Project: Moving Map Display

A moving map display is a situational awareness tool used by pilots in both the civil as well as the military aviation world. The display shows a two-dimensional view of different navigation charts as shown in table below.

Acronym	**Scale**	**Range**$^{\Psi}$	**Full Name**
GNC	1:5M	160 nmi	Global Navigation Chart
JNC	1:2M	80 nmi	Jet Navigation Chart
ONC	1:1M	40 nmi	Operational Navigation Chart
TPC	1:500k	20 nmi	Tactical Pilotage Chart

Table 1. Types of Charts

nmi : Nautical Miles
M : Million
K : Thousand

$^{\Psi}$ Range information based on the McDonnell Douglas Model #ASQ-196

Goal:

- To write an Ada95 program to read and display image files in the following formats
  - JPEG
  - BMP
  - GIF

- How would you zoom in and out of the image? Your program should allow the user to enlarge/ shrink the image using the '+' and '–' keys on the keyboard.

The standards for the formats can be found at the following links

http://www.jpeg.org/

http://www.dcs.ed.ac.uk/home/mxr/gfx/2d/BMP.txt

http://www.w3.org/Graphics/GIF/spec-gif89a.txt

Figure 1. SM-4000 COLOR Skymap IIIC by Bendix/King*

* Source : http://www.avionix.com/movmap.html

Given that your moving map display size is 4.5” x 4.5”:

Issues to take into consideration are

- Aircraft speed varies from 0 – 480 knots.
- Turns are constant at 7 degrees per second.
- Time taken to switch between the maps.
- Time taken to enlarge/ shrink the maps.

Which of the format (GIF/ JPEG/ BMP) would you choose for your moving map display? Justify your answer.

Project: Attitude and Direction Indicator

The Attitude Direction Indicator shows the roll and pitch of the A/C. The upper half of the display is blue (sky) the lower half is brown (terrain). The borderline between the halves is the horizon. The horizontal bar represents the A/C in relation to the horizon. The white bars (one horizontal, the other one vertical) are the indicators when in ILS modus, showing the aircraft's position in relation to the glide-slope and inbound vector of the runway. If the A/C outside the max. ranges of GS and Course, the bars are locked on one side of the indicator.

Goal:

- Write an Ada95 program to create the display shown below (Attitude and Direction Indicator). Use the AdaOpenGL binding to create the graphics.

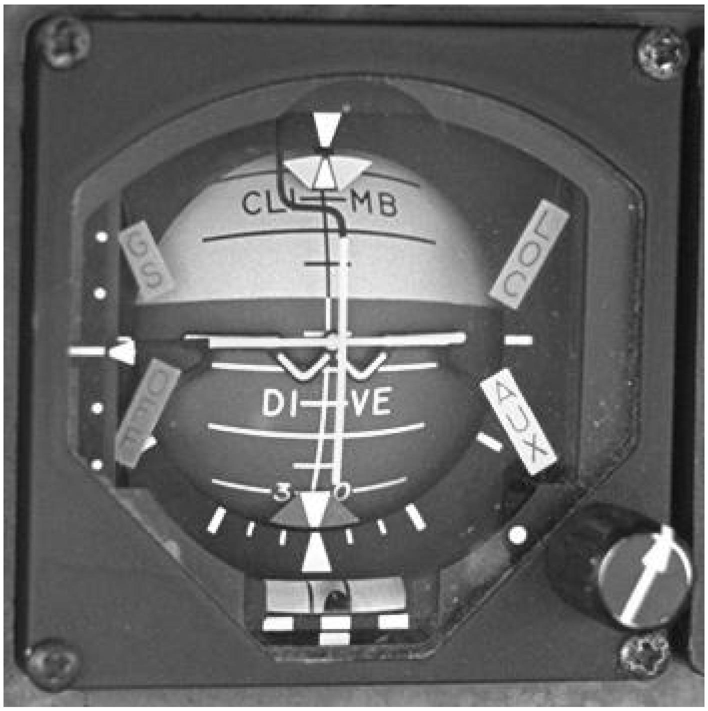


Figure 1. Attitude and Direction Indicator*

* Source: http://xflight.powerweb.de/original/parts/center_console/adi/adi_01.jpg

The openGL package can be found at
http://adaopengl.sourceforge.net/

- The user should be able to control pitch and roll from the keyboard. You may assign the keys ahead of time and display it when the program starts.

