Multiple Taxonomy Visualisation Requirements

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Abstract

A summary of the feedback from focus groups to demonstrations of a prototype visualisation tool at various locations over the course of 2006. This feedback was then distilled into a set of requirements that were linked to the seven original objectives of the TaxVis project.

Summary as of 20th December 2006

Demonstrations of the prototype visualisation were given to five separate groups of possible users in 2006 to gather feedback on the visualisations' current tasks, comments on the user interface, and to elicit further tasks the users would be interested in seeing the prototype perform. These demonstrations were carried out by an expert user as it was felt the application was not yet at the appropriate level of immediate usability for novice users.

Demonstration Parameters

Location	Users	Date	Data Sets
Kansas (remote)	Collection Managers (5)	Jan 23rd, 2006	MANIS
North Carolina	Ecologists (2) Taxonomists (1) Research Scientist (1)	Feb 1st, 2006	Moss/Ranunculus
London	Taxonomists (1) Research Scientists (2) IT Professionals (2) Other – Unspecified (1)	Feb 27th, 2006	Moss/ Ranunculus/ Fish
Copenhagen	Database Administrators & Taxonomists (5)	Sept 11th, 2006	ITIS/ MANIS/ Ranunculus/ Fish
Santa Barbara	Ecologists (4)	Dec 7th, 2006	Ranunculus / Fish / ITIS

The categories of users covered four of the user groups identified in the Seek Taxon Usability Activities document – Aggregators, Collection Managers, Taxonomists and Ecologists.

User type	Typical dataset size (taxa)	Typical specimen size
Aggregators	250000	
Collection Managers	4000	50000
Publishers	1500	
Taxonomists	200	1000
Ecologists	?	?

Summary

Over the course of these initial demonstrations we have collected a number of opinions on the usefulness of the multiple classification visualisation. Many of the received feedback reflects not only on the issues of tree visualisation but on the

quality of the data sets involved, where possible we have tried to separate out visualisation issues from other issues.

Perceived Benefits

Kansas

The collection managers saw the benefit in identifying incorrect data as it would increase data validity, and the alternative it offered to accessing collection data via a text-based portal (MANIS), but were the most negative of the groups tested. One participant did comment it would be useful for classification comparison to see how others classify specimens, but others stated they would not want to reference other collections, or if they did would rather go to a curator or other specialist relevant to their collection scope. All users commented on the necessity of referencing to geographic data, but especially the collection managers. One interesting point raised was that the tool could be used to justify a collection's existence e.g. the wealth of data in a collection. What if the opposite was also true? Post-demo questionnaires revealed that collection managers thought the ability to discover unique items / areas within collections and differences in collection organisation would be most useful, whilst discovering proportions of selected taxa within higher taxa to be least useful. More detailed analysis is available at:

http://cvs.ecoinformatics.org/cvs/cvsweb.cgi/seek/projects/taxon/usability/Jan2006-viz-demo-report.doc

North Carolina

The Carolina-based taxonomists / ecologists were shown taxonomic data sets that graphically portrayed synonymy relationships between concepts and received the visualisation more favourably overall. The potential for data correction was also noticed i.e. finding misspelled names, incorrectly classified names, plus the ability to discover when a named concept was first used. The ability to explore unknown concepts or groups was also commented on, as was the ability to order classifications chronologically so the timeline of a concept or name could be discerned. Geography data was said to be useful in comparing the spatial coverage of taxonomies under comparison, though finding this data through non-Darwin core data sources may be problematic. A post-demo questionnaire revealed that the tasks they thought most useful were comparing taxonomic concepts with the same name, and determining which classifications to involve in a comparison. Least useful was finding occurrences of a name in a set of taxonomies. A more detailed analysis is available at:

http://cvs.ecoinformatics.org/cvs/cvsweb.cgi/seek/projects/taxon/usability/Jan2006-viz-demo-report-tax.doc

London

The taxonomists during the London demonstration were also shown the collection data and in some areas contradicted the findings of the collection managers, stating comparing collections could be useful to them especially when planning which institutions to visit, especially given economic constraints. This would seem to indicate a difference in the usefulness of collection visualisation between those who maintain them as their job and those who consult them in order to further their research. One of the taxonomists further commented that it would be useful to discover change at the genera and family ranks. A fuller description of feedback from these users follows in the next section.

Copenhagen

The participants in Copenhagen had mixed IT and taxonomy knowledge. In general their opinions on the visualisations interface corresponded to the opinions voiced so

far by the other groups. They also foresaw tasks using the ability to find unique names in a classification as a method of ensuring data quality and correctness in taxonomies, similar to the taxonomists in Carolina. Matching by synonymy was also rated highly as it had been by all groups so far. A fuller description of the feedback from this group is given later on in this document.

Santa Barbara

The participants from NCEAS (National Center for Ecological Analysis and Synthesis) in Santa Barbara were all post-doctoral community or computational ecologists. They were mainly concerned with finding correct names for specimens or groups they analysed or collected. Again, a full description of feedback from this group of observers occurs later in this document.

