CPSC 645/VIZA 675 Geometric Modeling
Course Project

A major portion of the grade in this course will be determined by a course project. This describes some of the key information about the course project.

Important Due Dates
Tuesday, October 5, 12:45 p.m. – Project proposal
Thursday, October 28, 12:45 p.m. – First update report
Thursday, November 18, 12:45 p.m. – Second update report
Tuesday, December 7, 12:45 p.m. OR
Wednesday, December 15, 8:00 a.m. – Final Project Presentation
Wednesday, December 15, 8:00 a.m. – Final report

Topic
The choice of topic is up to you. The only specific requirement is that it should relate to modeling and have a strong geometric component. It does *not* have to directly involve topics that we cover in class. Since you will spend a significant amount of time working on this project, you should choose something both interesting and challenging to you. This is meant to be open-ended, and allow you to pursue almost any related topic.

Integration with Research: You are strongly encouraged to pick a topic that ties in closely with your research work; however, your topic should not be the *exact* same thing you are being paid for doing as a GAR. It can be really close, though – e.g. if your GAR work is focused on modeling neurons, you could try to develop a new geometric representation for neuron geometry, or a model of one neuron part not currently modeled. This project might give you a chance, for example, to initially explore a potential thesis topic. Or, you might use it as a chance to explore some idea you came up with while performing research but haven't been able to work on otherwise.

Originality: Your project does not have to be a completely new idea, but the originality of your work will play a part in your grade. An example of less original work would be implementing a method or algorithm described in a paper. More original work would include merging topics found in several papers, or exploring a completely new topic.

Possible Topics: At the end of this document is a list of possible topics. This list is meant to give you ideas, *not* to be a comprehensive list of topics. If you are uncertain whether your topic would be appropriate, please check with the instructors.

Grading
- 10% Literature Review (as part of project proposal)
- 20% Project Proposal, Updates, and Final Report (completeness)
- 10% Final Oral Presentation
- 60% Originality and Quality of Work

Reports

Four reports will be required. The first will be a project proposal, and this will include a literature review that will receive a separate grade. Two progress reports will be required. You will be expected to have made some progress on your project by each of these dates. A final report will be due at the time scheduled for the final exam in the class. The format of these reports is described below. Please be sure to include all the information asked for below. Grades on the reports will be based on how well you address each of the items asked for – not on the specific accomplishments on the project overall.

Web Page

All reports will be submitted via a project web page that you are to put together. Before the first report is due, you are to submit via Canvas the URL of a web site that will be used as your project web page. Your web page should be accessible from the time the proposal is due and should remain active at least through the time final grades are posted. The page will be shared with other students in the class, so realize that this is a public presentation of your work. The project web page should include links to each of the reports. Your page may be as simple as links to separate documents for each of the individual reports, or you may wish to design the entire page as a more comprehensive project page. However it is constructed, the distinction between the various reports should be clear. Your reports should not be edited after the time they are due, and you should leave them accessible for the entire course. If you have a report that you feel should not be public (e.g. if discussing a personal reason for lack of progress, or progress that will be part of a publication that you do not want to make public ahead of time), you may instead email the report(s) to the instructors by the due date.

Project Proposal

Your project proposal will contain two parts: an overall project proposal and a literature review; the literature review will receive a separate grade. The proposal portion (excluding the literature review) should be of a length no more than about two printed pages. Your proposal should include the following items:

- *Title* for project
- Your *Name*
- *Summary* – You should summarize the following items:
    - *Description of Problem* – What is it you are trying to solve/address?
    - *Importance of Problem* – Why is this an important/interesting problem?
    - *Your Proposal* – What is it you plan to do?
    - *Originality* – What is new (if anything) about the work you are proposing?
    - *Relationship to Geometric Modeling (optional)* – If it is not obvious how your topic relates to geometric modeling, you should explain it here.
- *List of Goals* – You should give a list of intermediate and final goals, specifying what you hope to accomplish by each of the following due dates (the two update points and the final point). Your goals should be as specific as possible. You are

welcome to include more intermediate goals, as well as additional goals that you might achieve if your work proceeds better than expected.

Literature Review (turned in along with Project Proposal)
The literature review should be included either as a section of the proposal, or as a separate document.

Your literature review should give a thorough overview of the prior and related work for the topic you are proposing to work on. It is expected that this will be a document the equivalent of approximately 5 pages in length, not counting references. While there is not a set number of references required, approximately 25 is likely to be common; it would be very surprising to have just 10, and 50 is likely more than needed. The number may vary based on how well-researched the topic is, how many different areas are related, and so forth.

Note that a literature review should not just be a collection of citations. The idea of a literature review is to:

a) Describe the overall topic and related topics, demonstrating how these are related to each other. Someone reading the literature review should be able to learn an overview of the topic from your review.
b) Describe the most important prior work in the field, including the main seminal papers in the area. After reading your literature review someone should be able to identify the most important previous papers related to that topic.
c) Describe the most recent publications and the directions of recent and current work in the field. The review should include an up-to-date discussion of recent developments in the field.

