An efficiency comparison between the BioGeomancer Workbench and manual methods in georeferencing natural history communities.

Lillian Chan

Abstract Worldwide natural history collections are a major source of spatial data associated with the time and place of specimen collection. Among many challenges hindering data use is the time consuming nature of geospatially processing specimen records (georeferencing). The goal of the BioGeomancer (BG) Workbench is to increase the quantity and quality of georeferenced specimen data by partially automating the process to reduce associated time. To quantify the efficiency of this automated tool, researchers from various U.S. natural history collections were asked to georeference two sets of location data using BioGeomancer and manual methods. Their results were timed and indicate a significant difference (df=293, p,<0.001) between BG times and manual times, distributed across all locality types. In addition, data shows that previous experience with manual methods results in significant variation in survey times (p=0.0384), though more experience does not necessarily correlate with more efficiency. Participants in the lower levels of experience performed faster than participants in the highest level. Even though BG was able to improve georeferencing rates, there is still need for continued work on the application in order to improve usability and processing speeds. Further Workbench development may result in greater time savings, permitting institutions previously hindered by time constraints to georeference their collections. This would allow the integration of all collection data worldwide into an online biodiversity library, freely accessible to researchers from a variety of disciplines.

Introduction

Natural history collections today, found in herbaria, universities and museums around the world, are the result of hundreds of years of specimen collection. In 1993, it was estimated that worldwide collections housed 2.5 billion specimens (Proctor 2004). Scientists have traditionally used these collections to do work in systematic biology, "the study of biological diversity and its origins" (What is systematics? 2007), and to store "type" specimens, which are representative examples of a particular species. Increasing interest in conservation research led scientists to look more closely at the temporal and spatial information associated with these specimens. Spatial information generally includes a locality (place) description of where a specimen was collected (e.g. "5 miles north of Berkeley"). Using these records today, researchers are able to extrapolate distribution patterns and trends over time (Shaffer *et al.* 1998) for use in conservation planning and threatened species identification.

This has become an important tool to document biological invasions, habitat loss/fragmentation, and climate change, all of which have significant impacts on global biodiversity (Suarez and Tsutsui 2003). Fisher and Shaffer (1996) used field sampling in conjunction with analysis of museum records to answer questions about amphibian declines in California's Great Central Valley. Reznick *et al.* (1994) looked at freshwater streams in Trinidad to show changes in fish communities coinciding with anthropogenic changes in habitat. They concluded that working with historical museum data has the potential for predicting consequences of land use patterns. After performing analysis on a large collection of georeferenced records for Neotropical mosquitoes, Foley *et. al.* (2008) concluded that "A worldwide database of georeferenced mosquito collection records would enable new insights into global patterns of mosquito biodiversity and survey history." All these studies show that museum specimens contribute to a well-documented history of species occurrence or composition and, at times, are the only record of a habitat that may no longer exist (Proctor 2004). The data extracted from such specimens are therefore of immense value.

However, data in their raw form are not necessarily useful in spatial analysis. In order to use these data, textual locality descriptions (e.g. Berkeley Post Office) must be converted into computer accessible geographic locations (e.g. latitude/longitude) in a process called georeferencing. Conversion of descriptions allows specimen localities to be mapped into applications such as a Geographic Information System (GIS). Manual georeferencing requires finding the coordinates associated with each locality by referencing digital or hardcopy maps. The advent of the Global Positioning System (GPS) allows current specimen collectors to incorporate these coordinates into their notes, eliminating the need to georeference data, however records created before the mid-1980s were likely to have been referenced by descriptions such as “5 mi E of Berkeley”. Of the estimated one billion specimens in collections worldwide, over 99% of them lack associated geographic coordinates (Garulnick *et al.* 2006), painting an incomplete spatial picture of past specimen distributions. This gap in available data points shows a need for the large scale georeferencing of natural history collections around the world.

The task of large scale georeferencing poses three significant challenges. The first challenge is to ensure the consistent and accurate interpretation of locality descriptions. This is difficult with the range of georeferencing methods used by institutions around the world. The data they produce are generally intended for individual collection management and often times are not processed with mass data communication in mind (Krishtalka and Humphrey 2000). With so much variation in the data, the task of comparative collection analysis is difficult, if not impossible. As a solution, Wieczorek *et al.* (2004) proposed a set of guidelines, called the “point-radius method”, for assigning coordinates and calculating error. This method has the georeferencer calculate the maximum distance from a set of coordinates where the specimen was likely found and take the area enclosed by that radius to contain all the possible points of collection. For example, if the processor sees “Berkeley” as the locality associated with a specimen, he/she would take the latitude and longitude of the center of “Berkeley” as the starting coordinates and draw a circle with a radius spanning from that center to the city's edge. The enclosed area would contain all possible points the specimen was collected. The “point-radius” technique improves the georeferencing process by eliminating some degree of subjectivity, introducing repeatability, and establishing a standard method by which to judge the ambiguity of a locality description.

The second challenge is making the data available to researchers. Specimen data is of no use to the scientific community if it is housed in the databases of separate institutions all over the world. And, even if all these databases were available online, searching for all the records associated with a given species would prove impossible. Through projects such as the Global

Biodiversity Informatics Facility (GBIF), disparate databases from institutions around the world will be connected within the GBIF portal and searchable online. Using standardized models for specimen metadata and the exchange of information, GBIF hopes to facilitate open and free access to biodiversity data worldwide.

