list matching for many applications, with a particular focus on medication list reconciliation. We acheived our goal by providing an intuitive way of separating identical and unique items, as well as highlighting differences in similar items. The use of animation helped connect the raw data and our layout emphasizing similarity. The power of this layout was enhanced by the use powerful tools to filter, sort and group data, allowing users to understand specific aspects of the dataset. By conducting a number of case studies, we gained additional insights about the design and use of this tool.

Evaluation results revealed that testing subjects from both populations were positively impressed with the tool and supported our expectations. From the medication reconciliation results, we can say that both users approved the idea of having the items of the two lists organized according to five levels of similarity, one of the main concepts behind TwinList. They also emphasized the importance of the highlighting (attribute-based differences) feature and proposed that the list of attributes should be shortened and limited to a few key properties more commonly employed in medication reconciliation, such as *Indication*, *Drug Class* or *Route*.

We also learned that the step-wise list matching feature appears to be superfluous and potentially troubling. The first physician did not use the feature, and the second was seriously confused by it. This suggests that list matching both from the procedural and animation perspective, should be performed atomically. Another lesson was that the acceptance of an item in the *Similar* column of one list will almost always imply the rejection of the other list's corresponding item (and vice-versa), therefore a third option that accepts one item and reject its counterpart appears to be desirable in the context of medication reconciliation. Other interesting conceptual ideas as well as small interface changes were discussed, as detailed in the previous section.

The exploratory experiments performed with CS/HCI students revealed some flaws in our interface designs, from minor issues such as wording of items (arguably, a data description matter instead) to the use of vertical space, unnecessary empty rows and bad resizing choices during filtering operations. Students also bumped into difficulties with the the *Accept/Reject* pop-up menu, as did the doctors. We will have to then re-think how to display these options, as well as how users would better interact with it and apply these changes to the next version.

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