Use of Subimages in Fish Species Identification: A Qualitative Study

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ABSTRACT

Many scholarly tasks involve working with subdocuments, or contextualized fine-grain information, i.e., with information that is part of some larger unit. A digital library (DL) facilitates management, access, retrieval, and use of collections of data and metadata through services. However, most DLs do not provide infrastructure or services to support working with subdocuments. Superimposed information (SI) refers to new information that is created to reference subdocuments in existing information resources. We combine this idea of SI with traditional DL services, to define and develop a DL with SI (SI-DL). We explored the use of subimages and evaluated the use of a prototype SI-DL (SuperIDR) in fish species identification, a scholarly task that involves working with subimages. The contexts and strategies of working with subimages in SuperIDR suggest new and enhanced support (SI-DL services) for scholarly tasks that involve working with subimages, including new ways of querying and searching for subimages and associated information. The main contribution of our work are the insights gained from these findings of use of subimages and of SuperIDR (a prototype SI-DL), which lead to recommendations for the design of digital libraries with superimposed information.

Categories and Subject Descriptors

H.3.7 [**Digital Libraries**]: User issues

1. INTRODUCTION

Many scholarly tasks involve working with contextualized fine-grain information, i.e., with information that is part of some larger unit. For example, a music professor may combine snippets of various compositions, to develop a multimedia presentation of a musical style. The professor is working with *subdocuments*, i.e., *in situ* parts of documents or fine-grain information where seeing subdocuments in their original context is useful. The subdocuments are snippets of musical compositions in the context of entire compositions.

Current approaches to working with subdocuments include a combination of paper-based and digital techniques. For example, a student might have class notes, images, audio lectures, etc. in digital form and refer to text books, personal notes and drawings, in paper form. People have used these techniques with a fair amount of ease and success in the past. However, growing volumes of such information coupled with manual information management, organization, and retrieval, can lead to ineffective and inefficient task execution. There are at least two problems.

- Subdocuments and whole documents are distributed across several locations (and may be paper and digital), thus making information management, organization, access, retrieval, and use tedious.
- Capabilities to work with subdocuments (in situ) and whole documents are also distributed across tools (storing in one place, taking notes in another, searching for information in a third place, etc.)

A digital library (DL) is an information system, with collections of documents/digital objects[1] and their metadata, and services to manage, organize, access, browse, index, and search through those collections. Most DLs provide limited or no support to work with subdocuments. Typically, there is no facility for identifying or distinguishing subdocuments of interest from their enclosing documents. Further, there is no provision for a subdocument to have its own metadata. As a result, subdocuments are not separately accessible, searchable, or manageable in most DLs. We use the following scenario to illustrate such a need in scholarly tasks. Consider a fisheries student, who is trying to identify the species using an image of a fish (Figure 1). She looks at the fish and identifies the family[2] of the fish. Then, to help with identifying the species of the fish, she might use this image to frame a query, such as:

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[1]Information in a digital library might be manifested in the form of digital objects of various content types.

[2]Fishes might follow a taxonomical classification, consisting of families, where each family consists of genera, and where each genus consists of species.

Find me species that are `darters` *that have a dorsal fin that looks like* Figure 1-A *and which is connected to another dorsal fin that looks like* Figure 1-B, *and that have an orange hue on its belly like* Figure 1-C.

In this scenario, the student searches for digital objects (species), of a class of digital objects (darter), and with three specific parts or subimages (Figure 1-A-C) that might be connected. Later, a teacher might use these subimages in a lecture to talk about the similar characteristics of `darters`. Support for such searches and uses is, typically, not present in DLs. This motivated the design and development of a **Digital Library with Superimposed Information** (SI-DL), which combines the idea of *superimposed information* with traditional digital library services. Superimposed information (SI) refers to new information laid over subdocuments which are part of existing information [1, 4, 8, 10]. Examples include new content such as annotations, labels, and tags; new structures/organizations such as citations, indexes, and concordances; and combination of new content and structure such as in concept maps and multimedia presentations composed from existing information. A core property of SI is to enable working with subdocuments in new contexts, while retaining its original information context.
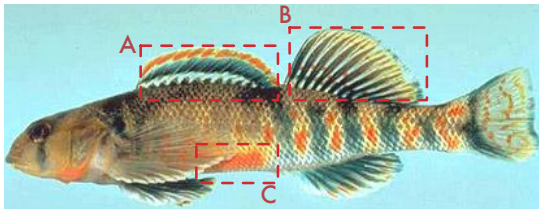

Figure 1: Searching on subimages and associated information.

By integrating the notion of SI within a DL, we believe that an SI-DL can provide enhanced support to scholarly tasks that involve working with subdocuments. We pursued this work with three main research themes: R1) The definition and description [14, 16], and the development of a prototype [11, 17, 12, 13, 15] SI-DL; R2) Understanding subdocument characteristics and how people work with subdocuments in scholarly tasks; and R3) Understanding the use of an SI-DL to support working with subdocuments in scholarly tasks.