Issues to be considered are:

- What is the maximum pitch rate/ roll rate of the aircraft?
- How long does it take to update the display once the user enters a command?
- Write a two page memo to the designers of the JSF based on your project, explaining what you think the key design issues in designing the display are.

The specification of the frame of reference is one of the most significant design questions for spatial displays, since it determines from where the situation is depicted and which variables are presented as dominant cues.

Inside-out refers to a presentation of the world related information as it would be observed from within the aircraft. Outside-in refers to a viewpoint which is stabilized in a world-referenced system. Stokes et al. (1990) present three principles that should influence the choice:

- The principle of the moving part.
- Constancy of reference frames.
- The principle of frequency separation.

The principle of the moving part assumes that people have certain expectations about what actually moves in a system. The element that moves on the display should be the same and move in the same direction as the operator's expectation of motion. The principle of constancy of reference frames is based on the fact that humans have a difficult time rapidly reorienting between different frames of reference. When an instrument represents an abstraction of the real world and the user is required to switch between the instrument and the real world, different frames of reference can result in control blunders. This is caused by the fact that to compensate for a given display movement, the required direction of the control action may be opposite between the two frames of reference.

In case of an artificial presentation of the outside world, the principle of the constancy of reference frames leads to the conclusion that, to maintain static compatibility with the outside worldview, an inside-out frame of reference should be used. However, the principle of the moving part suggests, that to maintain dynamic compatibility, the movement of the display should be consistent with the pilot's mental representation that the aircraft moves, and hence an outside-in frame of reference is required (Johnson and Roscoe, 1972). The attitude direction indicator (ADI) presents the pitch and bank of the aircraft relative to a depiction of the horizon. In general a so-called inside-out frame of reference is used (fixed airplane symbol against a moving horizon).

With an outside-in frame-of reference, the horizon is fixed and the aircraft rolls right and left and pitches up and down. To prevent the aircraft symbol from going off the scale, the complete pitch range must be visible, posing quite a design challenge since the combined range and resolution requirements can result in a rather large display.

Russian aircraft employ a hybrid solution, in which the aircraft symbol rolls but is fixed in the vertical direction, and the artificial horizon translates in the vertical direction to convey pitch information. By allowing the aircraft symbol to roll against a fixed background, the principle of control display motion compatibility is satisfied. When regarding an attitude indicator as a display of which the error must be zeroed, control reversals can results. Therefore, an inside-out frame of reference must convey the illusion that the aircraft is moving.

Project: Data Links

Data links allow aircraft to transmit information in real- or near real-time. A study released by Forecast International, Newtown, Conn., said that the U.S. airborne communications market will be worth some $2.63 billion over the next decade. There are two key communication links (besides the traditional data buses such as MIL-STD-1553, ARINC 429 and ARINC 629) are RS232 and TCP/IP.

- RS232 has been around for a very long time and is typically used to connect the fire control computer on-board the aircraft to the weapon delivery sub-systems (fuzing and release).

- TCP/IP, which has been the driving force behind the internet, and is now being explored for Aircraft use.

Goal:

- Write an Ada95 program that will enable RS232 communication between two computers.
- Write an Ada95 program to allow two computers on the internet to communicate with each other. Use Ada Sockets to establish the connection between the machines.
- Boeing/ Honeywell have been considering using TCP/IP in commercial aircraft. Write a two page memo detailing the advantages/ disadvantages of both serial communication and TCP/IP.

The RS-232 standard can be found at
http://www2.rad.com/networks/1995/rs232/rs232.htm

The AdaSockets package/ usage is present at

http://www.rfc1149.net/devel/adasockets

Project: Fuel Management

Full Authority Digital Engine Control (FADEC) is an engine manage that monitors fuel consumption and optimizes engine performance. The FADEC has to take into consideration the flight envelope of the aircraft, the mode of operation and inform the pilot when **bingo** fuel is reached.

Goal:

- Write a FADEC using Ada95 for a combat aircraft of your choice. Your software must take into consideration
  - Flight envelope of your aircraft
  - Engine performance over the entire flight envelope
    - Cruise
    - Mach hold
    - Altitude Hold
    - After-burners
  - It should inform the pilot when bingo fuel is reached.
  - It should handle air-air refueling operations and inform the pilot when to break away from the tanker

- The USAF has recently selected the x-35 to be the JSF. Write a two-page memo detailing what they should be looking for in the fuel management system..