The third significant challenge is the inefficiency of the georeferencing process. Participants in the MaNIS (Mammal Networked Information System) project were recorded to have a mean georeferencing rate of 16.6 localities per hour using digital maps (Wieczorek *et. al* 2004). The effort required to process entire collections of specimens is so great that many natural history collections cannot afford to georeference their data. Especially in recent years, many U.S. institutions have faced dwindling budgets with state cuts, falling visitor revenues, and reductions in private donations (Dalton 2003). The urgency of processing data for scientific research and the need to reduce costs associated with collection maintenance are two significant concerns that current georeferencing methods and applications are not suited to handle. A solution to this problem is to automate part or all of the process.

In response to the need for a more efficient and effective georeferencing method an international collaboration of natural history and geospatial experts has created an automated “georeferencing toolkit” aimed at improving the quality and quantity of data produced from the georeferencing process, called BioGeomancer (BG) (Garulnick *et al.* 2006). A key step is the development of the BioGeomancer Workbench (BG Workbench), an application that would automate georeferencing, allowing for batch processing of data (BioGeomancer Working Group 2005-2007) as opposed to manually processing data sets record by record. Converting place names into points is a function already accomplished by gazetteers, geographical directories used as a reference in georeferencing. BG is able to interpret not just place names but whole phrases, such as “2 miles south of Sacramento.” The Workbench is intended to increase average georeferencing rates “at least 5 fold” and provide a consistent method for defining uncertainty based on Wieczorek's “point-radius” method (BioGeomancer Working Group 2005-2007).

Since the BG Workbench is a recent application, no tests have been done on its performance beyond initial estimations of georeferencing rate gain. This study looks at the difference between manual versus Workbench aided georeferencing times for the seven locality types that the Workbench can currently interpret (Table 1). This was done through an online survey comparing the processing times of U.S. trained georeferencers with and without use of the Workbench. I predicted that (1) some localities will be inherently more difficult to georeference, (2) using manual methods will be five times slower than using BG, and (3) that greater prior experience with either method would not significantly decrease times for both groups.

Table 1. Common locality types that BioGeomancer can process.

#	Locality Type	Example
1	administrative unit (country, state, county, etc.)	Cook County
2	between features	Between Point Reyes and Inverness
3	feature	Springfield
4	offset from a feature at a heading	10 km N of Kuala Lumpur
5	orthogonal offsets from a feature	1 mi N, 3 mi W of Fairview
6	near a feature	Near Big Bay
7	PLSS descriptions, Township Range Section	T20S R1E Sec8

This information is important to the creators as well as the users of this application. If BG can increase rates substantially, there would be significant reductions in the time and cost barriers preventing many institutions from georeferencing their collections. In turn, more collections could include their data in global databases, such as GBIF, which would be freely available to researchers online. Instead of being limited to data from the few institutions with the resources to georeference their collections, scientists would have access to a vaster body of specimen data. Applications of global specimen data are numerous and include integration with data and research from other disciplines, such as geography, climatology, virology, agriculture and various others.

Methods

Data Collection Participants were recruited through email contact with various US natural history collections in January through March 2008. Contacts, consisting of curators, professors, students, and other georeferencing staff, either were attendees of past georeferencing workshops done through UC Berkeley's Museum of Vertebrate Zoology (MVZ) or are collaborators on MVZ georeferencing projects (e.g. HerpNET, ORNIS, MaNIS). Participation consisted of completing two online surveys comparing Workbench use with manual methods. Each survey contained seven questions, representing the seven most common locality types in US natural history collections (Table 1). There were five different variations of this seven-question survey in order to ensure rates are measuring the difficulty of a locality type and not the difficulty of a specific locality in the survey (e.g. administrative unit and not Alameda County). Surveys were assigned at random, according to a survey distribution system (Fig. 1).

