

TwinList: Visualizing List Differences

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ABSTRACT

We present a novel list visualization tool named 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 is comparing information from different sources or about different 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 may wish to compare the words used by different political parties during campaign speeches. Or as a more specialized example, a doctor performs the task of medical reconciliation. In medical reconciliation, a doctor crafting a treatment plan for a patient prior to their discharge from a hospital will need to compare medications the patient was taking before admis-

sion 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. The logic necessary to compare these items can be complicated, such as resolving a prescription 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.

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 lists, 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, TWINLIST provides sorting, filtering, and grouping functionality to allow users to explore different aspects of the data. Finally, the application supports choosing items that are relevant or irrelevant, helping users reach a strong conclusion.

Related Work

The specific problem of list comparison as we have framed has relatively little research. Research in areas such as visu-

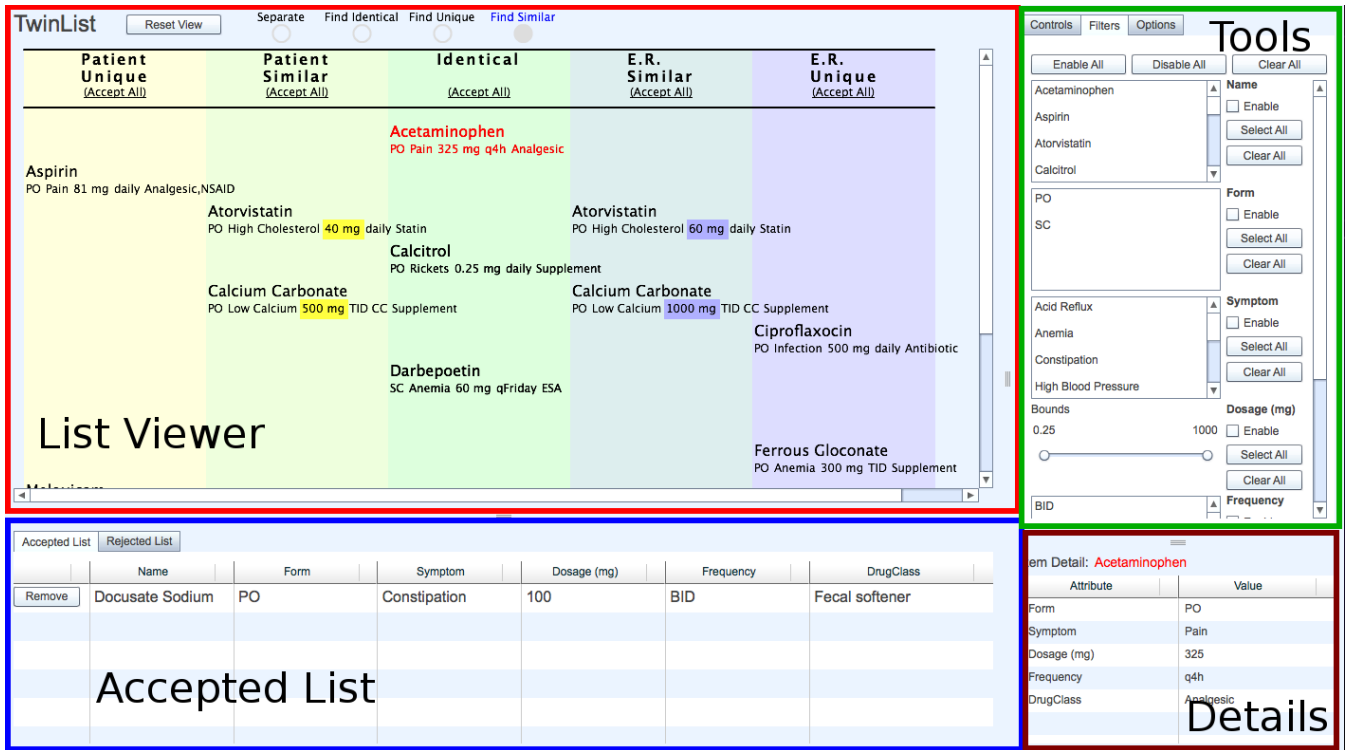


Figure 1. The TWINLIST interface: In this screen capture, the lists have been matched, displaying identical items in the center column, unique items in the outer columns and similar items in between. Color highlighting is used to indicate similar attribute values. In the bottom left panel is the *Accepted 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).

alizing 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 circumstance 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.

