Jeremiah K. Jones
Lab: I/O Labs 3-5
Duration – **3 weeks**
Completed on: **8/7/2005**

EXPLORING THE LIMITATIONS OF SPEECH RECOGNITION SOFTWARE

OBJECTIVE:

The objective of this lab is to gain a better understanding of speech recognition systems. In particular, this lab will strive to determine some of the limitations of speech recognition software, and what factors negatively affect the software's ability to recognize the user's speech. This lab will seek to answer the following questions:

- How does ambient noise affect speech recognition?
- How do pitch and vocal harmonics affect speech recognition?
- How does speaking speed affect speech recognition?
- How does reverberation affect speech recognition?

EQUIPMENT/SOFTWARE USED:

Hardware:

- HP Pavilion f1703
- HP Paviolion ZD7000
- IBM Speech Recognition Microphone/Headset
- Pre-amp Mixer

Software:

- IBM Speech Recognition Software
- Windows XP Professional
- Nero WaveEditor
- Araxis Merge
- MINITAB 14 Statistical Software

PROCEDURES:

The purpose of this lab was to experiment with speech recognition software in such a way as to determine some of the limitations inherent with such a system. The first step in accomplishing this was to first install the IBM Speech Recognition software. Part of the installation process includes training the software to recognize the user's voice and speech patterns. In order to properly train the software, there are several text excerpts that the user reads to the software, as it analyzes the speech and habits of the user. After several hours of reading, the software was able to dictate the user's text with a fair degree of accuracy. The following shows a sample of actual text as compared to the dictated text of the software:

Actual Text

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I am going to dictate text from a computer magazine.  Essentially video projectors
enhanced with sensors to gain information about the environment, smart projectors do not
require artificial canvases and allow correct projection of images onto many arbitrary
existing surfaces, such as papered walls or curtained windows.
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Dictated Text

```
I am going to dictate text from a computer magazine.  Essentially video projectors
financed with sensors to gain information about the environment, with smart to projectors
do not require artificial canvases and all-out correct projection of the images onto when
many arbitrary existing services, such as paper the walls or pretend windows.
```

The next step was to create a sample reading that would be used for the experiments. In order to reduce variations and to control the experiments as much as possible, the user read several paragraphs from a magazine article and digitally recorded the reading for later playback. The text was selected from "Embedded Entertainment with Smart Projectors" (*Computer*, IEEE Computer Society, January 2005 p 49). Please see page 10 of the Appendix for the complete text that was selected for the experimentation. Nero WaveEditor was used for the recording, and the recording was saved to the computer's hard drive. The recording was set for CD-quality to ensure a playback quality that would not affect the user's normal voice pattern. Once the text had been recorded and saved on the hard drive, the recording noise was analyzed and reduced by the software to ensure a clear sound of the user's voice. The recording levels were also normalized to ensure that the volume would be adequate without distorting the signal output.

Once the original recording was prepared, several variations of the recording were created using Nero's built-in digital effects and enhancers. A list of the variations is provided below.

- Same pitch, 150% speed
- Same pitch, 200% speed
- Same pitch, 75% speed
- Same pitch 50% speed
- Higher pitch, same speed
- Lower pitch, same speed
- Reverb added
- White noise added

Having made several variations of the recording, a separate computer was set up to play the recordings. This computer had the signal output fed into a preamp mixer in order to control the gain of the signal. The mixer was then connected to the speech recognition computer through the microphone input. Several of the sample audio files were played back while adjusting the gain of the mixer until the volume level matched the natural volume level while connected to the headset. By doing this, a virtual microphone was created to feed input into the speech recognition software, eliminating ambient noise and variation in microphone gain. Thus a controlled environment was created for the experiments.

Each of the recording variations was played back to the speech recognition software's dictation application three times. The original (without enhancement or variation) recording was also played for the dictation application three times.

Some general observations of the dictated text showed interesting results. For example, the readings at slower speeds showed that the dictation system would often misinterpret a single word as two or more words. Additionally, if the reading was too fast, the dictation system would not be able to keep up, and would miss virtually the entire reading. Also, with the slower dictations, each of the three trials were quite different, despite the fact that virtually all bias was removed from the trials, thus they should have given the same results (in theory).

The next step was to create some sort of standard for measuring the accuracy of each dictation. This created a unique difficulty in that the way the speech recognition software dictates text, the dictated text may have a variety of errors, such as spelling errors, single words being dictated as two or more words (and visa versa), missed words, or even entire sentences being removed.