In particular, you should be able to write at least 2-3 sentences about each reference, stating what the important results are from it and how it fits into the overall picture. If you do not have this much to say, then either the reference is not significant enough to include, or you should do more in your writing to describe its place in the field. Also, the review should be a narrative, putting prior work into the appropriate context – it should not just be an annotated bibliography like a bulleted list of papers and descriptions.

Project Updates
Each progress report should be the equivalent of no more than about 3 printed pages; it is unlikely that a complete update would be less than the equivalent of 1 printed page. Remember that the report does not need to be a separate document, and may be incorporated into the web page. The report should include the following items:

- Your *Name* and the project *Title* (if as a separate document from the web page)
- *Summary of Work to Date* – You should state exactly what work you've completed to this point. Summarize any results you've achieved, including unexpected complications that have come up. Feel free to include tables or figures if you feel they would help.

- *Analysis of Work* – You should refer to the intermediate goals listed on your proposal or previous update. State whether these goals have been met. If they have not been met, explain why not.
- *Plan for Completion* – You should update your original plan, including your intermediate and final goals, to describe how you plan to complete your project on time. If you are on schedule so far, state whether you anticipate remaining on schedule for the rest of the project. If you are behind schedule, describe what you will do to catch up. If you have encountered unexpected difficulties and feel that your overall goals will need to be modified, describe what your new goals will be and justify why you need to change them.

Be honest in your description. The update is primarily meant to help *you*, and your grade on the report is not related to what you've accomplished. If you have accomplished little, I would expect less writing in the summary section and more in the plan section. If you are on schedule, I would expect more in the summary and less in the plan. You should not try to change your project at this point unless you've encountered significant unexpected problems with your work to date and have discussed these with the instructor. "I haven't spent much time on it and don't think I can finish" is not a valid reason for changing your project at this point!

Final Report

The grade on the *report* will only be on the completeness of the report itself (rather than what you accomplished). Even though this is not a large portion of your project grade, remember that it is also a key part of our evaluation of your work. So, it is very important that you clearly and specifically state what you have accomplished – if you did great work but we couldn't tell, you might receive a low grade overall. Finally, be concise. I do not want to see code listings (except maybe brief sections to demonstrate a point), and I don't need to know every detail of the process you went through. The final project report can be the webpage itself, or can be made available via a link on your web page.

You are encouraged to format your report as an HTML document to facilitate including relevant links to supporting information or code, pictures, video clips, etc. For whatever you submit, please make sure that no special plugins or libraries are needed to view your report.

Your final report should be well-organized and should contain the following information, though the format and organization is totally up to you:

- Your *Name* and project *Title* (if a standalone report, not integrated on the webpage)
- *Problem summary* – Briefly summarize the problem you are dealing with and why it is important. This is likely to be a modification of your proposal.
- *Previous work* – You should summarize and reference the relevant previous work in this area which you are aware of or which you consulted. Remember to cite

any libraries or utilities you used in creating your program. This may be a condensed version of your literature review.

- *Description of work* – Describe the work you performed. Include any major "dead end" paths of research and why they failed, and any major challenges you encountered. Do not go into every detail of everything you've done.
- *Results* – Describe exactly what was achieved. State exactly what you have accomplished, giving concrete information (e.g. by charts, pictures, video, etc.) about what has been done.
- *Analysis of work* – You should analyze the work done from the standpoint of how successful you were on the project. You should include the following information:
    - *New results* – What have you accomplished that is new, if anything? If you claim novel contributions, you should have thoroughly researched the previous work on the problem.
    - *Meeting goals* – How well did you meet the original goals you set out? If you did not meet these goals, why not?
    - *Future work* – If you (or someone else) were to continue working in this area, what would be the next steps in both the short and long term? Do you feel that more work on this topic would yield interesting research results?

Final Oral Presentation

You will present your work in an oral presentation. We expect to split the presentations between the time scheduled for the final exam and the final classes. However, the class agrees on a different presentation time, that may also be used. Final presentations should be about 10 minutes each (including allowing about 8 minutes for presentation and 2 minutes for questions). More details on specific times, order of presentation, details expected to be included, etc. will be given later in the semester.

Each member of the class will be expected to grade other students' presentation. These will be combined with the instructors' evaluation to determine the score for the presentation itself.

Like the reports, although the presentation itself will receive a grade, even more important is that it will be a major source for helping the instructors understand your work, and thus determine you overall grade. It is important to do a good job with the presentation (and the final report) so that your "quality" grade will be reflective of the work you have done.

Quality and Originality of Work

A majority of the project grade will be based on the instructors' evaluation of the quality and originality of the work. This will of course be somewhat subjective, but the areas we will use for evaluation will include:

- Originality

- Implementation
- Testing/Measurement
- Analysis
- Comparison

Note that less original work will have higher expectations for the thoroughness of implementation and analysis. An "ideal" project would explore an original idea, generate a new method that is implemented well and robust in performance, have the results of that implementation analyzed both experimentally (on a wide variety of tests) and analytically, and have the method compared both experimentally and analytically to other similar or alternative approaches. A "poor" project would produce a buggy attempt to implement a known algorithm that is tested on only one or two cases.