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. It is where the list matching animation and user actions are performed. The matching animation is triggered by pressing the *Match List* button, or selecting any of the individual operations in the state diagram. The *List Viewer* can be reset using the same button or state buttons.

The five-column list placement

To visualize the and similarity and difference of two lists, a five-column list placement is used in TWINLIST. We used a different color tone to separate the two lists. That is, the items in the yellowish color columns are belong to the first list, while the ones in bluish columns are belong to the other list.

The identical items, both the name and attributes are the same, will be shown in the center column(green). The unique items that only appeared in the first list will be shown in the leftmost column(yellow). The items that are unique to the other list then will be shown in the rightmost column (slate blue). Then all the similar items will be placed in the Similar columns and the difference will be highlighted in the visualization. For example, in Figure 1, Acetaminophen, Calcitrol and Darbepoetin appeared on both lists, so they are placed in the center green column. Atorvastatin appeared in both lists. However the dosage of the two are different, 40mg on the patient list, and 60mg on the E.R. list. The different dosages are highlighted. Aspirin is unique to the patient list, so it is placed in the leftmost 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.

Item Detail: Acetaminophen	
Attribute	Value
Symptom	Pain
Form	PO
Dosage (mg)	325
Frequency	q4h
DrugClass	Analgesic

Figure 3. *Details Panel*.

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 user can see the similarity and difference clearly. TWINLISTsupport user to take actions about the list items. This feature is especially useful for medication reconciliation, for doctors will need to make decisions after examined the list items on both lists. If a user left click and hold, a menu with two options will show up and user can choose which action to take for that particular item (Figure 4). The item selected is then added to the *Accept/Reject*(Figure 5). The selected item in then remove from the *List Viewer*. User can choose to either gray out or the added item in the *Options Panel*. The action can be reversed by click on the Remove button in *Accept/Reject*, the item will be removed and reappear in the *List Viewer*. This is also consistent with "Permit easy reversal of actions" [?]of the design guideline

Controls



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.

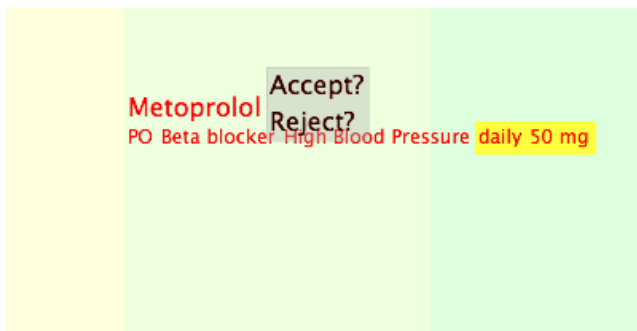


Figure 4. A detail of the action menu.

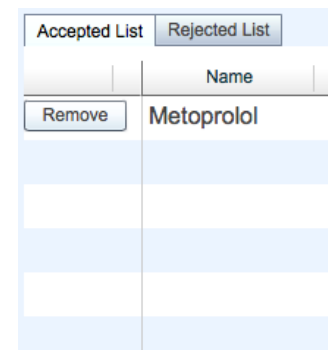


Figure 5. A detail of the added medicine in *Accept/Reject*.