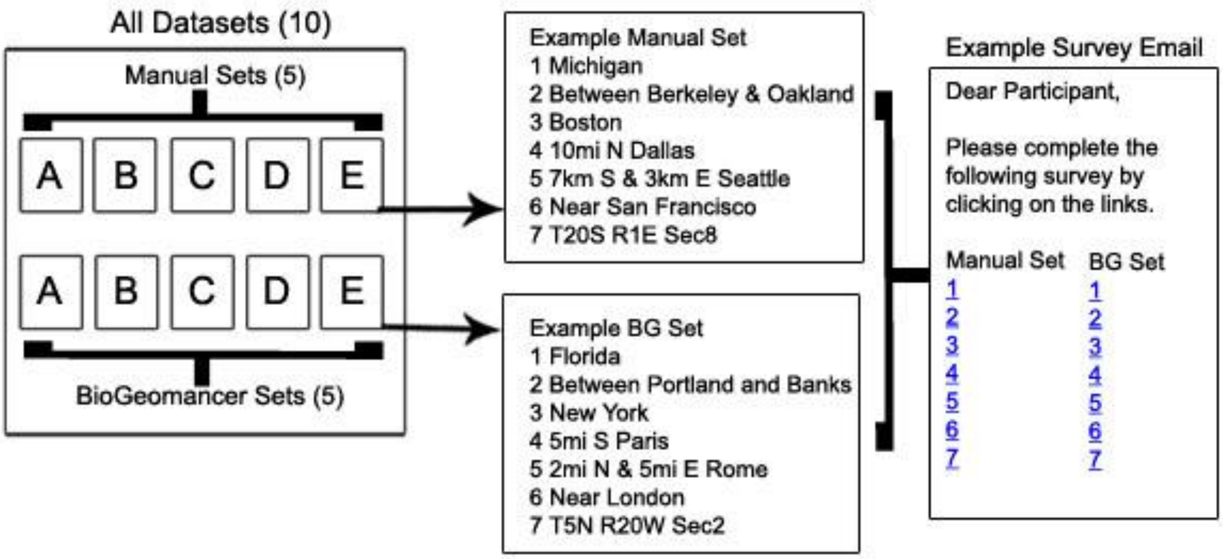
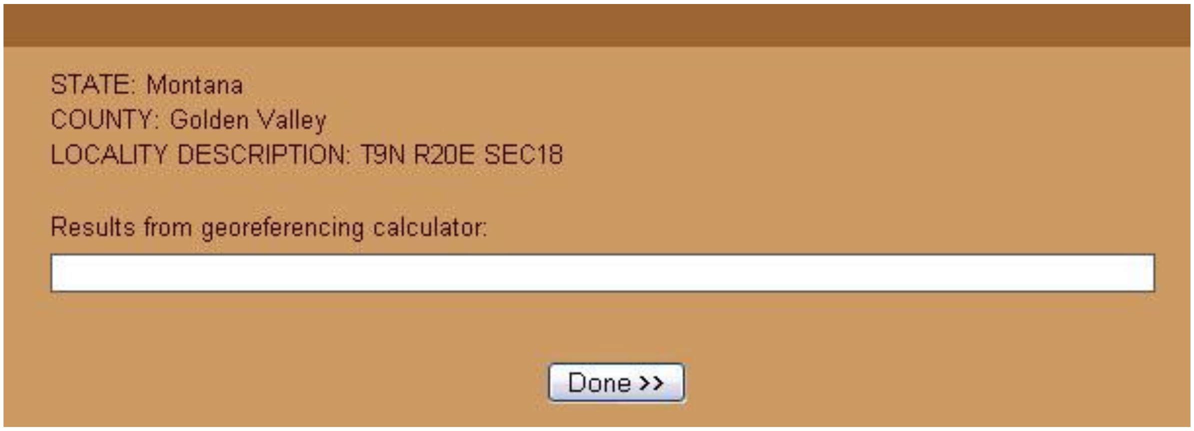


Figure 1. Dataset organization. There were ten datasets, five done using manual methods and five done using BioGeomancer. Within each dataset were seven online questions representing each of the common locality types that BioGeomancer can currently process (Table 1). Each participant was assigned one of the five dataset pairs (e.g. Manual Set E & BioGeomancer Set E), which they got as an email survey with links to the 14 questions.

Localities were situated in the US states of Montana and Nebraska. These states were chosen because they contain few collaborating institutions, therefore minimizing the possibility that a participant would be familiar with any particular locality due to previous georeferencing experience. This was done assuming that familiarity would give some participants an advantage when interpreting localities. The localities were chosen at random from maps of Montana and Nebraska. No one who participated in the survey reported familiarity with both Montana and Nebraska. One survey was done using manual tools of the user's choice (e.g. TopoZone, Google Earth, etc) and the Georeferencing Calculator (http://manisnet.org/gc.html), an online tool that walks through the steps of georeferencing according to the Georeferencing Guidelines (http://manisnet.org/GeorefGuide.html) used by the Museum of Vertebrate Zoology and affiliated institutions. The other survey was done using the BG Workbench (http://bg.berkeley.edu/latest/), which is already programmed to use the Georeferencing Guidelines. Participants input their coordinates and reported an approximate error calculation (done through the BG Workbench or the Georeferencing Calculator) in the surveys. Each of their responses was timed.

Survey pages were made through the Survey Monkey website (http://www.surveymonkey.com) (Fig. 2). Interested volunteers were asked to email me their affiliated institutions and which of the two states (Montana or Nebraska) they were most familiar with. Both surveys were from the same state but contained different localities (see Appendix B for a list of all localities used). For instance, if the manual survey had “Sacramento, California” as a location, the Workbench survey did not repeat this location, but it may have had a city of similar size found in California. This decreased the chance that a participant would be familiar with a location description before they processed it. I replied to volunteers with their unique survey links, a timeline for completion, and general guidelines for participation (see Appendix A for a sample reply email). The beginning of each survey presented a consent page in accordance with UC Berkeley’s Human Subjects Protocol guidelines and participants were given my contact information in case of questions/concerns.



STATE: Montana
COUNTY: Golden Valley
LOCALITY DESCRIPTION: T9N R20E SEC18

Results from georeferencing calculator:

Figure 2. Screenshot of an example survey page.

