An Integrated Human Computer Interface using Eye Gaze Tracking and Facial Feature Recognition

Coin 512: Project Proposal

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Contents

Aim

The aim of this project is to design an integrated human computer interface such that a computer responds to movements of the users eyes and face. The project will combine the use of eye gaze tracking with other facial recognition techniques. In summary the aims are:

- To recognise facial features.
- To detect changes in facial expression.
- To track eye gaze movements.
- To combine these signals to produce an integrated human computer interface.

Context

Ever since the development of Computer Systems there has been a requirement to provide a mechanism for human - computer interaction via some kind of interface. These have developed over the history of computing with the goal of producing interfaces which are more user friendly. Early human-computer interfaces had a deserved reputation for unfriendliness consisting of a combination of keyboards, command line interface , punch cards or tape and paper printouts. Users might have to wait hours or even days to receive the results of their labour however trivial this may have been. Menu driven interfaces were an improvement enabling users to more easily take advantage of their computer systems, albeit with a variety of “feels” even within interfaces from the same sources.

A major step forward came with the development of the Graphical User Interface (GUI) based on the use of a pointing device such as a mouse, windowed on screen environments and icons. This has encouraged a far greater degree of commonality between software packages from different sources and even across different operating systems and enabled users to access their systems more intuitively.

Science fiction writers have for many years portrayed a world where a user might interact with a computer as if it were another “living being”, the computer responding to the users voice and physical expressions, perhaps even to their brain waves. Computer technology has advanced in recent years to the point where this dream no longer seems impossible. Already there are commercials systems which use brain signals to decode human eye movement for eye gaze tracking and other eye tracking techniques are also available. Speech recognition is another technology which is commercially available. In order for humans to be able to communicate with computers as if they were dealing with another human being places very high demands on the computers ability to interpret and process information at very high speeds. It also demands that computers are able to infer understanding from the context of the signals they receive.

The modest aim of this project is to contribute to the goal of enhancing the human computer interface by trying to draw together work which has been done using non-intrusive eye tracking techniques and also facial action recognition. At the conclusion of the project it is anticipated that a system will have been developed which will enable a user to sit at their personal computer with a video camera mounted above or beside the monitor. The images received by the camera will be processed so that the user can control a cursor using eye movements and other facial gestures. A measure of the success of the project will be the degree to which the user is able to configure the system to their own personal requirements and, once having done that, to how unobtrusive the system is to use.

Literature Review

Since the average computer user spends most of their active computing time looking at a computer screen a number of researchers have found the detection of eye gaze to be a fruitful goal. Arne J Glenstrupp and Theo Engell-Neilsen [12] prepared a substantial review of Eye Controlled Media at the University of Copenhagen. They explore a number methods which have been used for detecting Eye-Gaze Tracking. These included commercially available techniques known as Electro-oculography based on electric skin potential such as those developed by H. Lusted of BioControl Systems[1,2,4]. Kaufman [3] also describes a system for controlling a cursor with success rates between 73% and 99% depending on the precision required by the task. Whilst these techniques have been demonstrated to be robust, hence it's availability as a commercial product, it is intrusive for the user. This only makes them suitable for us in specialised circumstances where the benefits, or the requirement for eye gaze tracking outweigh the encumbrance of wires attached to the users head. Other intrusive approaches described by Glenstrup and Engell-Neilsen include techniques based on the use of contact lenses using engraved mirrors or implanted electromagnetic coils. These are unlikely to be attractive techniques for widespread use but may be appropriate for specialised applications.

Jason Heuring and David Murray [13] at Oxford University have developed a system where a user wears a set of goggles with six infra red LEDS mounted. They use a video camera to detect the light from these LED's and using geometrical analysis of the number of LED's visible and their distance apart are able to track the orientation of the users head and hence direction of gaze. The signal this produces has been used to servo a pair of cameras mounted on a robot "skull" called Yorick. This too is a system which may be applicable to certain applications but it's dependence on the user wearing a visor and moving their head means that it is not appropriate as a means of interacting with a PC.