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

- **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 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

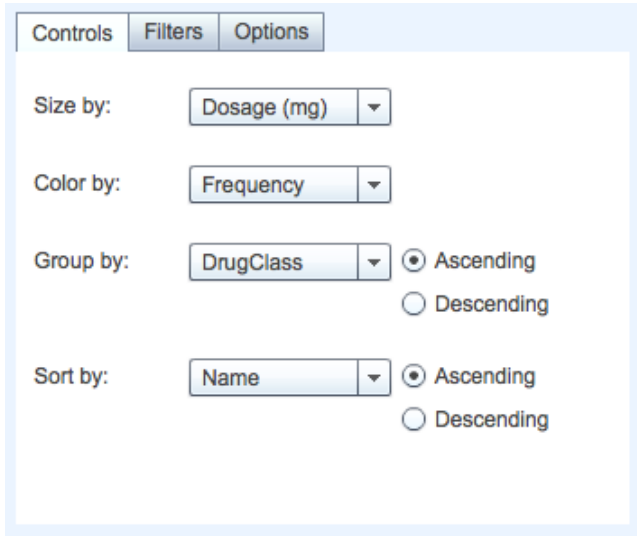


Figure 6. A detail of the *Control Panel*.

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 if it passes all filters, meaning its attribute values fall within the specified allowable sets or

¹While 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.

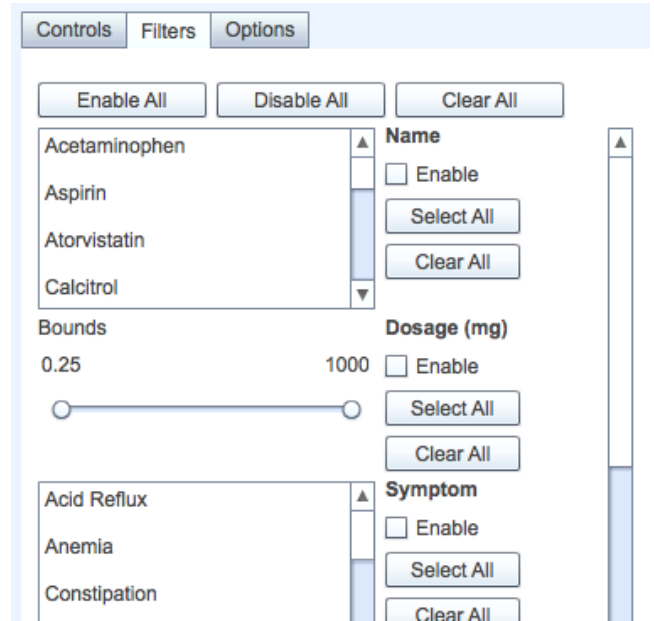


Figure 7. A detail of the *Filter Panel*.

ranges.

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

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

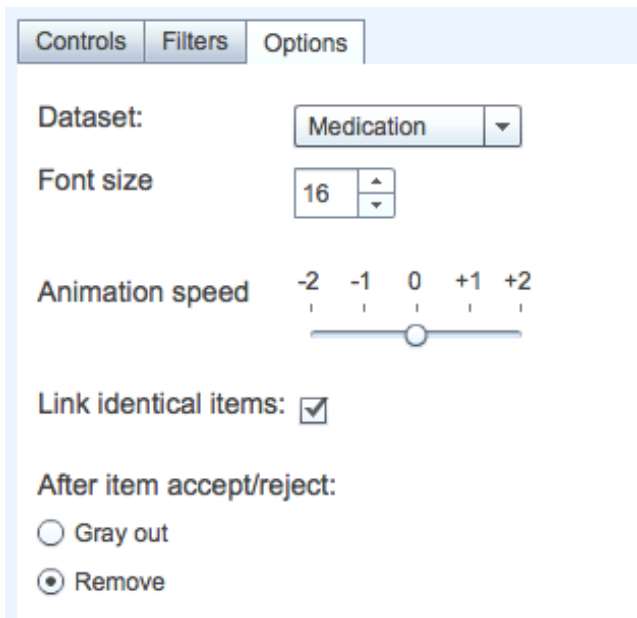


Figure 8. A detail of the Options Panel.

will hide the other from the *List Viewer*. When unlinked, they are considered completely separate items.³

- *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 TWINLIST to 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

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

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 step-wise 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

[[Short description of TWINLIST and how it can simplify list matching]]

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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