In order to be consistent with measuring the accuracy of the dictations, a differential text analyzer, Araxis Merge, was downloaded on a 30-day trial. This software allows for the comparison of multiple documents and highlights differences between documents for easy perusal.

To analyze the dictations, each of dictated documents was compared to the original text. The un-altered recordings were also compared to the original text. The differences were then counted and entered into MINITAB 14 for regression analysis. It should be noted that not all of the dictations could be counted for errors. Several of them varied from the original text so much that no similarities between the two could be found. The following dictations could not be counted due to such a major variance from the original text (please refer to page 18 of the Appendix for the results of error counts that the various dictations produced):

- 200% Speed, same pitch
- Higher pitch, same speed
- Lower pitch, same speed
- 50% Speed, same pitch

. The first analysis gave the following results (from MINITAB):

```
The regression equation is
Changes = 17.3 + 46.3 Echo + 9.33 Fast + 20.7 Noisy + 83.3 Slow

Predictor    Coef  SE Coef      T      P
Constant   17.333    4.093   4.23  0.002
Echo       46.333    5.789   8.00  0.000
Fast        9.333    5.789   1.61  0.138
Noisy      20.667    5.789   3.57  0.005
Slow       83.333    5.789  14.40  0.000
```

These results show that the speech recognition software seems to deal with a 150% speed increase fairly well, and that it can also handle the insertion of noise into the system with a fair degree of accuracy. The existence of a reverberating sound also negatively affects the accuracy of the dictation system, but does not have as much of a negative impact as does reducing the reading speed to 75%. However, as these numbers are considered, we also note that the 150% reading coefficient is only sure to about a probability of 86%, which is statistically rather low for making any reasonable conclusions. For this reason, the analysis was run once again, removing the 150% speed from the analysis. The following results were obtained from MINITAB:

```
The regression equation is
Changes = 22.0 + 41.7 Echo + 16.0 Noisy + 78.7 Slow

Predictor    Coef  SE Coef      T      P
Constant   22.000    3.098   7.10  0.000
Echo       41.667    5.365   7.77  0.000
Noisy      16.000    5.365   2.98  0.012
Slow       78.667    5.365  14.66  0.000
```

This second analysis showed that each coefficient is accurate to a probability greater than 98%. Once again, it shows that noise does not affect the system as much as does the variance of speed. Or rather, that the level of noise used in this experiment does not affect the system as much as the speed changes used in this experiment.

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REPORT:

The experiments outlined in the procedures of this document provided the following experimental results:

- Noise (at the level of noise used for this experiment) has the weakest negative impact on the dictation system.
- Reverberation (or echo) also has a small, but noticeable negative impact on the dictation system.
- Reading too fast causes the dictation system to miss almost all dictated text.
- Reading too slow causes the dictation system to misinterpret a word as multiple words.
- Varying the reader's pitch, or tone of voice, creates a strong negative impact on the dictation systems ability to interpret reading.
- For those trials in which the dictation system was most in error, each of the three trials resulted in dictations very different from one another (while in theory, they should be very close to the same).

From these results, it can be concluded that there are many factors that affect the ability of speech recognition systems to properly interpret dictations. Ambient noise appears to be something that the system can handle relatively well, while variations in the reader's speed, tone, or pitch appear to have an extremely negative impact on the ability of the system to properly dictate text.

Furthermore, there appears to be some degree of randomness, pseudo-randomness, or "guessing" as the system dictates text. This conclusion was drawn based on the extreme differences in dictated text for each of the three trials for which the system had the most difficulty interpreting. For example, at 50% speed, the system did not appear to correctly interpret the text at all. However, rather than having similar results for each of the three trials, each trial was quite different than the other two, which alludes to the idea that some form of learning may be taking place. This is probably some sort of neural network or other type of learning algorithm in which the system is attempting to adapt to the user.

CONCLUSIONS:

The results of this lab can be considered a success in light of the fact that each objective of the lab was met. Consider the following questions:

- How does ambient noise affect speech recognition?
  - Ambient noise does have a negative impact on the accuracy of the speech recognition system. However, the system appears to be able to handle noise relatively well, compared to other elements of change that were introduced into the system.
- How do pitch and vocal harmonics affect speech recognition?
  - This can not be quantitatively measured, due to the fact that the negative impact was so great that a quantitative conclusion could not be drawn. Nevertheless, it can be concluded that such changed dramatically affect the ability of the system to correctly dictate text. This further solidifies the importance of the system to be “trained” specifically to the reader’s voice.
- How does speaking speed affect speech recognition?
  - This is similar to the affect of changing pitch, although slightly faster reading was still relatively accurate. A reader’s tempo or speed of dictation is one of the factors that the system uses to learn the habits and style of the reader. Therefore, altering that speed too much will cause the system to misinterpret what the user is saying.
- How does reverberation affect speech recognition?
  - Reverberation has a similar affect to ambient or other types of noise. It does negatively impact the system, but still allows for a fairly accurate dictation (in comparison to the other experimental trials).