Existing Tasks

Table 7 shows the ratings given by the participants in all four demonstrations. Some questions differed between tests due to the different user groups, museum collections managers v taxonomists v information specialists. In the case where this difference was simply in terms of wording, i.e. ‘collections’ vs ‘taxonomies’, scores are collected as belonging to the same question. Other questions cannot be resolved this way so stand alone for their group. Also, only one post-questionnaire was returned by the NHM group – internet access was not available for them to fill in the questionnaire immediately.

The summary of the collected quantitative data below in Table 1 shows that potential users wish to compare taxonomies using both names and concepts (when available). Comparing taxa through their sub-taxa (either by name or concept) was also a highly sought after operation.

The ratings show that overall the visualisation was judged to be useful (3.9/5). For those questions answered by 10 or more participants, the highest usefulness was found for finding the various concept relationships, followed by determining which classifications to involve in a comparison, and then finding occurrences of a particular name across taxonomies, and showing the overlap of one classification against others.

The lowest usefulness rating was for displaying unique items to a classification. However this question also had the highest deviation, indicating a strong difference of opinion between the participants, which wasn’t explained by inter-group differences. The least disagreement was found on questions relating to finding relationships through concept matching, and the types of relationships that should be included.

None of the questions received a less than average rating (3), with the exception of “Discover proportions of selected sub-taxa within higher taxa” which was asked to the museum collectors only, indicating all tasks are to some extent relevant to a multiple classification visualisation.

Table 1. Usefulness of existing tasks

Question	Avg	N
Compare the taxonomic concepts which share a particular name.	5	5
Find those that are congruent	4.62	13
Compare taxonomic concepts based on sub-taxa.	4.6	5
Find those that are included in other concepts	4.46	13
Compare taxonomic concepts through explicit relationships.	4.42	12

Find those that include other concepts	4.30	13
Contrast name-based and synonymy-based matching	4.29	7
Determine which taxonomies to involve in a comparison.	4.23	13
Find those that overlap	4.23	13
Find the occurrence of a particular taxa across my collection or a set of collections. Find the occurrences of a particular taxonomic name across a set of taxonomies.	4.11	18
Display the overlaps between my collection and other collections. Determine the similarity of one particular classification to a set of other classifications. Compare classification name coverage against other classifications	3.94	18
Based on this demonstration, rate the overall usefulness of this visualization tool.	3.88	17
Compare a sub-tree in one classification and see its distribution in other classifications	3.86	7
Show how my collection is organized differently compared to other collections. Discover structural differences between taxonomies (based on names).	3.82	17
Find the first occurrence of a particular taxonomic name across a set of taxonomies.	3.5	12
Display what is unique to my collection as compared to other collections. Find unique names within a taxonomy (relative to other taxonomies). Find taxonomic names that occur only in one particular classification in a set of such classifications	3.44	16
Discover proportions of selected taxa within higher taxa.	2.8	5

Further Functionality

During and immediately after the demonstration the audiences supplied verbal feedback, either by asking questions that indicated a degree of uncertainty about some features of the visualisation, or by explicitly stating what they thought to be helpful or irrelevant about the visualisation. Further, they also indicated functionality they thought should be present but currently was lacking. This feedback was aggregated across the user groups and categorised according to perceived priority and by the aspect of the visualisation it referred to in Table 4 (i.e. interface issue, task issue etc). Those issues highlighted in Table 4 have been acted upon.

- Further functionality suggested during the course of these demonstrations reveals that specimen, including geographical, data should also be made available where possible, it was seen as critical by the museum collection manager group.
- The input and output of data from the visualisation was also the focus of suggested enhancements. At first the visualisation loaded data through a command line so obvious changes such as being able to load data through the UI were put forward. Output suggestions involved either exporting a selected subset of taxa, and the ability to link to related data sources such as metadata.

- Relationship logic tasks such as ‘guessing’ tools i.e. calculating further possible relationships from existing relationships and, similarly, transitive relationships where relationships are chained together to form another relationship were also put forward. Dave Thau has also suggested these types of operations in his research. The completeness of taxonomies and relationships was also queried, if possible could the coverage, geographically and taxonomically of a taxonomy be communicated along with the completeness of concept relationship coverage for a particular set of taxonomies?
- The ability to visually filter taxonomies or collections based on search criteria was also put forward, in effect focusing on only the subparts or skeleton of the taxonomy that is of interest. There were also requests for the ability to link names with slight differences in spelling (orthographic variance) and homotypic names. The ability to extend the visualisation to examine more than the half-dozen or so classifications used in the demonstrations was also commented on.
- Support for building and editing relationships was queried – this is currently being investigated in a related project.

User Interface Issues

General issues arising from the observer’s perceptions of the visualisation are of relevance, whatever the form of the final visualisation. Issues specific to the visualisation used in the demonstrations may not be as relevant if we do not pursue that form of visualisation, but can act as guides to what we shouldn’t do in any new visualisation interface. Therefore suggestions such as “indicate which taxonomy or classification currently has the focus”, or that the interface is too complex when it initialises, have relevance to any visualisation solution.