In previous work [12], in which we addressed research themes R2 and R3, we evaluated the use of a prototype personal SI-DL, SuperIDR. SuperIDR enables a user to work with subimages in multiple ways, including capabilities to annotate, search using text- and content-based image retrieval, browse, and compare in situ, subimages and all associated information. In the conducted evaluation, students in an undergraduate Ichthyology class used SuperIDR as an aid to fish identification.

Focusing on a single task enabled us to study in detail, how people work with parts of images, or subimages, and how an SI-DL might support working with subimages. However, there were insufficient data on *how* students worked with subimages in fish identification and how they used SuperIDR functions to support their working with subimages. Some specific questions that were remaining included: (Q1)

What constitutes subimages in fish species identification? (Q2) What are the contexts and strategies of working with subimages in fish species identification? (Q3) How do people use SuperIDR and how does it support their working with subimages in fish species identification?

These questions required a different mode of inquiry than the controlled experiment previously conducted [12]. Therefore, we chose qualitative design and inquiry as we wanted to explore emergent behaviors with regard to use of SuperIDR and how it supported working with subimages in fish identification. Another reason to choose a qualitative method was that a controlled experiment, such as the one that we conducted earlier, might not replicate situated use [18, 21]. Such situated use would give us rich data on using SuperIDR in the natural work/study setting of a person doing fish identification.

Findings from our study suggest that working with subimages are an important, and sometimes necessary, part of scholarly tasks. The analysis of subimages and associated information provides us with patterns of visual characteristics of parts of fishes (and their images), which can lead to improved ways of indexing and searching for subimages. The contexts and strategies of working with subimages in SuperIDR suggest new and enhanced support (SI-DL services) for scholarly tasks that involve working with subimages, including, new ways of querying and searching for subimages and associated information. The main contribution of our work are the insights gained from these findings of use of subimages and of SuperIDR (a prototype SI-DL), which lead to recommendations for the design of digital libraries with superimposed information.

The rest of the paper is organized as follows. In the next section, we discuss related work in DLs, SI, and in annotations. Then, we describe the study setup, procedures, and tasks. We follow that with sections on analysis and findings. In the next section, we describe guidelines for designing digital libraries with SI, in the context of the findings of the study. Finally, we conclude and list future work.

2. RELATED WORK

The prevalence of the use of subdocuments in scholarly tasks has been noted in past studies of use of scholarly materials. For example, in a study of annotations on 150 college text books [9], Marshall found that notes, symbols, etc. are often found near highlighted portions of text. In another study on the use of National Science Digital Library (NSDL) educational resources in creating instructional materials [19], Recker and Palmer found that teachers preferred to use resources at a smaller granularity level than that was catalogued by NSDL.

Some of the analysis of subimages with annotations that we do in our research is similar to the work done by Marshall [9] and by Winget [22], who analyzed annotations on structured data, such as musical notations. Our work adds to previous findings on annotation use by providing insight into use of subimages and associated annotations.

Our work in this paper is based on a customization of SuperIDR [11, 17, 12, 13, 15] to work with fish species descrip-

tions and images. We evaluated the use of SuperIDR by students in an undergraduate Ichthyology class, as an aid to fish identification [12]. Students were able to successfully use SuperIDR to identify species of fishes with a higher likelihood of correctly identifying the species of a fish specimen, than using traditional fish identification methods, including a dichotomous key (Figure 5-B) [7], fish web sites, and personal notes.

3. STUDY DESIGN AND SETUP

The rationale for the qualitative study design was to maximize use of SuperIDR, in various settings, and to get rich data from multiple sources on use of SuperIDR and how it supported working with subimages in fish identification. This gave us an opportunity for triangulation using different sources of data. Hence, we used the following criteria in designing the study: 1) Recruit people with interest and experience in fish identification and whose current work and study involved fish identification; 2) Have participants use SuperIDR in their natural work/study settings for a (relatively) long duration; 3) Have participants use SuperIDR on their own (data on use in the wild) and in targeted tasks (opportunity to observe use); and 4) Collect data, in multiple ways and from multiple sources, on subimage and SuperIDR use in fish identification.

Our target participants were experienced users because we wanted to study how SuperIDR would be used by fish professionals and scholars in their everyday, work activities. Experienced users would give us wider exposure to types of users in the fisheries domain as compared to the earlier classroom study [12]. In that study, the participants were undergraduate students, who were relatively new to fisheries and to fish identification. We advertised about the study in one of the meetings of the local American Fisheries Society (AFS) chapter. An invitation letter included an overview of the study, participation criteria, potential time and effort required in the study, and a mention of the compensation of $50 on completion of the study. In all, we recruited six participants for the study, five in that AFS meeting, one of whom referred us to the sixth participant.

We deployed SuperIDR for three weeks in the work/study environments of scholars/professionals in the department of Fisheries and Wildlife Sciences, Virginia Tech at Blacksburg, VA, USA, between October 21, 2010 – November 18, 2010. Figure 2 provides an overview of the study design and procedures. At the beginning of the study, we collected information on the participants background, fish identification practices, and computer usage in a pre-study interview. At the same time, we installed SuperIDR on each participant's personal computer and provided a step-by-step tutorial of its features. A manual tutorial was provided for later reference. At the end of the training, participants were asked to complete a set of tasks to validate their training in using SuperIDR.