- Issues to consider include
  - How do you model the aircraft?
  - How do you model engine fuel consumption?
  - How do you model fuel flow from tanker to fighter?
  - How do you simulate the operation of the aircraft?

Project : Kalman Filtering for Position and Velocity Estimation

In 1960, R.E. Kalman published his famous paper describing a recursive solution to the discrete-data linear filtering problem. Since that time, due in large part to advances in digital computing, the Kalman filter has been the subject of extensive research and application, particularly in the area of autonomous or assisted navigation.

The Kalman filter is a set of mathematical equations that provides an efficient computational (recursive) solution of the least-squares method. The filter is very powerful in several aspects: it supports estimations of past, present, and even future states, and it can do so even when the precise nature of the modeled system is unknown.

The US Navy has been working on the Small Autonomous Underwater Vehicle to act as a countermeasure for shallow underwater mines. One of the key components is to integrate the Inertial Navigation System and the Global Positioning System to improve navigational accuracy.

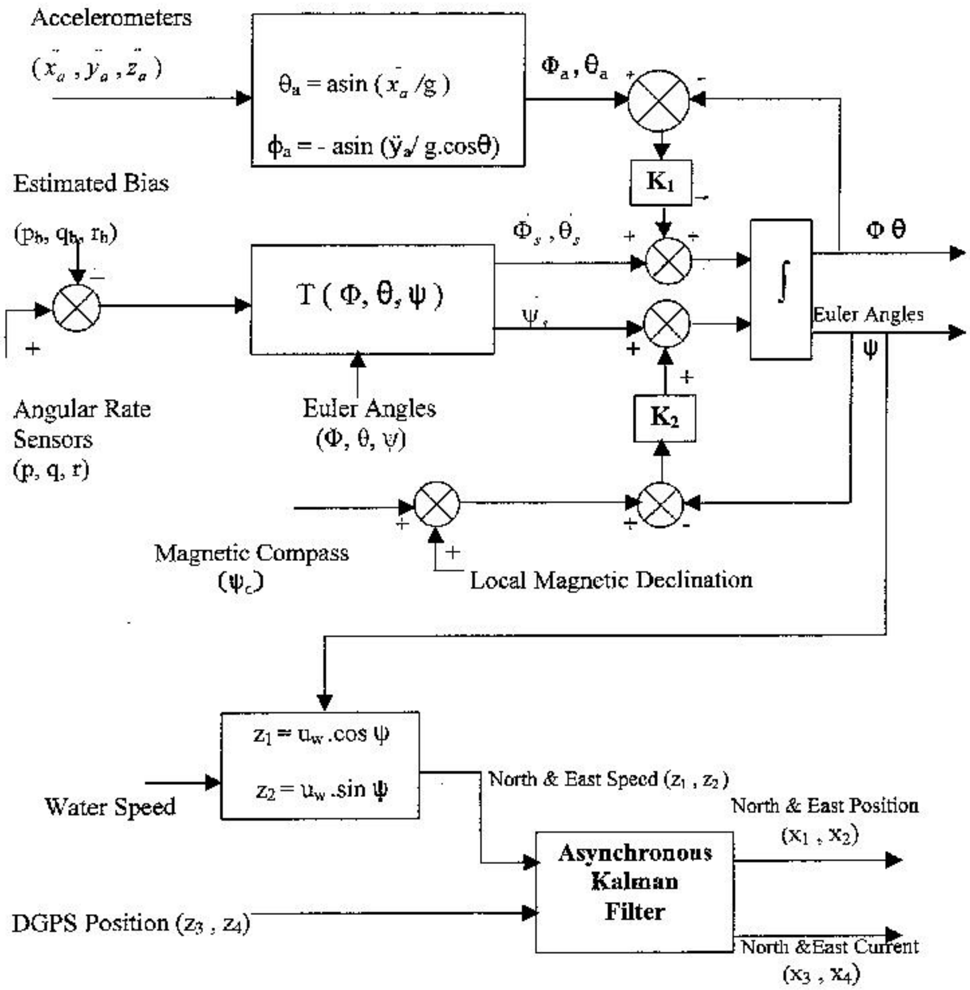


Figure 1. Block Diagram of the Kalman Filter

Goal:

- To write an Ada95 program that implements a kalman filter for integrating GPS and INS information.
- Based on your experience in this project, write a memo for the US NAVY, citing the advantages and disadvantages of using a kalman filter for integrating sensor information.