Data Analysis Data analysis was done through Microsoft Excel and the JMP statistical discovery software. Hypothesis (1) was tested using a one-way ANOVA followed by a Tukey-Kramer to see if there were significant differences between locality types (Table 1) when using either method. Hypothesis (2) was tested by first using a t-test between the two states (Montana and Nebraska) to see if being assigned one or the other region significantly affected times. If neither state nor locality was a significant source of variation, then data was separated into BioGeomancer and manual times and a paired t-test was used to analyze if BG significantly improved georeferencing times. Hypothesis (3) was also tested using an ANOVA followed by a Tukey-Kramer analysis to show whether experience level with manual methods or

BioGeomancer contributed to significant variation.

Results

117 emails were sent out, resulting in 96 replies. Of the 96 surveys sent, 42 were completed.

Locality Types (hypothesis 1) Average times for processing locality types ranged from 122-278 seconds for BG and 288-470 seconds for manual methods (Fig. 3). A one-way ANOVA between all the locality types did not indicate a significant variation in time for manual (F=1.04, df=293, p=0.393) or BG (F=0.919, df=293, p=0.481).

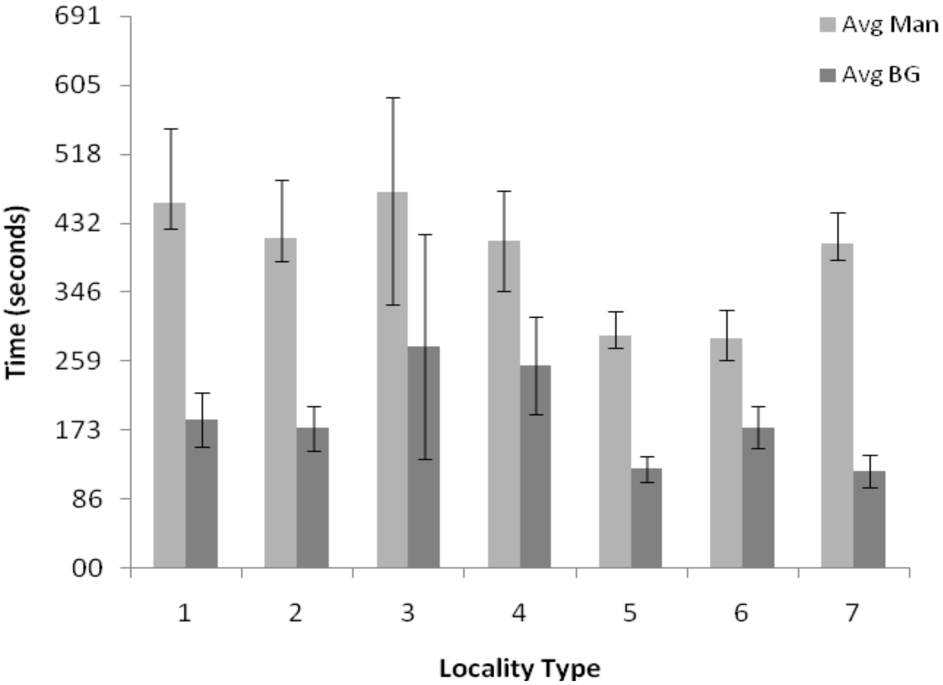


Figure 3. Average time (± S.E.) to complete the manual and BioGeomancer surveys for each of the seven common locality types (Table 1).

Manual versus BioGeomancer Efficiency (hypothesis 2) Average times for processing localities from Montana or Nebraska using BioGeomancer or manual methods ranged from 156-224 seconds for BG and 381-402 seconds for manual (Fig. 4).

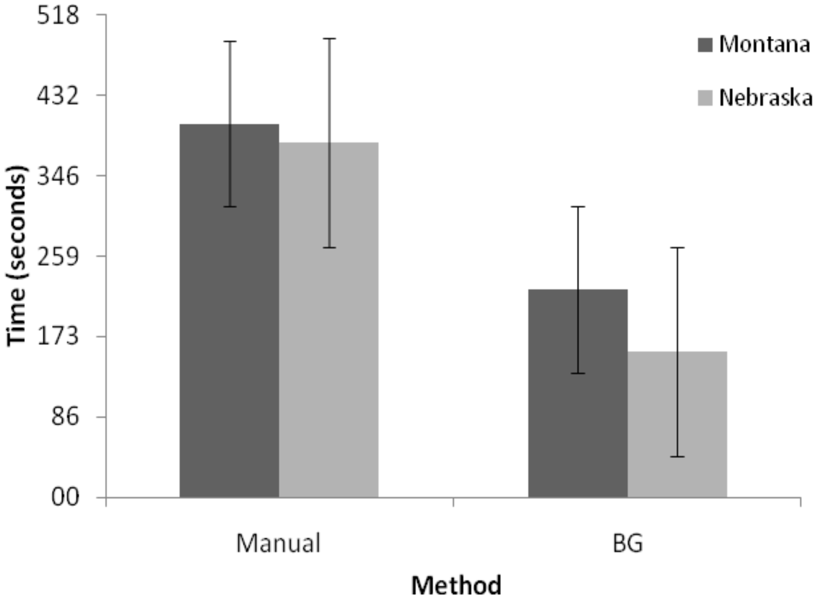


Figure 4. Average time (± S.E.) to complete the manual and BioGeomancer surveys for Montana and Nebraska.