For the first two weeks, we asked the participants to use SuperIDR in their work/study environments. We asked them to complete a text diary entry on every use. A diary entry feature was built within SuperIDR for this purpose. At the end of each week during this period, we met with participants in a task session and asked them to identify five–

six unknown fish specimens using SuperIDR. We observed and captured their use of SuperIDR while performing the identification. The diaries gave us a means of "observing" situated behavior in which, we (the researchers), were not present and therefore the interference with natural behavior was minimal[3]. In the task sessions, we "observed" the participants' use in a different way by being present. In the third week, we asked participants to use SuperIDR as in the earlier weeks. At the end of the third week, we conducted a semi-structured interview (60-90 minutes), to get participants' responses on the use of subimages and of SuperIDR in fish identification. We used the data collected earlier in the study to elicit further explanations, as required.

To encourage participants to add images and annotations to SuperIDR, we gave them a list of 38 species at the beginning of the study, indicating that the unknown specimens in the task sessions would be from this list. We wanted participants to make active use of the subimage features in SuperIDR, both in and outside of task sessions. We did not force them to annotate these species, however, we strongly encouraged it. To make the species identification task nontrivial, the list included species of unknown specimens and other species that were similar to species of the unknown specimens, either belonging to the same genus or family. For each of the task sessions (end of week 1 and 2), we asked participants to identify unknown specimens – some using a jarred/preserved specimen only, some using images only, and some using both a jarred specimen and images. This enabled us to observe how their use of SuperIDR changed while identifying jarred/preserved specimens versus identifying images of fishes (or preserved specimens).

Data collected in the study included interview responses, diary entries, log data of SuperIDR use, screen captures of task execution, spoken thoughts during task execution, snapshots of fish identification materials used by the participants, database image of each participants' version of SuperIDR, and fish identification responses in the task sessions.

During the study, the first author was at a separate location from all the study participants. The set up, configuration, and test of SuperIDR on all participants' computers was carried out by the second author, who was at the same location as the participants. All the interviews and task sessions were conducted over Skype [4] – an audio/video conferencing software, which has several collaboration capabilities including text messaging and screen sharing.

4. ANALYSIS METHOD

We used the questions framed at the beginning of the study (as mentioned in Section 1) to guide the analysis of the data that we collected. We looked at SuperIDR usage logs to understand how each participant used SuperIDR. Also, logs helped us in the analysis of the qualitative data. Using the logs, we were able to extract 940 subimages with annotations in total (Table 1), made by the participants. We analyzed these annotations for recurring types or patterns of

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[3] there was still some because we asked them to fill in the diary entries
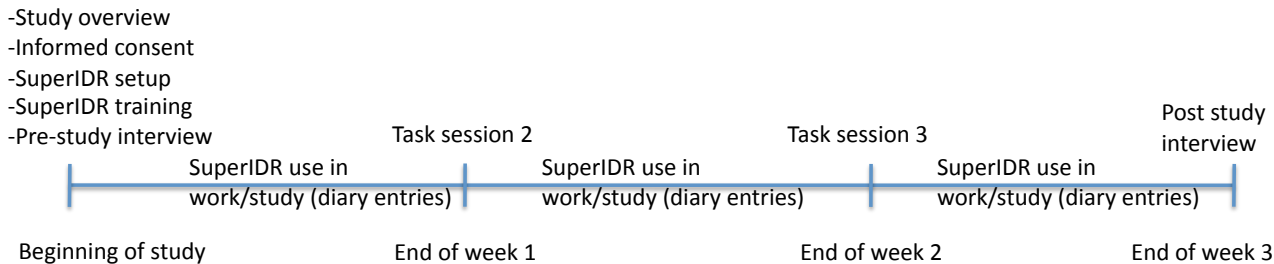
[4] http://www.skype.com

Figure 2: Study procedures

subimages/annotations. Our analysis of the qualitative data collected was informed by Grounded Theory [5, 6]. We followed Charmaz's Grounded Theory explanation and procedures [3], including open coding to identify emerging themes, developing categories of emerging themes, comparing and contrasting across different parts of the data, choosing the most important, relevant, interesting findings to report in relation with the research questions, and supporting findings with logs, excerpts, screen captures, pictures, etc., as required.

5. FINDINGS

In this study, all the six participants were students, two females and four males, although each performs additional roles (or had done so in the past) – including teaching assistant, research assistant, laboratory technician, and practitioner – which contributed to their experience in species identification. We used codes to refer to each participant during the study and analysis: P1, P2, P3, P4, P5, and P6. We analyzed the participants considering their fisheries and fish identification experience, current projects and fish identification practices and found three broad categories of participants: 1) Relatively less experienced, undergraduates (UG), including P2, P6, and P5 (recent UG); 2) Moderately experienced Master's students, working on theses and/or teaching/research, including P1 and P5; and 3) Highly experienced PhD students, working on research projects, including P3 and P4.

Our findings are categorized considering the initial research questions of the study.