GENERAL

- Retain highlighting (brushing) to keep last brushed node visible
- Capitalise genus name
- Higher colour contrast
- Font issue – use of san serif suggested
- Show which classification has the focus
- Interface is too complex initially
- Animation useful for moving up and down hierarchies
- Participants liked idea of query history
- Omit geographic terms from taxa list

SPECIFIC

- Vertical positioning to rank name mismatch
- Meaning of columns in list needs clarified
- Lines indicating synonymy need localised text information
- Dashing and hatching (structural change markers) was confusing
- Tree representation not universally intuitive? Option to switch horizontal/vertical?
- Triangles below some nodes to indicate deeper structure can mask other nodes
- Wrong colour for non-congruent relationships

Overall Requirements

Below are listed the initial aims of the project, with the requirements we have learned from our observations categorised according to how they fit in with each of these aims. In some cases limited feedback was given on issues surrounding extremely large hierarchies or rank structures, or specific mechanisms to allow communication

of discoveries, but these are still aims of the project. Conversely, the observers gave much feedback on what other data they'd like to see accessible from a taxonomic browser, such as geography data, specimen data, specific metadata from oceanographic surveys etc, and parts data. This may be possible if the data and indexing structures exist but the collection and construction of either of these is beyond the scope of this visualisation-focused project. Similarly requests for 'guessing tools' beyond the information supplied by concept or name tracking are outside the bounds of the project, suggesting as they do some form of AI functionality. Still, the requirements are included here as reference for any future projects that may wish to explore these particular needs of taxonomic data users.

R1. Deal with individual taxonomies on the scale of 200,000+ nodes.
R2. Encompass multiple hierarchies.
R3. Handle incomplete and incongruent rank structures within and between individual taxonomies.
R4. Encompass taxonomy specific aspects such as explicit synonymy and homonymy relationships across hierarchies.
R5. Allow detailed examination of and interaction with taxa sets at multiple levels.
R6. Allow taxonomists to explore the essential differences between taxonomies; not just the broad similarities.
R7. Provide a mechanism to allow viewpoints and discoveries to be shared between taxonomists.

Table 2. Original aims of project.

Requirement List	
RQ1. Compare the taxonomic concepts which share a particular name.	R5
RQ2. Find taxa that are congruent (via concept relationships)	R4
RQ3. Compare taxonomic concepts based on sub-taxa.	R5
RQ4. Find taxa that are included in other concepts (via concept relationships)	R4
RQ5. Compare taxonomic concepts through explicit relationships.	R4
RQ6. Find taxa that include other concepts (via concept relationships)	R4
RQ7. Contrast name-based and synonymy-based matching	R4
RQ8. Determine which taxonomies to involve in a comparison.	R2
RQ9. Find taxa that overlap (via concept relationships)	R4
RQ10. Find the occurrence of a particular taxon name across my collection/taxonomy or a set of collections/taxonomies.	R5
RQ11. Display the overlaps between my collection and other collections. Determine the similarity of one particular classification to a set of other classifications. Compare classification name coverage against other classifications	R2, R5, R6
RQ12. Compare a sub-tree in one classification and see its distribution in other classifications	R2, R5, R6
RQ13. Show how my collection is organized differently compared to other collections. Discover structural differences between taxonomies (based on names).	R2, R5, R6
RQ14. Find the first occurrence of a particular taxonomic name across a set of taxonomies.	R2

RQ15. Display what is unique to my collection/taxonomy as compared to other collections/taxonomies.	R2
RQ16. Discover proportions of selected taxa within higher taxa.	R5
RQ17. Including specimen-level data	R5
RQ18. Geographic indexing of data (related to previous point)	R5
RQ19. Reporting function – output of collection comparison results	R7
RQ20. Data mining functionality – text-based queries	R5
RQ21. Indication of completeness of taxonomy – in terms of geography and available species	R3, R6
RQ22. Show completeness of relationships – do they not exist because they have just not been considered yet (i.e. absence of relationships)?	R4
RQ23. Data input – facility to load files after start-up	R7
RQ24. 'Guessing' tools – i.e. Find transitive paths formed by synonymy	
RQ25. Access to other data such as metadata, oceanographic data	
RQ26. Auto-prune collections based on search criteria	R6
RQ27. Ignore inconsistently used ranks between taxonomies, especially in structure comparison	R3
RQ28. Linking by names with slightly different spellings (orthographic variance)	R2, R4
RQ29. Linking to homotypic names – binomials where a species has moved between genera	R4
RQ30. Ability to visualise extreme number of collections	R2
RQ31. Consider adding parts data and their relationships	
RQ32. Visualise massive million-taxa plus hierarchies	R1

Table 3. Requirements from previous work and gathered from observer feedback.

Further Functionality Request Table

Key **K – Kansas** **NC – North Carolina** **NHM – Natural History Museum** **G – GBIF, Copenhagen** **SB – NCEAS, Santa Barbara**

Importance v Frequency	1 Group	2	3	4
Critical				
	Including specimen-level data (K) Included after Kansas demo			
			Geographic indexing of data (related to previous point) (K, NC, NHM) Included after Kansas demo	
Important				
		Reporting function – output of collection comparison results (K, NC)		
		Data mining functionality – text-based queries (K, NC)		
	Indication of completeness of taxonomy – in terms of geography and available species (NC)			
		Similarly, completeness of relationships – do they not exist because they have just not been considered yet (i.e. absence of relationships)? (NC, G)		
			Data input – facility to load files after start-up (NHM, G, SB) Included after NHM demo	