A block diagram of the Kalman filter to be implemented is shown in figure 1.

A link to a tutorial on Kalman Filtering is given below

http://www.cs.unc.edu/~welch/kalman/kalmanIntro.html

Project : Missile Target Simulation using Proportional Navigation

Proportional navigation is the guidance law used by most missiles in operational use today. This method of guidance, generates missile acceleration commands in proportion to the line-of-sight (LOS) rate. The missile-target geometry is shown in figure 1 below.

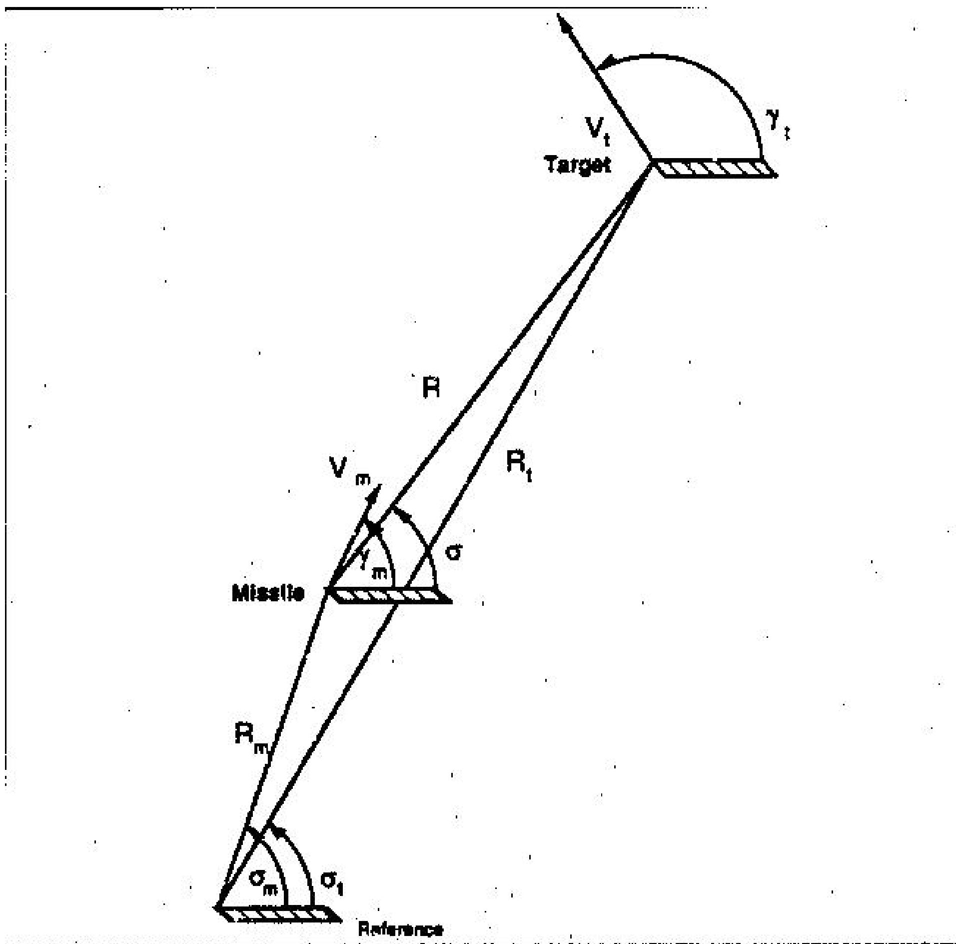


Figure 1: Missile Target Geometry

Where:

V_t : Target Velocity
V_m : Missile Velocity
γ_t : Target Flight Path Angle
γ_m : Missile Flight Path Angle
R : missile range to target
R_t : Target Range
R_m : Missile range
σ_t : Target Line of Sight
σ_m : Missile Line of Sight

The proportional navigation scheme is illustrated in figure 2. Assuming that the missile seeker head follows the aircraft, the transverse acceleration perpendicular to the line of sight will be equal to the acceleration of the R vector in that direction.