5.1 Characteristics of a subimage and associated information

To tease out characteristics of a subimage and associated information, we consider participants' species identification materials, their responses, and subimages/annotations made by them. All subimages/annotations, except one by P4, were added during non-task sessions. We see from Table 1 that P1 added many more subimages/annotations (578) compared to the other participants. Most of P1's subimages/ annotations were added in the third week of the study. P1 realized that all other features of the tool, especially search, worked more effectively when there are more subimages/ annotations. In his diary entry upon last use of SuperIDR, he said:

"I annotated several images, and performed searches based

on previous annotations. I also uploaded images for combined searches. I am finding that this program is much more useful if you have already added annotations for the species you are looking at."

Table 1: Number of subimages/annotations added by participants.

Participant	P1	P2	P3	P4	P5	P6	Total
Annotations	578	71	48	58	86	99	940

This feeling was echoed by other participants, such as P2 and P5. We now analyze this collection for patterns of commonly occurring characteristics.

We used TagCrowd [20], an online tag cloud generator, to get an overview of the words used in the participants' annotations. TagCrowd considers a stop word list and other options, such as minimum frequency of keywords, maximum words to show, and whether to group similar words or not (such as memorize and memorizing), while generating a tag cloud. We preprocessed the annotation text, to identify words that have the same meaning, such as "caudal" and "tail". We input this preprocessed text into TagCrowd, opting for: a minimum occurrence frequency of 1, the default English stop word list [5], and group similar words, in order to generate a tag cloud of the 50 most frequent annotation keywords, as shown in Figure 3.
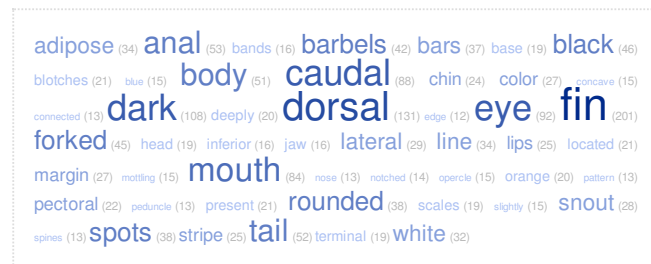

Figure 3: Tag cloud of top keywords in participants' annotations, generated by TagCrowd from 940 annotations

It is clear from the tag cloud that many of the keywords used in the annotations refer to subimages (caudal, eye, mouth,

[5]http://tagcrowd.com/languages/English

etc.). We analyzed a subimage and its characteristics further, with the following questions: i) What constitutes a subimage? ii) Were there repeated types of subimages and the keywords used to describe them? iii) What was the relationship(s) between the subimages and annotations?

We manually analyzed the annotations and found that most annotations had to do with body parts of a fish. Some of the distinct types of subimages/annotations that we noticed are listed in Table 2.

Figure 4: Examples of subimage/annotation: A.“long pointed nose, terminal mouth, big lips with little bumps”; B.“two dorsal fins almost connected”; C.“Eyes almost on top of head”; D.“one orange and one blue band on first dorsal fin”

Table 2: Type of subimages/annotations.

	Type	Description/Examples
1	Morphological description of a part	Body part and a set of terms which describes the body part. Example: “deeply notched dorsal fin”.
2	Size of a part	These subimages/annotations describe the size of a body part, such as “very large up-turned mouth”.
3	Color of or color-markings on a part	Example: “olive-brown gray-brown mottled color”.
4	Presence of a part	Examples: “Fin spines present” and “Dorsal and pectoral spines present”
7	Location of a part	Examples: “Eye on top of head” (Figure 4-C) and “U shaped marks on sides”.
5	Morphological comparisons	Usually some kind of size comparison or ratio. Example: “snout smaller than cataracte”.
6	Count of features	Counts of a particular feature. Example: “4 chin barbels”.
8	Description of multiple parts	Multiple body parts usually sharing a similar trait. Example: “Red pigment on nose and along side and belly”.
9	Co-presence of parts	Parts are different from each other and usually do not share a trait. Example: “Very long nose with subterminal mouth”, “Long pointed nose, terminal mouth, big lips with little bumps” (Figure 4-A).
10	Connections/ relationships with other parts	Describes some kind of connection/relationship among multiple body parts. Example: “Steep slope from snout to dorsal spine”, “two dorsal fins almost connected” (Figure 4-B).
11	Information-object as a whole	Considers the whole image or species. For example: “Roanoke basin” (geographic location of the species).
12	Comparison with other information-objects	Example: “solid line on back (not blotchy pattern as on Mtn Red Belly)” and “body similar to cyprinella”.
13	Combination of aforementioned types	Example: “similar to nigricans, however mouth and body form a right angle with snout”, “one orange and one blue band on first dorsal fin” (Figure 4-D).

Some of the common body parts that have been described are barbels, belly, body, chin, eye, fin (including various types, such as adipose, caudal, and dorsal), jaw, lips, mouth, side, snout, spines, tail, and teeth.