A two tail t-test between Montana and Nebraska did not indicate a significant difference in times for the BG (t=1.38, df=155, p=0.0842) or manual (t=0.377, df=244, p=0.353) surveys. Since neither state nor locality type were significant influences on variation, data was sorted into BG and manual times. A paired t-test indicated a significant difference between the two methods (t=10.9, df=293, p<0.001).

Experience (hypothesis 3) Each survey contained questions asking participants to rate their experience with BG and manual methods on an ordinal scale (Table 2). Average times for processing localities using manual methods ranged from 289 seconds for level 2 users to 534 seconds for level 5 users (Fig. 5). Average times for processing localities using BG ranged from 109 seconds for level 3 users to 211 seconds for level 1 users (Fig. 6). For manual, there was a significant variation in times (F=2.38, df=293, p=0.0384), with the Tukey-Kramer indicating one to six months (level 2) of experience with manual methods as the fastest group (289 seconds) and greater than 3 years (level 5) as the slowest group (534 seconds). For BG, an ANOVA showed no significant variation in response times according to experience level (F=0.899, df=293, p=0.441).

Table 2. Experience levels. Users self-reported their level during each portion of the online survey.

Survey	Level 1	Level 2	Level 3	Level 4	Level 5
Manual	≤ 40 hours	1 month-6 months	6 months-1 year	1 year-3 years	> 3 years
BioGeomancer	< 20 hours	20-40 hours	40 hours- 100 hours	> 6 months	

Table 3. Participant experience levels. Number of participants within each experience level.

Manual	# Participants	BG	# Participants
Level 1	7	Level 1	27
Level 2	9	Level 2	4
Level 3	6	Level 3	4
Level 4	12	Level 4	7
Level 5	8		

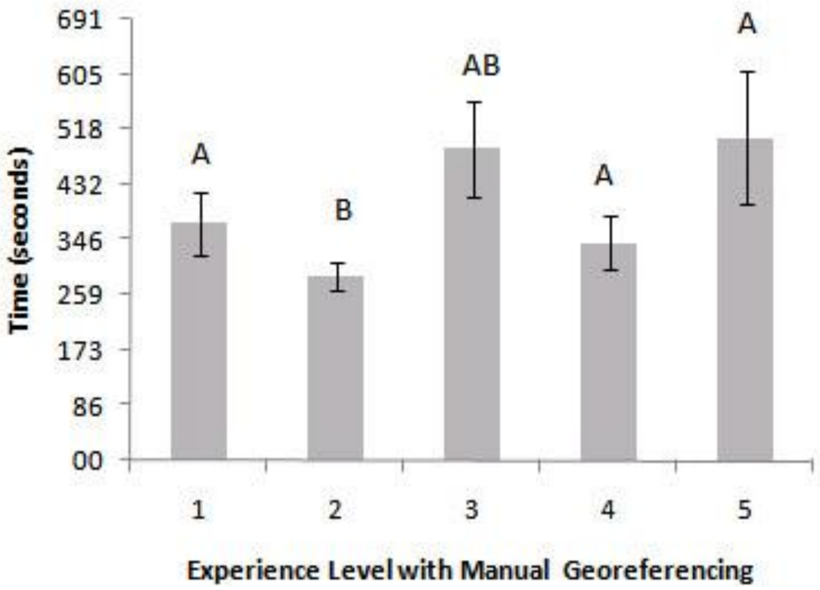


Figure 5. Average time (± S.E.) to complete the Manual surveys according to experience level. Letters indicate significant difference.

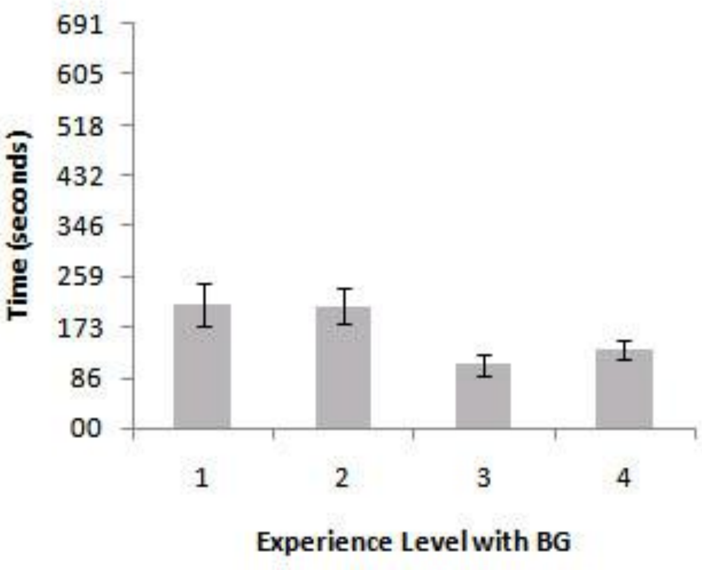


Figure 6. Average time (± S.E.) to complete the BG surveys according to experience level.