Other				
			‘Guessing’ tools – i.e. possible relationships via analysis of other relationships (K, NC, G)	
		Find transitive paths formed by synonymy (could come under data mining or previous point) (NHM, G)		
				Access to other data such as metadata, oceanographic data (K, NC, G, SB)
	Auto-prune collections based on search criteria (K)			
		Add relationships via drag-and-drop / line drawing (NHM, SB)		
	Ignore inconsistently used ranks between taxonomies, especially in structure comparison (G)			
	Linking by names with slightly different spellings (orthographic variance) (NC)			
	Linking to homotypic names – binomials where a species has moved between genera (G)			
	Ability to visualise extreme number of collections (K)			
	Consider adding parts data and their relationships (NC)			
	Visualise massive hierarchies (1M nodes +) (G)			

Table 4. Importance v Frequency of Further Functionality Requests

User Interface Issues

- Retain highlighting (brushing) to keep last brushed node visible (K)
- Capitalise genus name (K, G)
- Higher colour contrast (K)
- Font issue – use of san serif suggested (K)
- Vertical positioning to rank name mismatch (NC, NHM)
- Meaning of columns in list needs clarified (NHM, G, SB)
- Wrong colour for non-congruent relationships (NC)
- Lines indicating synonymy need localised text information (NC)
- Show which classification has the focus (NC)
- Dashing and hatching (structural change markers) was confusing (K, G)
- Tree representation not universally intuitive (NC)? Option to switch horizontal/vertical? (G)
- Triangles below some nodes to indicate deeper structure can mask other nodes (G)
- Omit geographic terms from taxa list (K, G)
- Interface is too complex initially (G)

Other comments

- Animation useful for moving up and down hierarchies
- Participants liked idea of query history

*Highlighted items have been addressed since or during the course of the demonstrations.

Natural History Museum, London, 27th February 2006

This section contains a rundown of the comments and feedback we received from the 'taxonomists' at the Natural History Museum on Monday (27th Feb, 2006). We showed the participants numerous data sets, first of all the taxonomy-oriented data sets (Moss, Ranunculus), then the collections-based data sets as some expressed an interest in seeing how the visualisation would deal with them.

General Interface Issues

- Some were confused by the rank matching to vertical position issue found in the previous user tests i.e. the nodes don't always align to the correct rank name when shown in groups. One asked why some of the nodes were drawn as upside-down skyscrapers.

- One contributor asked for clarification on the list, specifically why the list was divided into differently-coloured columns. This was explained and accepted as understandable once explained, but not intuitive at first.

What I can do

- "Can I tell if concepts are new or used beforehand" – it was explained that organising the taxonomies by 'year' could answer this question. It was pointed out by another contributor that since the list was similarly organised it would be easier to answer the question using that part of the interface.

- One of the contributors commented that the visualisation would be useful to discover movement of higher-level taxa i.e. genera within or between families. This appears to conflict with the collection manager's view of wanting to see low-level changes i.e. specimens and species. Due to user type?

- When showing one of the collection-based data sets, the participants expressed interest that it would allow them to see the relative coverage of different collections. The collection managers we previously demonstrated this aspect of the visualisation to had themselves (mostly) said this was not of interest to them. However, the contributors here said that if they were working to a limited travel budget, they would want to plan to go to the collections which afforded them the best coverage of species/specimens on the budget they had available. This would seem to indicate a difference in potential use between those who maintain collections and those who consult them as a reference?

- It was also re-iterated that collection-based data would need to be referenced to a geographic-based index to be of full use, this was demonstrated by showing them part of the fish data set from Kansas from which basic geography data had been extracted.

Further features

- "How do I get data in?" – This discussion centred not only about the specific format needed to get data into the visualisation, i.e. TCS 1.01, other XML formats, tab-delimited files etc, but also about getting paper-based data into a parsable digital format. There is a need to incorporate a data loading function into the visualisation, rather than have to reinitialise the visualisation per different data set.

- “Can it find and display linked relations” – This was a request about whether the visualisation could discover and/or display transitive paths between concepts. i.e. if A is congruent to B, and B is congruent to C, they wish to see A displayed as congruent to C. This is not just a visualisation question, but a data mining question which would involve manipulation of the graph structure denoted by the concept relations.
    - Also there is the question of whether transitive relations should only be made if the involved component relations are defined by the same person. Different people have different ideas of which concepts are related, joining those together without consideration may give multiple and conflicting paths between concepts i.e Peet says A is congruent to B which is congruent to C, Kartesz says A only overlaps C.

- “Can I add relations” – One contributor asked if relations could be added by drawing lines between nodes, in effect a drag-and-drop metaphor.
    - This led to a quick discussion and demonstration of the concept mapper tool

GBIF, Copenhagen, September 11th 2006

Similarly, this section contains a rundown of the comments and feedback we received from the participants at the Global Biodiversity Information Facility (GBIF) offices in Copenhagen on Monday 11th September, 2006. We demonstrated to the participants numerous data sets, first of all the large ITIS data sets to demonstrate the visualisation's use on large data sets, followed by the MANIS museum collection data set and then the Ranunculus concept data set. For completion the Kopersky Moss data set was also shown, along with the Kansas Fish collections to demonstrate how geographical data could be integrated into the visualisation style.