We see a variety of types of subimages/annotations. Some annotations (types 1, 2, 3, 4) directly describe a visual characteristic of the subimage. Some annotations are about location of a part (type 7). Some bring together multiple parts of the fish but use a single subimage/annotation to describe those parts (types 5, 6, 8, 9, 10). Some consider the image or fish species as a whole and/or might refer to information outside the image or the fish species (types 11 and 1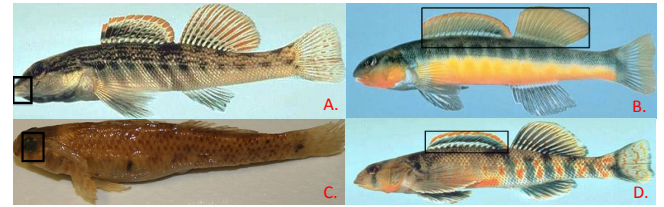2). Finally, there are annotations that combine the aforementioned types. This analysis of subimage/annotation types matches with the participants' responses on the characteristics of subimages/annotations, which they make and use while doing species identification.

5.2 Context and strategies that suggest working with subimages in fish identification

We found that participants engaged in two broad activities within fish identification - learning about a species and identifying species. Sometimes both would happen simultaneously as a participant tries to identify an unknown specimen and then learn about its details. Under this perspective, we described strategies used when learning about and when identifying fish species.

5.2.1 Learning about a species

Participants used various fish identification tools and methods when they learned about species in a class, such as Ichthyology, and in their work/research. Tools and methods include notecards, notes in other forms, printed lists, textbooks, and the identification key. Figure 5 shows examples of materials used by participants in learning about species, including a marked and annotated image from a book, a marked fish, a printed list of distinguishing characteristics (referring to parts of a fish) with notes, a structured table of fish species information including distinguishing characteristics (referring to parts of a fish) and images, and a key search list. In a class, such as Ichthyology, a student might work with several jarred specimens or, sometimes, go in the field to identify fishes. While learning about species in class, they use their fish identification materials. However, once they were familiar with the process (typically, after having taken a class), most of them do not use notecards or notes most of the time. They learn from books and learn in the field or in the lab by working with other people. Some of the participants, such as P1, P3, P5, said that they take cameras on the field to take pictures of fishes and of the location. They might, occasionally, make notes on the field about peculiar looking fishes, and study them when they return to the lab.

5.2.2 Identifying species

All participants used a top-down approach to learning about and identifying species. First, they would learn about/identify the family of the fish, then the genus, and finally work towards identifying the species. To identify the family, partic-
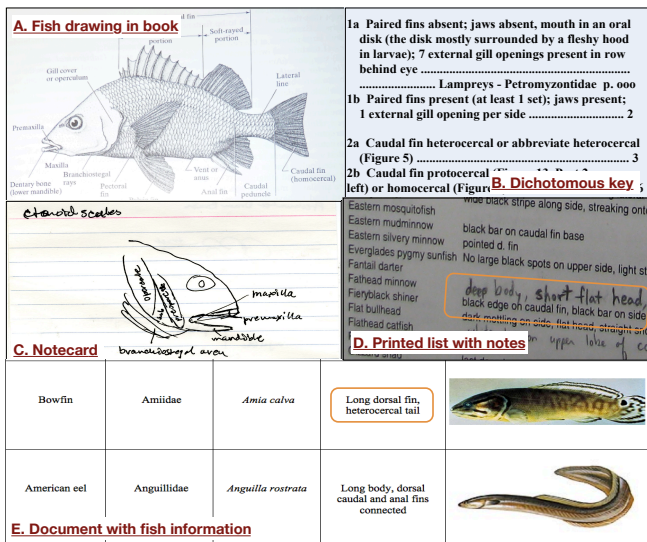
Figure 5: Examples of fish identification materials used by participants

ipants said that they use information about the fish, such as geographic location where it was found, and overall characteristics of the fish, such as shape or structure of the body, presence/absence of parts, etc. Usually, they are able to identify the family on a single glance. For genus and species identification, they focus on parts of the fish (and its images) and their co-occurrence in a single fish, keeping in mind all the information used to identify the family. Thus, subimages are used to analyze similar/different characteristics and help in narrowing down options of possible species. Participant P1 explained this process in his response to the question - explain your fish identification process and when/where do you use parts of images in fish identification:

"Yesterday, I went and annotated a bunch of herrings, and some of those you can tell apart pretty readily by the number of spots or the location of the spots on them [the fish]. It would not work if you said that this fish has dark spots. You know you get hundreds of species with dark spots. But, if you got down to a few species and you need to know how many they have ..." [P1 interview]

Additionally, participants reported they do most of their fish identification in the field instead of inside the laboratory. Besides researching the habitat, fisheries scholars prefer to identify in the field, so they might keep fishes alive (versus, bringing the fish to the lab, where they might have to kill it). This means that they need to work quickly to identify a fish. Using distinguishing characteristics helps in identifying fisher faster than the key, as one can look for these faster than having to walk through a decision tree to narrow down their options. Participants mentioned that they usually study (at times, prepare lists, notes, and other materials) about the species they expect to find in the field (considering the geographic location) before going on a field trip.