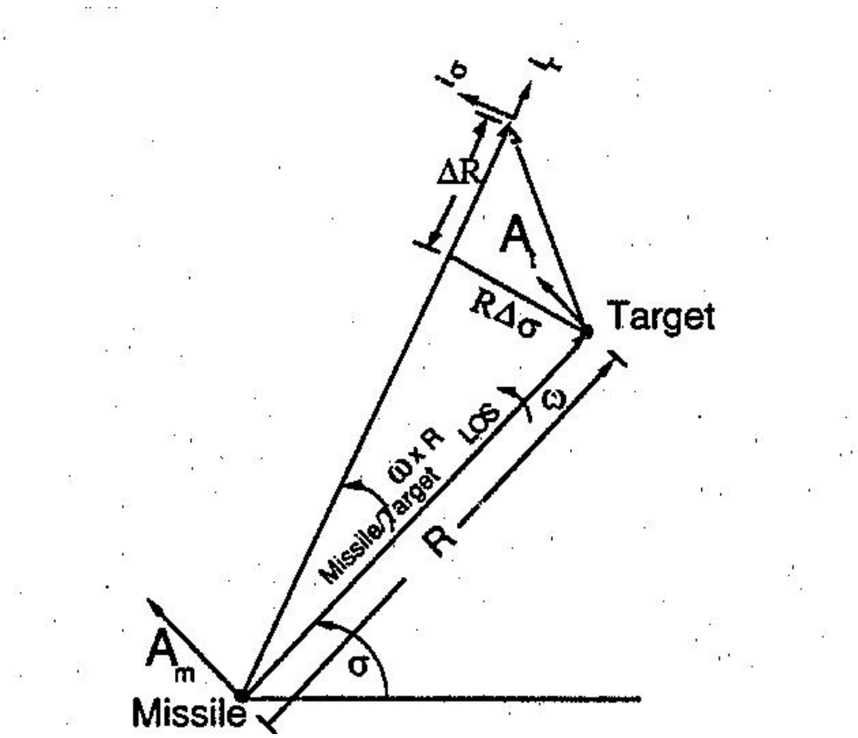


Figure 2. Vectorial Proportional Navigation

Goal:

- Write an Ada95 program to simulate a simple missile engagement scenario. Assume that the target travels at a constant velocity.
- The US ARMY is trying to decide which missiles to buy for a Surface-to-Air short range missile. Based on your experience in this project, write a two-page memo explaining which guidance algorithm you would choose and why.

Read **Tactical and Strategic Missile Guidance** by **Paul Zachran**. You will find a lot of code written in fortran which can easily be converted into Ada95.

Project: MIL-STD-1553

The MIL-STD-1553 is a military standard that defines the electrical and protocol characteristics for a data bus. The standard was released in 1973 with the primary user being the Air Force's F-16. Since that time, it has undergone two revisions, *Notice 1*, released in 1980 and the tri-service *Notice 2* in 1986. The *Notice 2* to the standard removed all references to 'aircraft' or 'airborne' so as not to limit usage of the bus. Outside of the military domain, it has been successfully applied to e.g., the BART (Bay Area Rapid Transit) subway system and manufacturing production lines. We use 1553 to refer to the protocol architecture defined in the MIL-STD-1553.

1553 Network Architecture

The transmission media is defined by the standard as a shielded twisted pair transmission line consisting of the main bus and a number of stubs. The Figure 1 below shows the basic multiplexed architecture.