Discussion

Contrary to what was predicted, georeferencing times were not significantly affected by locality type (hypothesis 1). In designing the survey/email layout (Appendices A), there was concern about the first question (locality 1) being significantly slower due to a learning curve related to inexperience with using BioGeomancer and/or the Survey Monkey interface, however this was not the case as there was no significant variation between locality georeferencing times ($p>0.05$). This suggests that the BG interface is generally simple to learn and that survey instructions sufficiently prepared participants for the tasks ahead. The lack of variation could be attributed to the localities being similar in complexity. In addition, most users are familiar with manual methods; the highest number of participants had one to three years of manual georeferencing experience before participating in the study (Table 3). Since the surveys presented seven of the most common localities in US collections (Table 1), participants were likely to have experience working with all the types. With further releases of BG, the complexity of localities will increase to encompass the range of locality types commonly found in natural history collections. It will be necessary to ensure that increased complexity does not mean decreased georeferencing rate.

In addressing hypothesis 2, BG was significantly faster than manual methods ($p<0.01$), although on average, BG times were only about twice as fast as manual times, which is lower than the intended efficiency gain of "at least five fold" (BioGeomancer Working Group 2005-2007). This indicates that more development needs to be done on BG in order to further improve efficiency. In addition, due to participant time constraints, this study did not address the accuracy of BG results. In the context of georeferencing, accuracy means correctly positioning locality points according to the locality description and correctly entering data (Yesson *et al.* 2007). An accuracy test of the first BG release, with significantly less features than the latest version, indicated that efficiency gains were negated by low percentages of "correct" georeferences. Of the three data sets tested by Murphy *et al.* (2004), BG correctly georeferenced 29% of one set and 45% of the other. In addition, there was efficiency lost to post-processing of the data to check for errors. They also found that BG needed precise formatting in order to correctly interpret some localities. An example cited was the inability of the application to interpret ft., mi., and km., abbreviations which have since been added to BG capabilities. A similar study should be done with the latest version of BG to show whether further development has improved accuracy, however the question of "correctness" is complicated as there is no standard georeferencing protocol for all institutions. It might be useful to look at the accuracy of BG when compared to manual processing protocols from various institutions/projects.

In looking at experience levels (hypothesis 3), there was significant variation in the manual georeferencing times (p=0.0384), but not for BG times (p=0.441). For BG, the group with 40-100 hours of experience seemed to georeference the fastest. For manual, level 2 (1-6 months) georeferenced the fastest, while level 5 (>3 years) georeferenced the slowest. A possible explanation for the loss of efficiency with experience is that museum staff who have high levels of background will generally not be georeferencing on a daily basis. They are likely to be the professors, academics, and curators who supervise and train others to do the museum's large scale georeferencing projects. Participants with less georeferencing experience are more likely to have had recent practice georeferencing and training. In addition, new georeferencing tools and/or protocol may give newer georeferencers an advantage. For example, newer georeferencers may be taught using tools such as Google Earth, whereas more experienced goereferencers may have been trained using paper maps and other less internet oriented tools. As for BG, it has gone through significant development over the last couple years, so prior knowledge of the interface may not have been advantageous for participants. In addition, some of the less experienced levels may contain younger georeferencers (e.g. university students) who may be more familiar with the Google Maps interface used as the platform for BioGeomancer Workbench development.

The BG Workbench was released in beta form in spring 2007 to a select audience consisting of institutions that were already working on the BG project. It extends the concept of the gazetteer, a geographical directory that converts place names into points, to interpret the grammar that biologists commonly use in the field, including phrases, distances, and cardinal direction (BioGeomancer Working Group 2005-2007). The eventual goal of the BG workbench is to allow users the ability to batch georeference localities by uploading a text file with all the data to be processed to the BG server as opposed to entering each locality description individually. With further testing and refining of the accuracy and reliability in processing individual localities with BG, there would be minimal post-processing of batch georeferenced localities. This would theoretically eliminate a large amount of time spent manually georeferencing localities. This efficiency study serves as an initial test of the Workbench on a large user pool. As the Workbench acquires more users and, in turn, generates more feedback, modifications will continuously be made. One important modification is the eventual inclusion of all the most common locality types found in natural history collections around the world. At present, BG can only interpret seven of these locality types from US collections. With each modification, it will be useful to revise and deploy this efficiency survey again to see the effects of any modifications on georeferencing rates. If one day the Workbench achieves the goal of significantly improving georeferencing rates over manual methods, then testing of the batch processing function will likely follow.

In addition, efficiency research on the Workbench can be combined with cost analysis to create a cost function for museums hoping to use BG to georeference their collections. With enough participants, an efficiency study could establish the average rate of georeferencing particular localities using BioGeomancer and georeferencing staff with varying experience levels. A given institution could then look at the experience level of their staff along with the ratio of each particular locality in their collection and use the average rates to calculate an expected time frame for completion. Then, using individual institutional data on pay rates and the calculated time frame, a collection manager could estimate the cost to their institution of georeferencing their entire collection. This would be invaluable in budgeting and/or grant writing.

As museum collection data transition over to the digital realm, there are problems inherent to the conversion. The point-radius method (Wieczorek *et. al* 2004) and Global Biodiversity Informatics Facility (GBIF) represent potential solutions to variation between georeferencing methods and data availability, respectively. The implementation of an automated georeferencing system such as BioGeomancer (BG) to improve processing rates would complete the steps needed for many institutions which were previously impeded by time, manpower, and funding, to contribute their data collections to a worldwide portal of natural history collections such as GBIF. The availability of larger amounts of historical data would open the possibility for research in climatology, geology, geography, biology, social sciences, and more. A biogeographer could map evolution over time. A biologist could research migration patterns. Researchers could predict the impacts of global climate change on biodiversity and the spread of agricultural pests (Lowe 2004).