Besides identifying and working with live fishes, participants

also deal with preserved fishes, which look very different from live ones, which on the other hand, might vary in appearance considering the variability in habitats, where the fish might be found, its age, and its gender. Some characteristics that remain unchanged in live fishes once they are preserved, are black marks or lines. The experienced participants in the study used this knowledge while identifying specimens. For identification, some participants preferred having the preserved/jarred specimen as they could get a good understanding of the size of and patterns in a fish by holding it. Some, who preferred having the images, said that the color images of the fishes showed their distinguishing characteristics clearly and hence were easier to identify. Also, they felt that in the field, where most fish identification takes place, one could see the live colors as was captured in the color images. Some preferred having both, to take advantage of both types of specimens.

5.3 Working with subimages in SuperIDR

We summarize the participants' contexts/strategies of working with subimages in SuperIDR for fish identification.

Using SuperIDR to identify an unknown specimen. Participants followed a top-down approach to identifying fishes while using SuperIDR just as they normally do with traditional methods. In most cases, they identified the family of the specimen within a minute of looking at it (for both, preserved/jarred specimens and images of specimens). Then, participants followed one of several paths, to narrow down their choices, including: 1) Using the taxonomy, tree, or key browser; 2) Using the text, image, or combined (text and image) search; or 3) Visually analyzing the specimen or image and identifying their choices. At the end of this step, they usually ended up with two to three species from which to choose. Then, they would open the descriptions of these species options and browse through the description, the images, and the annotations (if any) of the species. They would go back and forth between these species, analyzing and comparing the species. Sometimes, they used the comparison features to do this analysis of similarities and differences. Finally, they would select one species.

To help with this top-down approach, participants suggested additional ways they might use subimages/annotations within SuperIDR: 1) Be able to see all annotations on a species at one time and space, to help with inspecting information about a species. Also, this would help a user to avoid duplicating subimages/annotations; and 2) Be able to see the distinguishing characteristics (and subimages) that are different in a species, which is similar to the current species being viewed. This would help in deciding whether to view the similar species or not.

"It would be nice to be able to see all annotations for a species simultaneously - not just for the photo I am currently viewing; same for the comparison view." [P3 diary entry]

"The tool already uses a 'similar to' feature, but it would be nice if it listed that another species was similar, but also told how to distinguish them. This could be added with custom annotations, but I know it is already a common problem and sometimes not so easy to distinguish with pictures." [P5 diary entry]

Manual inspection and analysis of subimages and images. In the study, participants constantly felt the need to manually verify distinguishing characteristics of fishes by examining fish images even after correctly identifying the species of a fish. They marked up images, browsed through the annotations and species description and visually analyzed images and subimages of the species. Just as it is hard for the human eye to discern between two similar objects and one needs to make sure that the right one has been identified/selected, participants wanted to manually inspect images to make sure that they the correct species had been chosen among similar looking ones.

"It depends on how distinct that species [is] . . . and how many other species are similar to that species, I guess . . . I would never trust the result, I guess, 100% . . . you know, based on just one picture and a little bit of written text. I would always want to pull up other species that are somewhat similar and just do a visual inspection myself to be sure that it just was not some bad [query] image that I used or a bad search term." [P3 interview]

Advanced search capabilities. We included three different ways to search for information within SuperIDR to give users an idea of how one might search for subimages and associated information. Our objective was to get their feedback and tease out contexts and other strategies of searching for subimages and associated information. In this regard, participants suggested improvements and additional capabilities they might use in fish identification, which included: 1) a facility to filter subimage/annotation results considering the family or genus of a specimen; 2) ability to perform faceted search, considering as facets - subimages/annotations, taxonomical classification (family, genus, species), and other attributes, such as geographic location, characteristics of habitat, and so on; 3) suggestions/replacements of similar meaning terms in the annotation or query (possibly, using an ontology); and 4) being able combine multiple search criteria, to express co-presence of subimages/annotations, along with other constraints, such as belonging to a family or genus. We describe this in detail in the following paragraph.

Using multiple subimage-annotation pairs in combined/image/text search. Almost all participants used the search interfaces to enter multiple subimages, [6], annotations, or subimage-annotation pairs in the image, text, and combined search interfaces, respectively. They expected SuperIDR to return images or species, which had all the subimages/annotations entered in the query.

Figure 6 shows examples of queries from three different participants. All queries have been made in the combined search interface. In Figure 6-A, P1 input an image in the image part of the query AND entered keywords in the text part of the query. Each line in the text part of the query is an annotation. In Figure 6-B, for the image part of the query, P3 input an image and marked the eye of the fish in the image. For the text part, P3 specified the family of the fish and two separate annotations. One of these annotations is "tear drop", which is associated with the marked region of