Pre-Questionnaire Summary

The participants who witnessed the demonstration declared themselves to be a mixture of taxonomists and information specialists (inc. database administrators). Since they were working at GBIF their current roles tended towards information specialists, but all cited various degrees of taxonomic experience ranging from formal taxonomic qualifications (PhD) to knowledge picked up during the course of their careers.

All except one stated they used multiple hierarchies at some stage in the course of their work. The exception stated they only used single hierarchies, whilst two stated they used both, plus list-based taxonomic data. All except one also stated they preferred to use multiple hierarchies, the exception being the same person who stated they only used single hierarchies – they preferred using single hierarchies. Again, all except one said they thought of multiple hierarchies as separate but related structures, one thought of them as a merged single structure; this was not the same person as the exception in the previous two questions.

Comparison of hierarchies was said to be currently accomplished in a pairwise procedure by three of the participants who answered this question, one stated they contrasted one given classification against many others simultaneously. Only one claimed to have seen any previous visualisations that displayed taxonomic classifications, citing a hyperbolic tree style of visualisation.

Feedback

This section contains feedback gained from the open-ended elements of the questionnaires and from verbal comments made during the course of the demonstration.

General Interface Issues

- The list containing the list of global taxa names received many comments. These were questions about whether the list covered all names or just the classification currently being probed in the main visualisation area.
    - It was also said it was not obvious it was divided into columns, checkboxes or radio buttons were mooted as a more recognisable way of displaying whether a name occurred in a given classification.
    - Later, there was a question of whether the ordering of the columns matched the ordering of the classifications in the main display, which was confirmed by demonstration.
    - There was also a comment that it was useful to see the relative alphabetical distributions of names by studying the letters in the list's scroll bar (new since previous test).

    - Again, the consensus was that the list should only include taxa names, not other terms such as geographical information.
    - There was a difference of opinion between the participants on whether the list was intuitive overall, one saying it was useful for gaining a quick overview of a taxon's coverage,

- The yellow-tinted triangles underneath the names that are used to indicate the presence of deeper undisplayable nodes were said to occlude some of the displayed data directly below said nodes.
- It was commented that at start-up the interface presents too much information and options – overload.
- The issue of capitalisation of genus / species name was also raised (some data sets use uppercase only for names).
- The texture marking used to indicate structural differences between classifications was said to be more confusing than other interface elements – it was harder to imagine what the texturing implied.
- The 'Taxon details' panel was explained as it was queried as to its functionality.
- Some participants were not used to top-down tree layout, they were more used to horizontal layouts. Top-down is good for a global overview, but the ability to choose between orientations would be useful.
- Generally the interface was felt to be complex – too many options and details appearing from the start.

What I can do

- It was felt that the feature of showing cross-classification taxa matching through colour was intuitive (three out of five mentioned this feature in the questionnaire in the open-ended section).
- The ability to show distinct (unique) taxa to a classification was also understood easily and described by one participant as very informative. Finding unique names could aid the cleaning up and validation of data sets as a QAQC (quality assurance & quality control) mechanism. Such a situation could occur when attempting to incorporate or compare classifications against large taxonomies such as Species2000, maybe by integration into services such as Manis or Tapir; unique names in a data set could be sent back to the data providers for clarification. It could also help find homotypic names when comparing two data sets, i.e. 'Felis concolor' in one data set, and 'Puma concolor' in another.
- History bar stated to be useful to go back to previous selections, especially if selection settings were captured at the time as well.
- Hyperlinks to further information was said to be a potentially useful feature. The Google / Wikispecies hyperlink feature was shown, and participants revealed GBIF had recently started looking into this functionality as well.
- A default classification to be selectable, to compare all other classifications in a set against (this seems to capture a one-to-many approach to comparison of classifications.)
- The current tasks were deemed to be useful and would be as independent processing steps i.e. independent of the style or visualisation or even in a non-visual context (i.e. finding unique names).

Further features

- Questions were asked about how to load and save data and how to generate concepts over a data set. This would indicate a requirement for a taxonomy editor of some form, either to add concepts over existing data sets or
- Finding homotypic name matches was also raised as a possible function. These are species that have moved genera and thus the first part of their binomial name has changed.
- Extra annotations to names (author names, [=catus] type appendices etc) can cause problems for exact string matching. Similar to homotypic names, an ability to partially match names would be needed here. Apparently methods / services exist for auto-parsing name strings into constituent parts.
- 'Uniqueness' should be defined so that a 'unique' name also has no explicit synonymy relating it to another name.
- The possibility of a simpler interface, comparing only two classifications, for use in a web-based environment (i.e. browser) was put forward. The current vis would be useful for someone with large amounts of data, but a simpler plug-in for websites (GBIF develop along these lines) could work for other users.
- The ability to ignore intervening ranks when those ranks are inconsistently used between taxonomies, especially in structural comparison.
- When selecting a 'reference' (main) taxonomy, a function to view a summary of all relations to a group of classifications from a particular name.
- Other types of data could be displayed in the visualisation; this view was prompted by the geographical data set. Phylogeography and preferred temperature ranges were put forward as two examples.
- The nature of the synonymy used in the concept-based data sets was also probed. The participants wanted to know how such relationships were arrived at, were they made automatically, inferred from existing relationships (the NHM group also asked for this kind of transitive relationship) – could they be generated from data in a TCS document? Currently our concept synonymy is based on expert opinion, performed by hand.
- When asked what further information they would like the visualisation to show, inferred relationships (transitive, reciprocal etc) were put forward. Authorities for names and synonymy were also nominated.
- A further synonymy based comment was to ask if a relation wasn't in a data set, did that mean it definitely did not exist, or that relationship had not yet been considered? This is analogous to the 'coverage' issue of taxonomies, is there a way to find the completeness of taxonomy by comparison with other taxonomies? Similarly is there a way to find out the completeness of a set of concepts? This was also brought up by the North Carolina group.
- Extremely large classifications such as the Species2000 hierarchy can contain over a million taxa, can the visualisation cope with that size of structure?