Even though BioGeomancer did not meet the "five fold" goal of improving georeferencing rates over manual methods, the creation and testing of an automated georeferencing tool is one step closer to the digitization of all natural history collection data. Through global portals this digital information will be accessed and combined by researchers in previously disparate disciplines. Overlaying such varied data will likely produce interesting results, furthering our understanding of this world and how changes, such as global warming and human consumption, might affect the future.

Acknowledgements

This study was funded by a National Science Foundation (NSF) Research Experience for Undergraduates (REU) grant and completed under an Office for the Protection of Human Subjects approved exemption (CPHS Protocol #2007-11-60). I would like to acknowledge Carol Spencer, John Wieczorek, and Heather Constable at the UC Berkeley Museum of Vertebrate Zoology for giving me the opportunity to pursue this project and my ES196 instructors, Peter Oboyski, Gabrielle Wong-Parodi, Shelly Cole, and Shannon May, as well as the entire ES class of 2008 for being there to support and guide my research. Lastly, my work would not have been possible without the 42 wonderful georeferencers who participated in this study and the various friends who kept me going in times of doubt.

BioGeomancer Working Group. BioGeomancer. 2005-2007. http://www.biogeomancer.org/about.htm, accessed 2 February 2008.

Dalton, R. 2003. Natural history collections in crisis as funding is slashed. Nature 423:575.

Fisher, R. and Shaffer, H.B. 1996. The decline of amphibians in California's Great Central Valley. Conservation Biology 5:1387-1397.

Foley, D.H., A.L. Weitzman, S.E. Miller, M.E. Faran, L.M. Rueda, and R.C. Wilkerson. 2008. The value of georeferenced collection records for predicting patterns of mosquito species richness and endemism in the Neotropics. Ecological Entomology 33: 12-23.

Guralnick R.P., J. Wieczorek, R. Beaman, and R.J. Hijmans. 2006. BioGeomancer: Automated georeferencing to map the world's biodiversity data. PLoS biology 4:1908-1909.

Krishtalka, L. and P.S. Humphrey. 2000. Can natural history museums capture the future? Bioscience 50:611-617.

Lowe, J. 2004. Bone Rooms, Bird Bodies, and Biodiversity Informatics. Geospatial Solutions. http://www.geospatial-solutions.com/geospatialsolutions/article/articleDetail.jsp?id=90069, accessed May 11, 2008.

Murphy, P.C., R.P. Garulnick, R. Glaubitz, D. Neufeld, and J.A. Ryan. 2004. Georeferencing of museum collections: A review of problems and automated tools, and the methodology developed by the Mountain Plains Spatio-Temporal Database-Informatics Initiative (Mapstedi). Phyloinformatics 3:1-29.

Proctor, E.J. 2004. “Reducing variation in georeferenced locality descriptions.” Master of Arts thesis, San Francisco State University. 201 pp.

Reznick, D., R.J. Baxter, and J. Endler. 1994. Long-term studies of tropical stream fish communities: the use of field notes and museum collections to reconstruct communities of the past. American Zoologist 34:452-462.

Shaffer, H.B., R. Fisher, and C. Davidson. 1998. The role of natural history collections in documenting species declines. Trends in ecology evolution 13:27-30.

What is systematics? Society of Systematic Biologists. 2007. http://systbiol.org/, accessed 11 May 2008.

Suarez, A.V. and N.D. Tsutsui. 2004. The value of museum collections for research and society. Bioscience 54:66-74.

Wieczorek, J, Q. Guo, and R. Hijmans. 2004. The point-radius method for georeferencing locality descriptions and calculating associated uncertainty. International journal of geographical information science 18:745-767.

Yesson, C., P.W. Brewer, T. Sutton, N. Caithness, J.S. Pahwa, M. Burgess, W.A. Gray, R.J. White, A.C. Jones, F.A. Bisby, and A. Culham. 2007. How Global is the Global Biodiversity Information Facility? PLoS ONE. 11:1-10.

Appendix A:
Example Survey Email

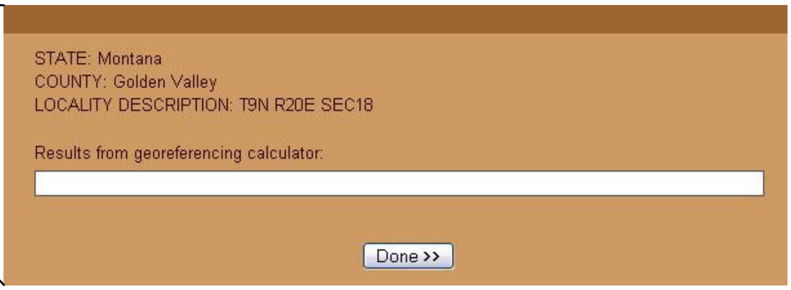
Hi [insert participant name],

Thank you for agreeing to participate in the BioGeomancer Geoferencing Efficiency Study. Below you will find two sets of links. The first set contains locality descriptions that should be georeferenced using manual methods of your choosing and the second set contains descriptions that should be georeferenced using BioGeomancer. More detailed instructions for doing each set can be found in the first couple links for each set. There is also a Frequently Asked Questions page to help you (http://herpnet.org/Gazetteer/bgfaq.html).