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[6]This was not allowed in SuperIDR, but repeated clicking of the image showed the participant's intent in doing so. We confirmed this in the final interview.
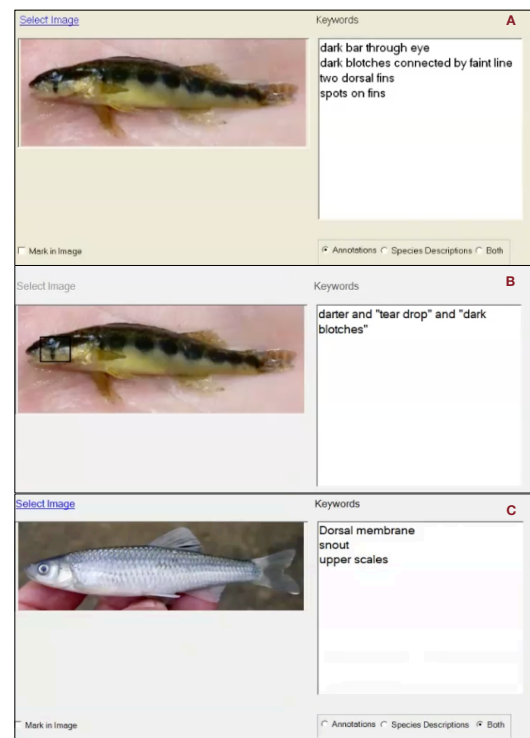

Figure 6: Examples of complex objects as queries. A) Query by P1; B) Query by P3; and 3) Query by P5

the image. In Figure 6-C, P5 entered a query similar to P1 in Figure 6-A, and entered multiple keywords and phrases in the text portion of the query. When asked about what they expected as results from SuperIDR, they said that they were looking for one or both of the following: 1) a species with all subimages/annotations on a single or on multiple images of the same species; or 2) an image with all subimages/annotations.

SuperIDR feedback. Most of the participants had internalized the use of subimages while identifying species and typically, did not use any reference (other than recalling from memory) while identifying species. However, they felt that marking subimages within images, using the comparison feature, the text search and the combined search features would all be useful while learning about species.

SuperIDR was well received among all the participants. All participants, except P3 (who was using someone else' laptop and hence had to uninstall SuperIDR), chose to keep SuperIDR installed at the end of the study, indicating that they would use it in the future for their fish identification tasks.

One of the goals of SuperIDR was to demonstrate that, combining SI capabilities with traditional DL services, supports scholarly tasks that involve subimages. This view of SuperIDR resonated with the participants of this study.

". . . It [SuperIDR] is pulling together different ways of get-

ting to information, ... So, not only do I have a taxonomy [and] dichotomous key, but it is also supported by images, many images that I have loaded in myself, that I can compare and contrast right there in the program [SuperIDR]. I can annotate the images, so I know that I am kind of looking somewhat into their future [use]. And it kind of just pulls all those tools together, more so than [pulling together] information. It gives me many ways of accessing the same information. The more ways you can come to that information, the better [it is]. Because it is always going to make you more confident about the decision that you are making." [P1 interview]

6. DISCUSSION

Because of the study design, we try not to generalize the results of the study (to the fisheries population). Although the study participants provided a varied representation of potential users of an SI-DL (undergraduate student, Master's thesis student, Ph.D. student, research assistant, teaching assistant, practitioner, laboratory technician), they were not numerious enough quantity to be considered a sample. Some important findings from this study include:

- We analyzed 940 subimages/annotations made by participants, to determine 13 repeated patterns/types of subimages/annotations made by the participants.
- We confirmed that searching on subimages and other information related to subimages is important, either from using SuperIDR or from recalling one's memory.
- Participants follow a top-down approach to fish identification and use subimages in fish identification, when the options are similar, to identify and analyze the similarities/differences and eliminate options.
- The context of subimages is important and might be described by co-presence of subimages and associated information.
- Participants felt that the bringing together of capabilities to work with subimages – i.e., annotation, text-based search, content-based search, browse – is helpful. Their main feedback was targeted towards improving search effectiveness. To improve search effectiveness, they suggested additions/improvements, including: 1) using faceted search to filter/view results based on subimages/annotations and other fields; 2) filtering results by the family or genus; 3) using an ontology to suggest similar meaning terms for the annotation or query.
- Five out of the six participants repeatedly made use of a combination of multiple subimages, associated annotations, and other species information, as a query and expected the tool to match against species with images with similar subimages and annotations. We consider such a combination query as a complex object query.
- We found that manual analysis of subimages is an important part of working with subimages. Even when SuperIDR returned the desired species as the top result, participants felt the need to confirm the species by analyzing all its images, its distinguishing characteristics, and other information, after they had successfully identified the species of an unknown specimen.

6.1 Recommendations for Digital Libraries with Superimposed Information

As result of our study, this section describe a set of recommendations for DL design with superimposed information.

6.1.1 Subdocuments as first-class digital objects

The preliminary user studies and the SuperIDR user studies showed that working with subdocuments (including subimages) is valuable, important, and sometimes, necessary, in scholarly tasks. When asked about the value of distinguishing characteristics (subimages and/or their combination) in fish identification, participant P2 in the qualitative user study, stated this in his response, :

"... it [parts of fish (images)] is pretty much the whole thing [referring to the fish identification process]. If they didn't have characteristics [parts or combination of parts of fish (images)], they'd all be the same fish..."

Subdocuments help us contextualize information and be specific about information to which we might refer. In many tasks, we organize them, search for them, browse through them, use them, and re-use them for various purposes. Thus, digital libraries with superimposed information should treat subdocuments as first-class objects, such that they have their own metadata, and might be indexed, searched, browsed, visualized, accessed, and used by others services and people as required. When subdocuments are treated as digital objects, they might be used in services in the same way as digital objects.