Other researchers have tried to use a video camera pointed at the user to detect eye movements for a variety of purposes. David Trock and Ian Craw [29] have placed a video camera on the dashboard of a car to monitor the eye and eyelid movements of driver in order to try and detect when a driver is becoming drowsy. The system has an initialisation period when it learns which regions of the picture are of interest and to be monitored. It can cope with the normal head movements associated with driving as the driver turns their head at a junction for example. It is also able to reinitialise if the head position changes as the driver settles into their seat during the journey. It has not however been developed with a view to detecting the gaze direction and also suffers from lighting difficulties.

The latter authors [29], along with Glenstrup and Engell-Neilsen [12] refer to other systems which use reflected light from the eye. Some of these systems require some hardware to be worn or for the users head to be constrained in some way, clearly not acceptable for normal use. These methods make use of different reflections, known as Purkinje images, occurring at the various boundaries within the eye structure. These have produced quite good results and have been used for opthalmic and psychological research. Applied Science Laboratories [15] produce a range of such equipment for a variety of applications. Ebisawa [11] and Muller [14] also describe two other methods which at first sight seem to be less intrusive for the user. These are *limbus* tracking, where the boundary between the white sclera and dark iris of the eye are optically detected, and corneal reflection and eye imaging using neural networks. Computational algorithms exist for detecting the eye position in both these ways though as yet not with such a high degree of accuracy as other techniques. It is thought that improving the accuracy of either of these latter two systems may result in a more generalised system which could be used with low cost video cameras such as those now on the market for video conferencing priced at about £100. It is these latter methods which are of greater interest in this current project. However there are some other areas of research which impinge upon these techniques and may lead to solutions which have wider application and hopefully reduce the computational expense of any software developed. Patricia Churchland et al [33] discuss in some detail physiological and psychological aspects of human vision and it is clear from other authors [32,33,34,35,36,37,38,39,40,41] that some understanding of these areas is required in order to develop systems which are effective and usable.

The task of generating a usable eye tracking signal as defined in the aim of this project can be divided into two broad components. The first has to do with identifying the face and eyes and the second to monitoring their movements. As soon as one removes the possibility of attaching physical hardware to the users head, or constraining the head with a restraint a major concern is knowing where the eyes are and being able to distinguish eye movements from other head movements. This places a requirement on the system to be able to identify the head and face and to track these.

A number of authors [42-51] describe techniques which they have developed for recognising objects within a field of view which may be cluttered by other features. Balkenius [42] and Shams [48] describe methods of applying what they call an elastic template to the field of view. Essentially the template consists of a geometrical wire frame representation of the object being sought in the image. The wire frame is stretched or compressed until it can be laid over the part of the image containing the object being sought. Although their work uses objects such as cars and other landmarks a similar technique is used by Yuille & Clark [50] to match a deformable template to the eye.

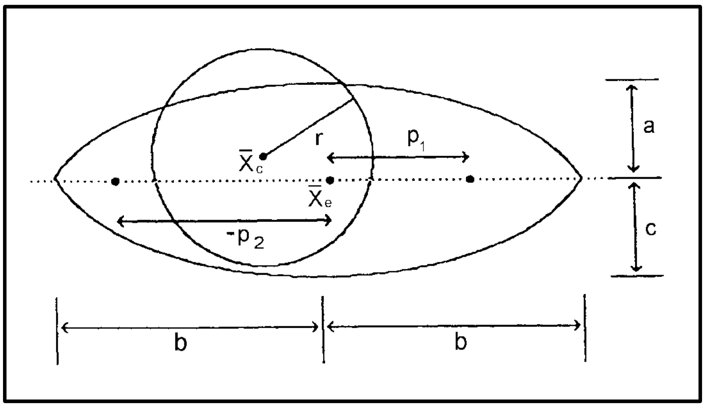


Figure 1 - Eye template from Yuille & Clark [50]
The circle radius r, centred on Xc represents the iris Rb. The whites Rw by the region outside the circle but inside the two parabolae specified by Xe, p1, p2, a, b, c.