DO NOT click on the survey links (Manual 1-7 and BG 1-7) until you have read the directions and are READY to start the survey. Your times will be recorded as soon as you click on the links to each question.

Please read the following consent page before proceeding with the survey.

Survey:
Manual Set:
Manual Instructions
  Manual 1(click)
  Manual 2
  Manual 3
  Manual 4
  Manual 5
  Manual 6
  Manual 7
  Manual 8



STATE: Montana
COUNTY: Golden Valley
LOCALITY DESCRIPTION: T9N R20E SEC18

Results from georeferencing calculator:

BG Set:
BG Instructions
  BG 1
  BG 2
  BG 3
  BG 4
  BG 5
  BG 6
  BG 7
  BG 8

Please complete both sets of questions for the survey by 24 March 2008 and feel free to contact me (chan@berkeley.edu) if you have any questions/concerns before, during, or after the survey.

Sincerely,
Lillian Chan

Appendix B:
All Question Used in Surveys

Montana Sets	**Nebraska Sets**
Manual A	*Manual A*
Missoula	Bassett
Near Three Forks	Near Battle Creek (city)
Powder River County	Adams County
Between Ekalaka and Baker	Between Nelson and Red Cloud
6mi E of Livingston	6mi E of Gretna
8mi W, 2mi N of Hardin	8mi W, 2mi N of Cozad
T31N R45E SEC15	T24N R32W SEC12
Manual B	*Manual B*
Columbia Falls (city)	Albion
Near Malta	Near Elgin
Yellowstone County	Clay County
Between Chester and Galata	Between Stanton and Madison
7mi S of Sidney	7mi S of Hebron
2mi S, 8mi W of Laurel	2mi S, 8mi W of Minatare
T19N R18W SEC29	T12N R2W SEC27
Manual C	*Manual C*
Lewistown	Creighton
Near White Sulfur Springs (city)	Near Hartington
Ravalli County	Madison County
Between Wibaux and Hodges	Between Taylor and Burwell
1mi E of Harlowton	1mi E of Holdrege
6mi E, 2mi N of Fort Benton (city)	6mi E, 2mi N of Blue Hill
T9N R20E SEC18	T30N R46W SEC3
Manual D	*Manual D*
Forsyth	Alma
Near Thompson Falls (city)	Near Ainsworth
Pondera County	Wheeler County
Between Havre and Chinook	Between Beatrice and Wilbur
9mi N of Cut Bank	9mi N of Fort Calhoun
8mi W, 5mi N of Glendive	8mi W, 5mi N of Osceola
T24N R26E SEC5	T14N R19W SEC31
Manual E	*Manual E*
Conrad	Chappell
Near Miles City	Near Neligh
Wibaux County	Blaine County
Between Philipsburg and Anaconda	Between Auburn and Falls City
1mi S of Plentywood	1mi S of Bloomfield
9mi N, 4mi W of Whitefish	9mi N, 4mi W of Broken Bow

T5S R26E SEC30	T11N R40W SEC2
BG A	*BG A*
Great Falls (city)	Bennington
Near Libby	Near Crofton
Chouteau County	Logan County
between Kalispell and Quintonkon	Between Tekamah and Breslau
6mi E of Red Lodge (city)	6 mi E of Indianola
8mi W, 2mi N of Columbia Falls (city)	8mi W, 2mi N of Lamar
T26N R50E SEC9	T29N R24W SEC28
BG B	*BG B*
Kershaw	Benkelman
Near Ronan	Near Milford
Gallatin County	Cuming County
between Bozeman and Clasoil	Between Papillion and Elyria
7mi S of Polson	7mi S of David City
2mi S, 8mi W of Dillon	2mi S, 8mi W of Newman Grove
T14N R18W SEC13	T7N R6W SEC24
BG C	*BG C*
Belgrade	Curtis
Near Troy	Near Loup City
Missoula County	Pierce County
between Ferdig and Buelow	Between Gothenburg and Ogallala
1mi E of Scobey	1mi E of Chadron
6mi E, 2mi N of Hamilton	6mi E, 2mi N of Clay Center (city)
T13N R26E SEC10	T35N R48W SEC25
BG D	*BG D*
Roundup	Bayard
Near Townsend	Near Arapahoe
Musselshell County	Saline County
between Rothiemay and Ryegate	Between Cornlea and Tarnov
9mi N of Big Timber	9mi N of Long Pine
8mi W, 5mi N of Havre	8mi W, 5mi N of Oshkosh
T15N R14E SEC26	T16N R15W SEC10
BG E	*BG E*
Wolf Point (city)	Deshler
Near Shelby	Near Beaver City
Broadwater County	Arthur County
Between Monida and Bannack	Between Burchard and Steinauer
1mi S of Conrad	1 mi S of Blue Springs (city)
9mi N, 4mi W of Colstrip	9mi N, 4mi W of Minden
T2S R21E SEC	T8N R35W SEC4