Quantitative Feedback

The questionnaire the users filled in during the course of the demonstration also contained a number of questions on specific tasks and portions of the interface, which were to be assigned a number from 1 (low) to 5 (high). Since the number of participants was only five, no statistically valid declarations can be made but the numbers do provide some useful feedback (see Table 2 for full details.)

The basic task of finding names across multiple classifications was judged to be the most useful task and showing synonymy relationships and their differences compared to name matching were also judged to be highly useful. All the basic tasks scored highly (none less than 4 on average). The largest difference of opinion occurred on judging whether finding unique nodes to a classification was a useful task.

Finding the different types of possible relationships between concepts were all said to be useful, with overlapping taxa relationships being slightly less so than the others.

The questions asking which elements of the interface they considered useful, found the individual tree representations to be most useful, with the ability to sort taxa by metric the least. None scored below the middle value (3) on average.

Overall, the visualisation was said to be useful (4.25 / 5), with one person omitting to score this question.

Other Feedback

The participants also said that the taxonomies they deal with will get larger (ITIS has ~250,000 whilst Species 2000 has 1,000,000+ taxa). Other taxonomies, though smaller, have more complicated structures, the NCBI taxonomy for instance has many more ranks than ITIS.

The opinions expressed for comparing either classifications in a pairwise fashion or for selecting one ‘main’ classification to contrast against a set of others would seem to indicate these two methods are how taxonomists currently compare taxonomies. The more complex alternative of comparing many classifications against each other simultaneously was shown using the old graph visualisation based browser which overlays multiple classification links on a set of name nodes. This was universally said to be less intuitive than the current visualisation, other comments included “overwhelming” and “it would frighten people I think”.

Please rate the usefulness of being able to perform the operations listed below	P1	P2	P3	P4	P5	AVERAGES	STDEV		
Select a subset of classifications to operate over	4	4	4	4	5	4.2	0.447213595		Low diff
Find all the occurrences of a taxonomic name across multiple classifications	5	5	5	4	5	4.8	0.447213595	Highest usefulness	Low diff
Find the first occurrence of a taxonomic name in a set of classifications	3	4	5	3	5	4	1		
Find taxonomic names that occur only in one particular classification in a set of such classifications	2	4	5		5	4	1.414213562		High diff
Compare classification name coverage against other classifications	3	4	5	5	5	4.4	0.894427191		
Compare a sub-tree in one classification and see its distribution in other classifications	3	4	5	3	5	4	1		
Discover structural changes between classifications (based on names)	4	4	3	5	4	4	0.707106781		
Compare taxonomic concepts based on explicit relationships	5	4	5	5	4	4.6	0.547722558	Highly useful	
Contrast name-based and synonymy-based matching	5	4	4	5	5	4.6	0.547722558	Highly useful	
If comparing taxonomic concepts through relationships, rate the usefulness of the operations below									
Find Congruent taxa	4	5	5	4	4	4.4	0.547722558		
Find Overlapping taxa	4	4	3	4	4	3.8	0.447213595		Low diff

Find taxa included in other concepts	4	5	5	4	4	4.4	0.547722558		
Find taxa that include other concepts	4	5	5	4	4	4.4	0.547722558		
Which of these techniques used in the interface did you find useful for interpreting the taxonomic data?									
Animated transitions in classification	3	4	4	3	3	3.4	0.547722558		
Alphabetical list of names	5	5	4	4	2	4	1.224744871		high diff
Individual Classification Tree Representation	5	5	4	4	4	4.4	0.547722558		
Many Classification Trees Representation	4	5	5	3	3	4	1		
Showing relationships through connecting lines	4	4	5	5	3	4.2	0.836660027		
Showing relationships through shared colours	4	5	4	5	2	4	1.224744871		High diff
Temporary highlighting (brushing)		4	4	4	1	3.25	1.5	Low usefullness	
Synchronised navigation of classifications	4	5	4	4	3	4	0.707106781		
Changing ordering of sub-taxa in classifications	4	3	3	3	3	3.2	0.447213595	Lowest usefullness	Low diff
Marking points of structural differences with textures		4	3	4	2	3.25	0.957427108	Low usefullness	
How would you perceive the overall usefulness of the multiple hierarchy visualisation tool?		5	5	3	4	4.25	0.957427108		
Average:	3.952380952	4.375	4.333333333	4	3.708333333	4.077586207	0.856188338		

Table 5. Quantitative Post-Q Numbers

NCEAS, Santa Barbara, December 7th 2006

Similarly, this section contains a rundown of the comments and feedback we received from the participants at National Center for Ecological Analysis and Synthesis (NCEAS) offices in Santa Barbara on Thursday 7th December, 2006. We demonstrated the visualisation to the participants using several data sets, first of all the Ranunculus concept-based data set, followed by a Fish-based data set we obtained from Kansas, and finally the large ITIS data sets.