Use of Others' Work and Implementation Expectations

You are expected to implement the work of the project yourself, and all projects are expected to include a significant amount of coding. The exact level, however, may vary depending on the nature of the project (e.g. one requiring greater theoretical analysis may have less implementation).

You must be extremely clear in your presentation and documents about what you may have used from others, and what you might have done yourself. In general, you are expected to implement your own code for all key parts of the project – the method should be one you implement. You must **clearly** cite any external code or other sources used in your project.

On the other hand, it is reasonable to use outside sources for things like:

- Standard libraries to support basic computations (e.g. a library to perform linear algebra operations)
- Libraries or programs that are used to demonstrate results/application. For example, you might incorporate your new work into a larger system that was not developed by you, or use an external program to plot curves, make charts/graphs, etc.
- Implementations of alternative algorithms that you compare to (e.g. if you are comparing to prior work, you may use other people's implementations of those methods.

Ideas for Project Topics

The following pages are **not** meant to be a comprehensive list of topics, but rather to be a source of ideas. To get other ideas, you might consider looking through journals and conference proceedings such as the ones listed below (these are just a few of the publications that might be good sources for ideas):

Conferences:

Note: most recent conferences publish their proceedings as an issue of a journal.
Proceedings of ACM Symposium on Solid and Physical Modeling (journal: *CAD*)
Proceedings of Geometric Modeling and Processing (journal: *CAGD*)
Proceedings of Symposium on Geometry Processing (journal: *CGF*)
Proceedings of Shape Modeling International (journal: *C&G*)
Proceedings of SIGGRAPH (journal: *TOG*)
Proceedings of Eurographics (journal: *CGF*)
Proceedings of Pacific Graphics (journal: *CGF*)
Proceedings of IEEE Visualization (journal: *TVCG*)

Journals:

Computer Aided Design (CAD)
Computer Aided Geometric Design (CAGD)
Computer Graphics Forum (CGF)
Computers & Graphics (C&G)
ACM Transactions on Graphics (TOG)
IEEE Transactions on Visualization and Computer Graphics (TVCG)
ACM Transactions on Spatial Algorithms and Systems (TSAS)
International Journal of Computational Geometry and Applications (CG&A)
Graphical Models
IEEE Transactions on Robotics and Automation
Journal of Computing and Information Sciences in Engineering

Some possible project ideas

Here are a few slightly more specific project ideas. Again, you are encouraged to choose a topic that will fit well with your graduate research work.

- Implicit modeling of shapes by neural networks
  - Efficient learning of shape models
  - Learning of classes of shapes
  - Performing operations with neural implicit models
- Surface reconstruction
  - Registration of scans of point clouds
  - Sampling and simplification of point clouds
  - Denoising and smoothing of mesh surfaces
  - Hole-filling of scanned data
  - Point cloud triangulation
  - Mesh simplification
  - Radial basis functions, Poisson surface reconstruction, etc.
  - Generation from interior point data (e.g. level sets)
- Highly accurate or robust computations
  - Exact intersections of curves/surfaces
  - Degeneracy analysis
  - Representations and operations with non-manifold data
  - Storage/memory analysis of exact representations of objects
  - Consistent rounding methods
  - Fuzzy object representations
- Modeling deformations or changes in objects' geometry/topology
  - From natural physical processes (e.g. fracture, pressure, wind/water, etc.)
  - In response to external forces (user-defined or collision-defined)
  - Free-form surface deformation maintaining model properties/behavior
- Modeling of difficult-to-model objects
  - Objects with fine geometric detail/detail at many scales
  - Objects with high topological complexity
  - Things with difficult to define boundaries (e.g. clouds, fracture patterns)
  - Modeling biological structures
- Conversion between various modeling paradigms
  - Segmentation of objects from volume data
  - Medial axis extraction
  - Standards for data transfer
  - Storing features and functionality with data
- Motion of objects
  - Envelopes of sweep paths
  - Tool path generation
  - Determining physical properties (mass, moments of inertia)
  - Collision detection
  - Motion planning

- Rendering of models
    - Faster rendering (generating levels-of-detail, triangle stripping, etc.)
    - Exploiting structured data (e.g. terrain meshes)
    - Rendering volumetric information
- Mesh generation for an object
    - Surface meshing
    - Finite element generation
    - Generation of grids or other structures to support computation across geometric objects
- Analysis of model properties in various formats (e.g. moments of inertia, stress, heat, etc.)
- User Interface issues for model creation/modification
- Procedural model generation
- Mapping/parameterizing on surfaces
- Variational methods
    - For shape modeling
    - For packing and coverage on a surface
- Structural reconstruction from 3D scans
    - Of buildings/rooms
    - Of small/thin objects (e.g. trees)
    - Of 3D objects when information may be hidden
- Shape fitting with curves and surfaces
- Shape description for shape matching and retrieval
- Sketch-based shape modeling
- Applications of Centroidal Voronoi Tessellation
- Detecting symmetry in geometric models
- Mean Value Coordinates – theory and application