The formal metamodel helped abstract this idea of a subdocument. Through SuperIDR, we demonstrated how subimages might be organized (using complex objects of species), searched (text- and content-based retrieval), browsed (annotations/subimages in a species and subimages in search results), used (to some extent by the comparison feature).

6.1.2 Preserving and using context

At the beginning of this work, we referred to a subdocument as contextualized fine-grain information. A subdocument has several sources of contextual information, which can be important in working with the subdocument. Besides the original information context, other information associated with the subdocuments (directly or indirectly) can be useful. For example, the co-presence of multiple subimages/annotations, along with other information, such as family name, habitat, location, etc. are important in identifying a species. Bush wrote about using context to browse through a linked structure in a memex [2].

"... any item may be caused at will to select immediately and automatically another. This is the essential feature of the memex. The process of tying two items together is the important thing ..."

He goes on further to explain how items will be connected with each other and traversed. In an SI-DL, this notion of context and links is expanded by the presence of subdocuments and references to all linked information in multiple directions - base document — subdocument — superimposed document.

In the SI-DL metamodel, we represented context using links to other digital objects. For example, a subdocument maintains links to the base document using the base document handle and address, or a superimposed document has a structure, which defines the relationship among its constituent subdocuments (and other information), or the link between digital objects and their metadata.

In SuperIDR, the species complex digital object consisted of images, species description, subimages, annotations, links to similar species objects, and metadata for all the above.

A similar example for using context can be seen in the music domain while dealing with musical snippets and trying to identify the composition. The context of other snippets from the same composition, the particular musical style, the composer, and the time period of the composition will be useful in identifying the composition.

6.1.3 Multiple ways to describe, access, explore, and visualize superimposed information content

We saw the utility of multiple descriptions in accessing and retrieving information from SuperIDR. This is exemplified in this diary entry from P3:

"using combination of specimens and photos was the easiest way to search because could see body in jar and colors in life allowing for good search terms"

A straightforward search interface works for day-to-day information needs, as shown by the success of web search engines, such as Google, Yahoo, and Bing. However, when the task comprises of several activities, we need multiple ways to describe information needs.

We developed the combined search feature in SuperIDR trying to combine search on multiple types of information at the query and at the search results level. We used text- and content-based image retrieval as an example to illustrate this combination. Such combination of data and techniques was found to be important while dealing with subdocuments and complex objects, which might contain a variety of objects of heterogeneous types and formats. Having such a combination enables flexibility in forming a query, while being specific about the information that one is seeking. Consider if we had geographic locations as part of the fish species information. A complex object query, such as that outlined below, will help deliver effective results. Search for all species which have:
images with a part that look like subimage-query1
ASSOCIATED WITH
annotations containing text-query1
AND
images with a part that look like subimage-query2
ASSOCIATED WITH
annotations containing text-query2
AND
is of family consisting of text-query3
AND
is present in geographic locations geo-query1 OR geo-query2

The result of such a query might be species in the same family with similar subimages associated with annotations with similar keywords, which are present in a geographic location in the vicinity of the query location.

6.1.4 Support for manually working with and automatically processing subdocuments

People want to manually examine information, even if the software performs effectively and efficiently, such as by organizing information in a desired manner or by retrieving expected results. We saw this in the qualitative study, where participants, constantly felt the need to manually verify distinguishing characteristics of fishes by examining fish images even after correctly identifying the species of a fish. They wanted to be able to zoom into images, be able to browse through annotations and description of the species, be able to look at similar species and understand where the two species differ and where they are similar, etc. Such manual access to and exploration of content should be supported in an SI-DL.

In addition, an SI-DL should have services/functions to automatically process subimages and other superimposed information. For example, once a user has marked a subimage and described it using the annotation, "lines in the rear dorsal fin", image processing and machine learning techniques might be used to recommended other subimages with similar content.

7. CONCLUSION

We conducted a qualitative study to understand the use of subimages and of SuperIDR, a prototype digital library with superimposed information, in fish identification. We gained insights into characteristics of subimages and strategies and contexts of subimage use in species identification. Participants' use of SuperIDR to work with subimages suggest new and enhanced ways for digital libraries and information systems to support scholarly tasks that involve subdocuments. The findings gained from the aforementioned work led to design recommendations for a digital library with superimposed information.

Future work includes the development of improved subimage search and combined search capabilities, especially considering our findings from the use of a complex object as a query. Another direction for future research would be to leverage existing collections of subimages and associated annotations, such as those in Flickr[7] group pools to study the use of subimages in domains such as art history, architecture, and other biology domains. Finally, it would be valuable to comparison of various forms and functions of subdocuments and associated information, similar to the studies conducted by Marshall [9], by Winget [22], and as in this research.

8. ACKNOWLEDGMENTS

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[7]http://flickr.com

inputs. We are grateful to the American Fisheries Society for use of copyrighted material from Jenkins and Burkhead's *Freshwater Fishes of Virginia*.

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