Pre-Questionnaire Summary

The participants who were present at the demonstration all described themselves as post-doctoral community or computational ecologists. None of them had encountered software that displayed taxonomic classifications graphically, and only one claimed any real previous experience with taxonomic issues. This respondent differed in their other responses as well, stating they used hierarchical data sets and compared a single data set simultaneously against many others. The other two respondents stated they'd only encountered list-based data sets of taxonomic names and would perform comparisons on a one-to-one pair wise basis.

Feedback

This section contains feedback gained from the open-ended elements of the questionnaires and from verbal comments made during the course of the demonstration.

General Interface Issues

- The list containing the list of global taxa names received comments
    - About the shading behind the names – what did this represent?
    - One observer noticed letters in scroll bar matched to first letter of names in the list
- The history bar at the bottom was noticed and commented upon before it had been demonstrated.
- The animation when navigating was said to make a difference when seeing how movement was made inside the taxonomic hierarchies.
- Linking between the hierarchies using colour was said to be intuitive 'pretty quickly', but not analogous to anything else they'd seen.
- Layout of individual taxonomies as top-down was not seen as a problem by this group – *"I don't think it makes any difference, it's hierarchical*"
- Asked about how many colours can be used simultaneously (explained there were perceptual limits when colours became indistinct from one another).
- The concept relationships as communicated through the drawn lines were said to take some getting used to, and was attributed to the fact there were now different types of relationships to digest rather than simple 1:1 name linking.

What I can do

- The observers were comfortable with the use of colour to show matching names between taxonomies

- An observer declared the visualisation could be a good way of figuring out equivalences between data sets if you knew which taxonomy a data set was categorised under.
- Comparing by concepts as against (or in comparison to) names was said to be powerful. Previous approaches mapping by name strings were acknowledged to be under-powered and lacking in accuracy, so the ability to visualise concept relationships was useful.
- Structural comparisons by names was used to show differences in classification in fish data set between tissue and whole specimen samples
- Geographical data was also said to be important. Demonstrated current ability of visualisation i.e. a geographical hierarchy that works on names rather than absolute coordinates or references.
- Demonstration of whole classification overlap comparison was said to reveal differences in scope of taxonomies or collections.

Further features

- A lot of the features the observers mentioned involved getting legacy data from sources such as excel spreadsheets into a usable format for the tool. This is not a visualisation problem but is widespread amongst taxonomists, ecologists, in that they have data but often not in electronic or in a non-standard format.
- When demonstrating data taken from the MANIS data repositories, it was questioned whether searches could be done on some of the non-taxonomic data such as longitude, specimen collector etc
- Is the visualisation used on top of a database – explained that currently it uses flat XML files for speed and awaiting development of TOS server.
- Does structural comparison work on concepts as well as names – as yet, no, as concept relationships have 1:N cardinality discovering structural differences on the basis of relationships is a step of complexity above simple name matching.

Quantitative Feedback

The questionnaire the users filled in during the course of the demonstration also contained a number of questions on specific tasks and portions of the interface, which were to be assigned a number from 1 (low) to 5 (high). Since the number of participants was only five, no statistically valid declarations can be made but the numbers do provide some useful feedback (see Table 2 for full details.)

Other Feedback

The participants asked many questions that were not directly related to the visualisation itself but to the processes of making existing data into an importable format and how to generate concept relationships within such data. For the first point they were told that data needs to be transformed for the current visualisation tool into either TCS or Digir/DarwinCore XML formats, whereas their wish is obviously just to drop Excel spreadsheets into such an application. There seems to be a gap here between what current tools accept as input and what practitioners have to hand as data, especially legacy data.

As for the generation of concept relationships it was explained that these were generated by expert taxonomists, and could then be used to negotiate between overlapping taxonomies, either directly or indirectly via intermediate taxonomies. The observers wondered whether they would need to, or whether they'd be able to,

generate such relationships themselves. One observer commented that the ability to drag links between concepts to generate relationships would be feasible, an approach that is currently being explored elsewhere. It was also asked whether current data sources, such as MANIS, used concepts so comparisons between museums with different classifying systems could be more accurately performed. Concept relationships seemed to be acknowledged as a very important development.

They also mentioned difficulties with data sets that had been collected at different levels of resolution i.e. where specimens had been grouped by genus rather than species, or species rather than sub-species because the collector did not have enough knowledge or information to classify them more accurately. How would the visualisation, or indeed, concept-based relationships, deal with this?

One commented that for ecologists, a visualisation that compares taxonomies is not essentially that useful when all they want is a name used in one taxonomy matched up to the correct name(s) in another taxonomy. With this in mind it may be that ecologists are not suitable users for further trialling of a visualisation that compares multiple taxonomies.