It seems likely that this kind of technique may be profitable to explore in this project since a similar method has been exploited in work carried out into facial action classification [5,6,7,8,9,10]. Some authors (Bartlett et al [5]) describe classification based on the measurement of various features such as wrinkles, or amount of visible sclera. These features are quite individual specific and better results have been achieved by Essa [6], Ip [7], Morishima [8] and Yuanzhong [10] in their work applying templates to the face.

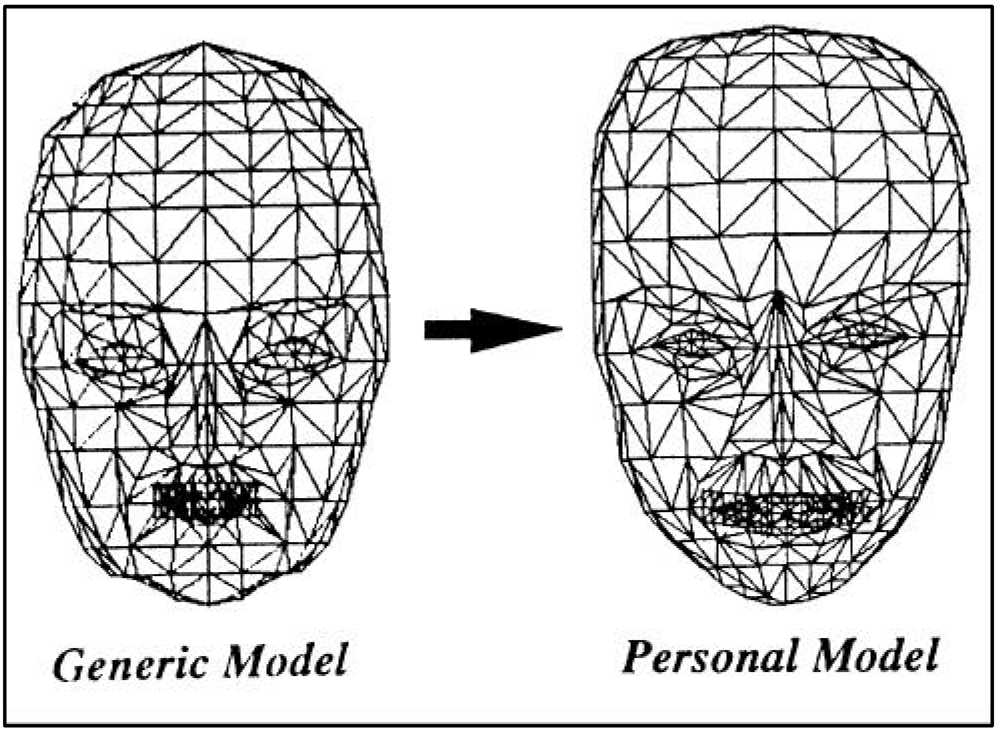


Figure 2 *- Face template from Morishima [8]*

Having used a method of this nature to locate and track the head it is hoped that information about what other parts of the face apart from the eyes may provide useful information. The work of Hager and Toyama [28] in applying a "clowns face" to a video image using X Vision for face tracking shows some of the potential in this area.

