MAE 255 Winter 2013

Computer Aided Design & Manufacturing

Rida T. Farouki, office: 2048 Bainer
phone: 752–1779, e–mail: farouki@ucdavis.edu

lectures: Tues. & Thurs. 10:00–11:50 am in 203 Wellman
office hours: Tues. 2:00–4:00 pm in 2048 Bainer

Synopsis: The emphasis in this course is on understanding the geometrical, analytical, and algorithmic foundations of modern CAD software. Although commercial CAD systems have achieved a high degree of maturity over the past few decades, their utility and robustness is limited by the lack of efficient and rigorous algorithms for many of the fundamental computations required in modelling parts bounded by free–form surfaces. The aim of the course is to develop the student's expertise to a point where he or she can embark upon original research in the field. Instead of using a commercial CAD system, the practical aspect of the course will involve a first–principles implementation of and experimentation with CAD system algorithms.

1 prerequisites

Proficiency in a high–level programming language such as FORTRAN, C++, C, or Pascal is required (Mathematica and Matlab are not well–suited to the assignments in this class: you will find that they do not offer sufficient control as the problems become more challenging). If your programming skills have become "rusty," this course offers a good opportunity to improve them — provided you are willing to invest time and effort. You should also have a firm grasp of basic algebra, calculus, analytic geometry, and numerical methods.

2 textbooks & references

There is no *required* text for this course — you should be able to manage fine with just the lecture notes and hand–outs. As a *recommended* text, however, I suggest my own recent book:

- R. T. Farouki, *Pythagorean–Hodograph Curves: Algebra and Geometry Inseparable*, Springer, ISBN 978–3–540–73397–3 (2008)

There is a copy in the Shields Library, and it is also available electronically as an e–book through the library website (you can download one chapter at a time, but not the whole book as a single file). The book sells for about $80 — less at some on–line discount stores — if you wish to buy a hard–copy.

The book is divided into seven parts. Parts I and II give a comprehensive review of the required background in algebra and geometry; Part III describes the "classical core" of computer–aided geometric design (the main focus of this course); Parts IV through VI deal with the more–specialized subject of Pythagorean–hodograph curves (my own invention); and Part VII provides a detailed treatment of two specific applications: rotation–minimizing frames for spatial motion control, and real–time CNC interpolators.

Here are some other suggested titles, that correspond roughly in scope to Part III of the above book:

- G. Farin, *Curves and Surfaces for Computer Aided Geometric Design* (4th edition), Academic Press (1997).
- G. Farin, *NURB Curves and Surfaces*, AK Peters (1995).
- G. Farin, J. Hoschek, and M–S. Kim (eds.), *Handbook of Computer Aided Geometric Design*, North Holland (2002).
- I. D. Faux and M. J. Pratt, *Computational Geometry for Design and Manufacture*, Ellis Horwood (1979).
- J. Hoschek and D. Lasser, *Fundamentals of Computer Aided Geometric Design*, AK Peters (1993).
- M. E. Mortenson, *Geometric Modeling*, Wiley (1985).
- H. Prautzsch, W. Boehm, and M. Paluszny, *Bézier and B–spline Techniques*, Springer (2002).

- B. Q. Su and D. Y. Liu, *Computational Geometry — Curve and Surface Modeling*, Academic Press (1989).

The premier journals in the field are *Computer Aided Geometric Design* and *Computer Aided Design*. Both are available in the Physical Sciences Library, and papers can be downloaded as pdf files. Consulting these journals for term project ideas is a good idea — I can also direct you to important references in specific areas of interest.

3 outline

The following list summarizes the topics to be covered — we will spend 3 or 4 lectures on each, with due allowance for the expertise level of the class.

- review of basic algebra
- fundamentals of numerical analysis
- coordinate systems and transformations
- Bernstein–Bézier methods
- introduction to spline curves
- the B–spline representation
- surface representation schemes
- rudiments of algebraic geometry
- curve and surface intersections
- offset curves and path planning

There will also be an opportunity to depart from this list, and cover other topics, based on prevailing interests in the class.

4 homeworks

There will be five or six homeworks,[1] one approximately every $1\frac{1}{2}$ weeks, and due dates will be announced in class. For many of the homeworks, you will need access to a 2D plotting package. You can use any package you like, but please note that when plotting geometry, rather than functions, it is essential to maintain equal scales for the x and y axes — a circle should not look like an ellipse! In some case, it may be preferable to have your program write an output file, that can subsequently be read into the plotting package.

You may consult with colleagues on matters of principle, but all written calculations and software implementations must be done *individually*. Use of other (current or former) students' work on homeworks or projects — I am adept at identifying this — is unacceptable, and will not be treated leniently! Always submit a copy of your program listings with your results.

Some of the assignments require you to read data files into your programs. I will distribute these files by e–mail and/or place them in a public directory.

5 term project

You can choose between implementing an algorithm of your own concoction, accompanied by a brief report ($\sim$ 8 pages, with illustrative examples) on your experiences with it; a more substantive paper (16–24 pages) that surveys and assesses the state–of–the–art in some chosen area and attempts to extend it; or the formulation of some novel algorithm or mathematical proof and a brief report thereon. You are encouraged to consult the research literature and to discuss your project ideas with me. As a foretaste of "real life" the project is deliberately loosely–structured. Ingenuity, diligence, and clear and succinct presentation of results will be best rewarded.

6 final grade

There are no exams — the homework assignments will count for 65% of the course grade, and the project for 35%.

[1] These are really "miniprojects" — do not underestimate the amount of effort involved!