Please rate the usefulness of being able to perform the operations listed below	P1	P2	P3		AVERAGES	STDEV		
Select a subset of classifications to operate over	4	4	4		4	0		Low diff
Find all the occurrences of a taxonomic name across multiple classifications	5	4	4		4.333333333	0.577350269		
Find the first occurrence of a taxonomic name in a set of classifications	3		2		2.5	0.707106781	Lowest usefullness	
Find taxonomic names that occur only in one particular classification in a set of such classifications	3	3	2		2.666666667	0.577350269	Low usefullness	
Compare classification name coverage against other classifications	4	3	3		3.333333333	0.577350269		
Compare a sub-tree in one classification and see its distribution in other classifications	3		4		3.5	0.707106781		
Discover structural changes between classifications (based on names)	5		4		4.5	0.707106781	Highest usefulness	
Compare taxonomic concepts based on explicit relationships	5		3		4	1.414213562		high diff
Contrast name-based and synonymy-based matching	4		4		4	0		Low diff
If comparing taxonomic concepts through relationships, rate the usefulness of the operations below								
Find Congruent taxa	4	4	5		4.333333333	0.577350269	Highly useful	

Find Overlapping taxa	4	4	3		3.666666667	0.577350269		
Find taxa included in other concepts	5	5	3		4.333333333	1.154700538	Highly useful	high diff
Find taxa that include other concepts	3	4	3		3.333333333	0.577350269		
Which of these techniques used in the interface did you find useful for interpreting the taxonomic data?								
Animated transitions in classification	5		3		4	1.414213562		high diff
Alphabetical list of names	4	4	2		3.333333333	1.154700538		high diff
Individual Classification Tree Representation	4		3		3.5	0.707106781		
Many Classification Trees Representation	5		4		4.5	0.707106781	Highest usefulness	
Showing relationships through connecting lines	4	4	4		4	0		Low diff
Showing relationships through shared colours	5	4	4		4.333333333	0.577350269	Highly useful	
Temporary highlighting (brushing)	3		4		3.5	0.707106781		
Synchronised navigation of classifications	5	4	4		4.333333333	0.577350269	Highly useful	
Changing ordering of sub-taxa in classifications	4		4		4	0		Low diff
Marking points of structural differences with textures	3	3	4		3.333333333	0.577350269		
How would you perceive the overall usefulness of the multiple hierarchy visualisation tool?	5	2	3		3.333333333	1.527525232		
Average:	4.125	3.714285714	3.458333333		3.774193548	0.818221879		

Table 6. Santa Barbara Questionnaire

Kansas						Raleigh						NHM		GBIF						NCEAS					Average	No.	Standard Dev
Discover proportions of selected taxa within higher taxa.	2	3	4	2	3																				2.8	5	0.836660027
						Find the first occurrence of a particular taxonomic name across a set of taxonomies.	2	5	4	2		4		3	4	5	3	5		3		2		3.5	12	1.167748416
Find the occurrence of a particular taxa across my collection or a set of collections.	3	4	2	3	5	Find the occurrences of a particular taxonomic name across a set of taxonomies.	2	5	5	3		5		5	5	5	4	5		5	4	4		4.111111111	18	1.078609611
						Compare the taxonomic concepts which share a particular name.	5	5	5	5		5												5	5	0
						Compare taxonomic concepts through explicit relationships.	5	4	5	5		3		5	4	5	5	4		5		3		4.416666667	12	0.792961461
						Compare taxonomic concepts based on sub-taxa.	4	5	5	4		5												4.6	5	0.547722558
Display the overlaps between my collection and other collections.	3	3	3	4	4	Determine the similarity of one particular classification to a set of other classifications.	4	5	4	4		5	Compare classification name coverage against other classifications	3	4	5	5	5		4	3	3		3.944444444	18	0.802365783

Display what is unique to my collection as compared to other collections.	3	4	5	4	2	Find unique names within a taxonomy (relative to other taxonomies).	3	5	4			1	Find taxonomic names that occur only in one particular classification in a set of such classifications	2	4	5		5		3	3	2		3.4375	16	1.263262971
Show how my collection is organized differently compared to other collections.	4	2	4	4	4	Discover structural differences between taxonomies (based on names).	4	4	5	2		3		4	4	3	5	4		5		4		3.823529412	17	0.882843001
						Determine which taxonomies to involve in a comparison.	5	5	5	5		2		4	4	4	4	5		4	4	4		4.230769231	13	0.832050294
													Compare a sub-tree in one classification and see its distribution in other classifications	3	4	5	3	5		3		4		3.857142857	7	0.899735411
													Contrast name-based and synonymy-based matching	5	4	4	5	5		4		3		4.285714286	7	0.755928946
																									0	
						Find those that are congruent	5	5	5	5		5		4	5	5	4	4		4	4	5		4.615384615	13	0.506369684
						Find those that overlap	5	5	5	5		5		4	4	3	4	4		4	4	3		4.230769231	13	0.725011052
						Find those that are included in other concepts	4	5	5	5		5		4	5	5	4	4		5	4	3		4.461538462	13	0.660225292

						Find those that include other concepts	4	5	5	5		5		4	5	5	4	4		3	4	3		4.307692308	13	0.751067616
Based on this demonstration, rate the overall usefulness of this visualization tool.	3	3	4	3	4		4	5	5	4		4			5	5	3	4		5	2	3		3.882352941	17	0.927520414

Table 7. Quantitative task usefulness ratings