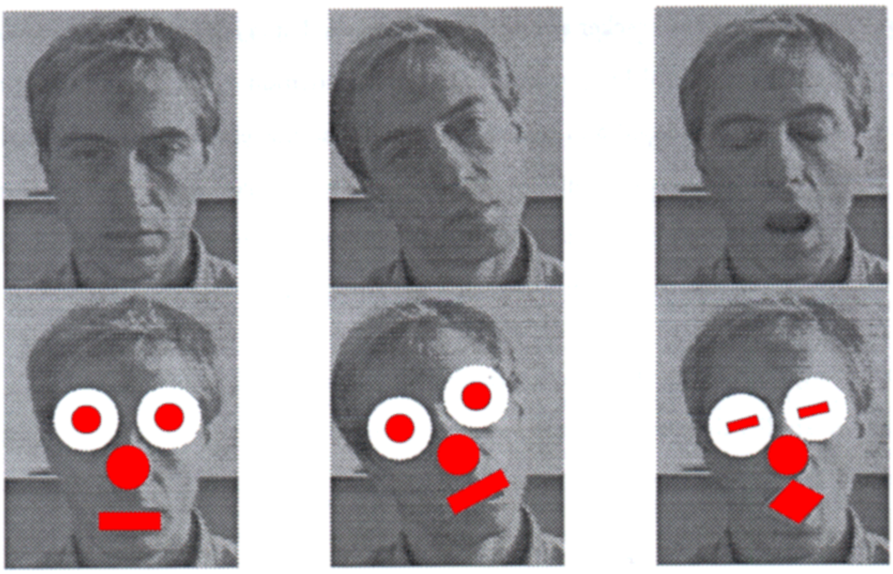


Figure 3 *- Clown face tracker from Hager and Toyama [28]*

Having detected the head and located the eyes it is then possible to start trying to detect the eye movements. Baluja and Pomerlau [26] describe a system for doing this using an artificial neural network with an 15x15 square input retina a single divided hidden layer and 50 output units for both the X and Y signals which achieved an on-line accuracy of 1.5 degrees when controlling a cursor on a monitor approximately 50 cms from the user. Xangdong et al [30,31] describe an alternative method which uses Kalman filtering and detects the grey level centroid of the eye region as the measurement vector. The tracking signal signal was not used for control and had a tracking error of about 0.25 pixels in the eye window of about 75 by 45 pixels. A number of authors have written at some length about the problems to be overcome by eye gaze tracking based human computer interfaces [16,17,18,19,20,21,22,23]. Jacob [20,21] reviews a number of important issues including, the problem of the jerkiness of eye movements and what he describes a s a "Midas touch" where a user involuntarily selects features with his eye gaze that were not intended. Istance [18] makes a similar contribution and also makes a direct comparison between the use of a mouse and an eye gaze controlled graphical user interface. Among the key issues which need addressing from all of these sources is the coarseness of the tracking resolution which can be achieved. Accuracy levels described suggest that on screen buttons about 1 cm in size can be selected with a reasonable degree of accuracy but distinguishing between characters or even between rows in standard 10 or 12 point text is not yet attainable.

Approach

A review of the literature reveals that a number of different approaches might be profitable to pursue. If eye gaze tracking is to be successful as a control mechanism the problem seems to divide into two components and it is proposed to tackle these in two phases.

- Phase 1 - Facial Feature Recognition
- Phase 2 - Eye Gaze Tracking

Phase 1 - Facial Feature Recognition

Facial feature recognition provides a way of tackling the problem of knowing where the users head is. Without this information it is impossible to know where the users eyes are and in what direction they are looking. The intention in this project is to apply a deformable template over the region of the video image which seems likely to contain the face and to use that to identify key facial features such as the eyes, nose and mouth. Once the face has been detected the system will need to track movements of the head and changes in it's orientation. It may also be useful to be able to recognise facial actions such as raising an eyebrow or blinking as these are potential sources of signals which could be used as "switches" to replace mouse buttons.

Phase 2 - Eye Gaze Tracking

Once the position of the eyes has been established on the face the next step is to develop a mechanism for detecting the movement of the eyes. Since a template has already been applied to the face movements can be calculated relative to the position of this template which it is hoped will minimise the problems associated with the head moving and causing false signals. A utility will need to be produced to calibrate the system for a user so that the software and the user are able to learn about each other.

Potential Difficulties

From the reading carried out so far it is clear that while much has been done in trying to produce a viable eye gaze interface there is also much still to be achieved. The key areas which need addressing include:

- Tracking resolution - if eye gaze tracking is to replace the mouse it needs to achieve a resolution level which appears comparable to the user. One approach may be to use the eye gaze signal to move the cursor in to the general area of interest and then use other facial movements to “nudge” the cursor to the desired location.

