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Project IV - Face Recognition - 2011/12

The problem

The problem of face recognition by machines can be approached from a variety of angles, and there is at present no 'best' way of doing it. The aim of this Project IV is to look at some of the more established techniques, and then, when time permits, perhaps have a shot at understanding some of the more recent research in this direction.

The main issue is simple to illustrate. Consider a computer image of a face; this will typically consist of 10^5 to 10^8 pixels, each with on the order of 2 to 10^6 different values. In order to determine whether two such pictures contain a face (the problem of 'face detection') and whether they describe the same face ('face recognition'), we need a clever way to search through this *huge* space of images. Most of the maths is related, in some way or another, to the problem of reducing this huge space of possible face images down to something more manageable, and finding smart ways of searching that reduced space of images.

While many algorithms have been developed over the years, there is a current trend to try to take hints from biological experiments with the visual cortex, and several groups have made interesting progress with that. It is up to you whether you would like to pursue that direction or whether you want to stick to the more pragmatic side of the field which 'tries to get the job done' without worrying too much about whether the mathematical ideas actually follow what the visual cortex is doing.

Structure, supervision & meetings

The Project IV rules require that we will have 1 hour of supervision per week. Initially it makes sense to stick to that schedule, but at a later stage it is sometimes more useful to have meetings arranged when actual problems arise, not when the clock says it is time to meet. You can always reach me by email, and it is often advisable to first ask your question that way because it forces you to think carefully about what bugs you.

One of the goals of Project IV is that you learn how to find your way through the literature and come up with your own questions and problems. As such, I will not give you a fixed problem to work on. However, to get the ball rolling, we will do a few sessions at the beginning to get a grasp of some of the basic maths. Some of the topics that we might address include

- principal component analysis, Gaussian mixture models.
- filter and convolution theory (e.g. Gabor, Kalman, condensation filters).
- machine learning basics, support vector machines, boosting.

- eigenfaces, Fisherfaces, linear discriminant analysis
- neural networks
- hierarchical memory models
- hidden Markov models
- local features, SIFT, SURF, ...
- ...

If you want to prepare yourself over summer, googling for these topics is not a bad idea. Try to figure out which aspects you find most interesting, even if you have only a rough idea.

Literature pointers and summer reading/viewing

As far as literature is concerned, the web is your friend. Some concrete hints:

- There is an extensive web site with literature links available at www.face-rec.org. The "algorithms" section of that site has a list of mathematical ideas which underly the various face recognition techniques in use today. There is also a list of 'classic' papers in the field, many of which are well-worth reading.
- Another good resource for computer vision papers is www.cvpapers.com/.
- Machine learning is a large topic, but there is some very readable and to-the-point material in the "Learning OpenCV" book (chapter 13), even if you are not interested in doing any programming.
- The project page of last year contains a large list of papers related to basic maths relevant for the project; this will be updated over summer. http://maths.dur.ac.uk/~dma6kp/pr4_face_recognition.html
- Finally, some papers appear on the arXiv preprint archives, in particular at uk.arxiv.org/list/cs.CV/recent.

There are also some interesting video lectures on the net, which do not always give a lot of details but can be inspiring. See for instance

- Thomas Serre, "Mechanisms of bottom-up and top-down processing in visual perception", http://www.archive.org/details/Redwood_Center_2009_04_22_Thomas_Serre
- Jeff Hawkins, "How brain science will change computing", http://www.ted.com/talks/jeff_hawkins_on_how_brain_science_will_change_computing.html

Use of computers

Even though this is not a computer project, and you are not required to do any programming, you can potentially benefit tremendously from trying to implement the mathematical ideas in a concrete program (so you can 'play with them'). Experience with this project in the previous years has shown that the topic becomes much more 'alive' if you are able to see things happen in front of your own eyes. Many ideas can be explored easily with general purpose programs such as Mathematica, Maple or Matlab, and you really do not need to be an expert of any kind to use these systems.

If you want to do a bit more sophisticated things, Python is a good choice, as there is good support for all sorts of maths (especially linear algebra and graphics) in the NumPy and SciPy libraries (see http://docs.scipy.org/doc/). If you go the C/C++ route, you can avoid doing a lot of low-level work by using the OpenCV library (see http://opencv.willowgarage.com/wiki/). Do not hesitate to ask me about these libraries.

Finally, remember that even though there is a lot of computer-related material out there on face recognition, this is a **mathematics** project. Resist the temptation to simply write a computer code which implements a face recognition algorithm which you read off from some paper, without thoroughly understanding how the underlying maths actually works. At the end of the day, you will be marked on the maths content.