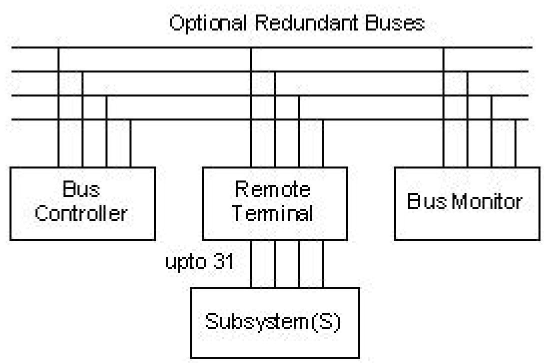


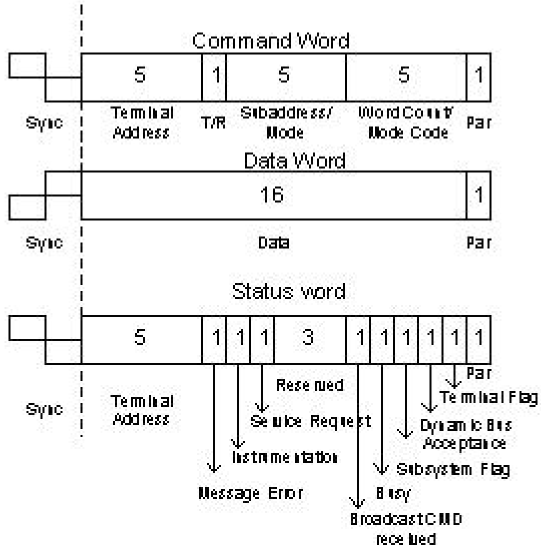
Figure 1. 1553 Multiplex Architecture

The Bus Controller (BC) is responsible for directing the flow of traffic on the data bus. Typically this function is contained within some other computer such as a mission computer, a display processor, or a fire control computer. The standard does not define the internal working of the bus controller, only that it issues commands on the bus.

A Bus Monitor (BM) is a terminal that listens to the exchange of information on the bus. The standard clearly defines that information obtained from a bus monitor may only be used for "Off-Line applications" or to provide a backup BC with enough information to take over as a bus controller. All terminals on the bus that are not acting like a BC or a BM are termed Remote Terminals (RT). An RT typically consists of a transceiver, an encoder/ decoder, a protocol controller, a buffer or memory, and a sub-system interface. It can only respond to commands from the BC. On receiving a valid command, the RT must respond within a finite closely defined amount of time.

Bus Access

The control, data flow, status reporting and bus management functions of the bus are provided by three word types: Command words, Data words and Status words. All three words have a common structure but each has a unique format as shown in Figure 2. Each word is twenty bits in length, allowing the decode clock to resynchronize at the beginning of each new word. The next sixteen bits are data bits and the last bit is a parity bit. The parity computed is odd parity.



Goal:

- Write an Ada95 program to simulate the behavior of a bus controller
- Write an Ada95 program to simulate the behavior of a remote terminal.
- Can you run both tasks (controller and remote terminal) on the same machine?
- How will you validate your design?
- The USAF is designing a new aircraft and wants your input on the bus architecture to use. Based on your experience in this project, write a two page memo explaining the advantages and disadvantages of 1553 over other available bus architectures.

Links of Use:

http://www.1553-mil-std.com/mil-std-1553-tutorial.html

http://www.1553.com/1553interp.htm

Project: Conflict Detection

In the current aerospace system, commercial flights are controlled by Air Traffic Control (ATC) from gate-to-gate. Before a flight can take place, the complete route plan must be sent to the ATC authorities in charge of the geographical sectors crossed by the aircraft.

During the flight, even minor changes to the plan require a clearance from ATC before they can be performed. New distributed air-ground traffic management concepts are being developed to address the inefficiencies of the current system. For example, the free-flight concept allows direct flight routes without ATC intervention, and the Airborne Information for Lateral Spacing (AILS) concept allows simultaneous and independent landing on closely spaced runways.

A key aspect of these new concepts is that they shift responsibility for aircraft separation from air-traffic controllers to pilots and automation. This change is theoretically possible because recent technology such as D-GPS (Differential Global Position System) and ADS-B (Automatic Dependent Surveillance Broadcast) can provide very accurate data-flight information to pilots and on board computers. Computer systems can warn pilots when other aircraft are dangerously intruding into their own airspace.

Aircraft kinematics can be modeled using

$$\begin{aligned} x'(t) &= v\cos(\theta(t)) \\ y'(t) &= v\sin(\theta(t)) \\ \theta'(t) &= (g/v)\tan(\phi(t)) \end{aligned}$$

where x,y, θ, ϕ are the location co-ordinates , the heading and bank angles respectively.

Given the maximum bank angle for a commercial aircraft is

$$|\phi(t)| \le 35\pi/180.$$

Goals:

- Write an Ada95 program to carry out conflict detection
- Allow the user to create aircraft in your airspace and specify the basic flight paramaeters (altitude, acceleration, heading, bank)
- How would you show that your algorithm works?

- The FAA asks your for advice on a new conflict detection system. Based on the work you have carried out for this project, write a two page memo explaining the advantages and disadvantages of your system over other systems.