- The “Midas touch” - it can be irritating enough to find that a mouse has left a cursor in an inconvenient position or to accidentally select the wrong section of text, however the potential for miss-selection using eye gaze is much greater and protocols need establishing which will enable the user to easily choose when and perhaps how to activate the interface rather than simply reading or viewing the screen image. This might be achieved by using signals from other facial actions, or alternatively by having a location on the screen where the pointer is “parked”. To activate the pointer the user would look at the parking bay and pick up the pointer. On completion of the task the pointer could be moved back into the parking bay.

- Eye jitters - these are natural movements of the eye which are unnoticed in the normal course of events. However when they are transferred to the screen by an eye gaze interface they become distracting and irritating. How significant a problem these prove to be will depend on the image sampling rate which can be achieved rate. It may be necessary to include a smoothing algorithm to reduce the impact of these.

- Delayed action - there is likely to be a trade off between the accuracy of the system and the speed at which it can respond. The finer the resolution which can be applied to the region of interest the greater the accuracy with which the system can respond. However a fine resolution will be more computationally expensive and will have an impact on the sampling speed. These factors will also be limited by the resolution of the camera and by it’s scanning rate.

Action Plans

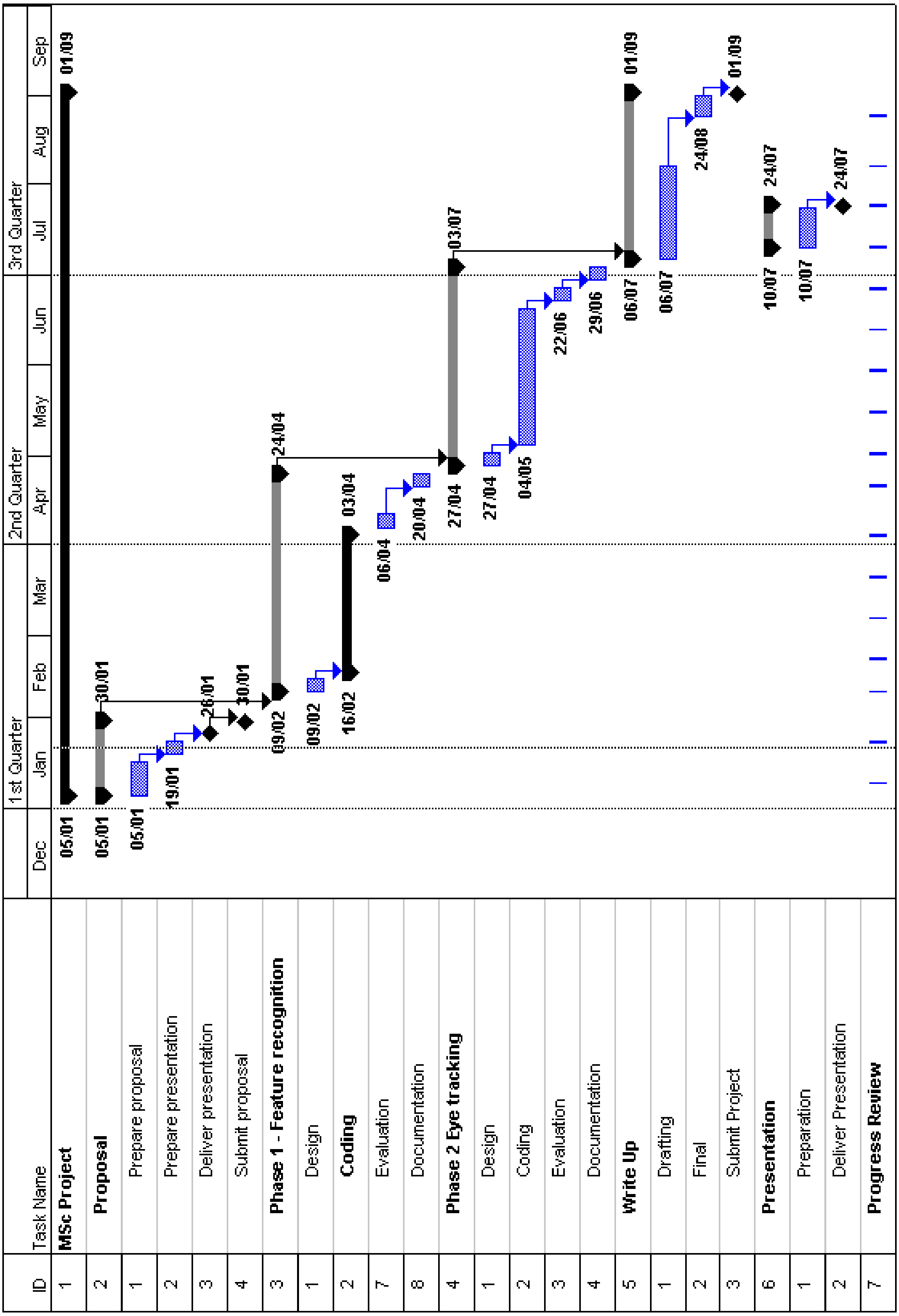
The two phases which have been identified for the project provide a basis for the overall scheduling of the project. In addition to these two major implementation phases time has been allocated to the following key stages.

1. Proposal - completion date 30th January with a presentation on the 26th January. (4 weeks)
2. Phase 1 - Facial feature recognition. (10 weeks)
3. Phase 2 - Eye tracking. (10 weeks)
4. Write up. (7 weeks)

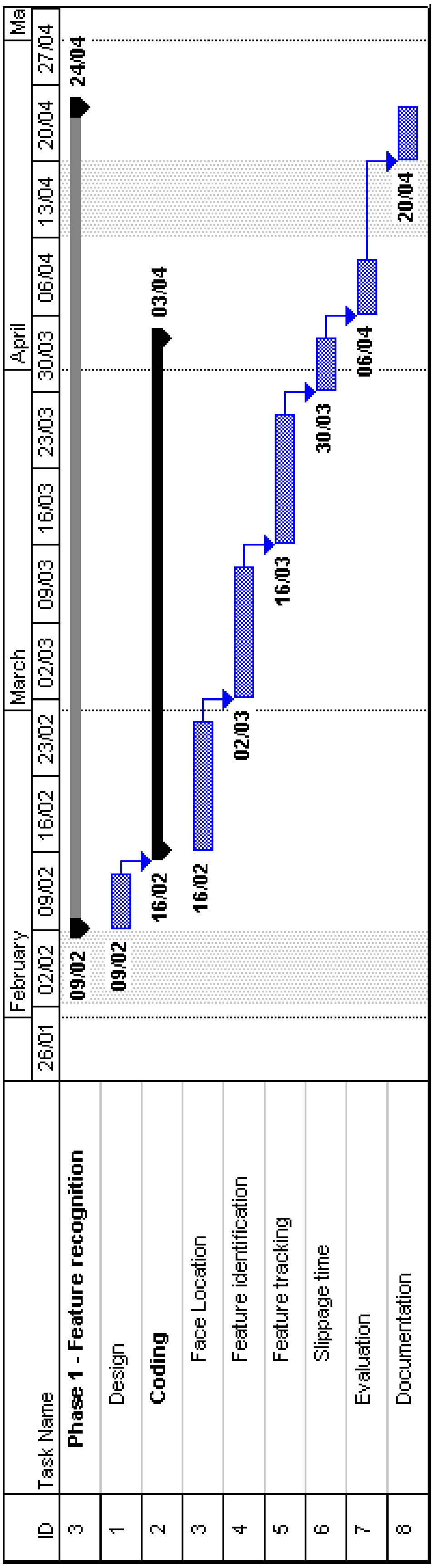
5. Presentation - presentation date sometime in July. (2 weeks)
6. Progress reviews at regular intervals.

The schedule is represented graphically on page 8 and a more detailed schedule for the first phase is shown on page 9. Breaks for family holiday have planned into the schedule at February, Easter and in August. These appear as grey bands on the more detailed schedule for Phase 1.

Overall Project Schedule



Phase 1 Schedule



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