This lab produced very enlightening and interesting results. This lab helps to highlight some of the difficulties that speech recognition systems encounter, and heightens the student’s appreciation for the complexity of such systems. There are many ways that a reader can vary the manner in which they dictate text, and it is difficult to accurately interpret speech when so many factors are present. This also gives insight into the amazing ability for the human mind to be able to correctly understand speech. A human can encounter an individual they have never met before, and can still understand speech with amazing clarity. This can even be accomplished in crowded areas, with a great amount of noise, and even with dramatic inflection or variance in speaker's speech patterns.

Some suggestions for future study have also evolved from the results of this experiment. Future research should include a comparison between multiple users as well as multiple speech recognition programs. It would be interesting to understand some of the differences between speech recognition systems and their unique learning methods. It would be interesting to discover the "best" or most accurate speech recognition system commercially available (for a reasonable price). It would also be interesting to study how the reader's volume affects the dictation system. Would a louder voice be easier or more difficult to understand? Would a softer voice have greater clarity, or cause misunderstandings in the speech recognition system? Another element would be the equipment used; would different microphones affect the system dramatically?

Speech recognition technology is complex and very interesting. It is something that is both frustrating and enjoyable. This lab was successfully able to introduce some of the complexities of such systems to the student, while also deepening the student's understanding of speech pathology in general.

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APPENDIX:

Text selected for dictation (*Computer*, IEEE Computer Society, January 2005 p 49):

Creating Virtual projection canvases the smart projector concept combines camera feedback with structured light projection to gain information about the screen surface and the environment. Calibrating the system does not require having information about either the surface geometry or the internal or external parameters of the projector and camera. This makes the system extremely robust and easy to use crucial attributes for home entertainment and similar application. The modular camera component can be detached from the smart projector's projection unit for calibration. It must be temporarily placed approximately at the observers' optimal viewing location or sweet spot pointing at the screen surface as figure 1a shows. The projection unit can be placed at an arbitrary location. Its light frustum must also cover the screen surface area. During calibration, the camera mimics the target perspective the optimal viewing position for which the projection unit will be calibrated. The user can either define the display area by sketching the outlines of a virtual projection canvas over a portion of the camera image or derive it automatically from the margins of the camera's field of view. The calibration process compensates for camera lens distortion at the start to provide video images without radial distortion. the system then determines all parameters required for real-time geometric predistortion and color correction of video frames delivered by a PAL/NTCS-compliant device such as a DVD player or game console. The fully automated calibration process takes less than 30 seconds with the chosen hardware configuration.

Echo – trial 1:

Kriendler he will reject any but calibrated as does not require having an information about either this is geometry or the internal or extern of all parameters are * of the projector and camera. A This makes the system extremely robust ahead and easy-to-use crucial I The modular the camera complement and can begin tackling this local projector's the projection unit It must is this is as if you the projection unit can then place a at a former First locations. He's it's like I frustum must also 3 Ronald Reagan in, who Camel many of its cars are for Detective at the optimal viewing position full with a projection unit to use and can either The system then determines all of rounders ecclesiastics compliance he I cite such data he player organdy consul The fully automated calibration each processor takes less the other is as with the chosen hardware or an ungracious. Third

Echo – trial 2:

Creamier will projection Johanneses with the supplier file projector's consul at combines how happy that at structured like a high-tech and again informations about a screen surface of San and mine. He wrote calibrating the system does not require have had information about either this is held her the or the internal or extern all the parameters are * of the projector and had her heart. This makes the system extremely robust the health easy-to-use crucial I hadn't for home The modular the camera complement and can begin tackling on this local projector's the projection unit It mustThe the pre distortion of the video frames and delivered live by a key 8 L/I and he suggests after complaining-Chadli he player The fully automated and calibration of processing takes less the other is the seventh for chosen hardware

Echo – trial 3:

This will help projector's, I'm I'm I'm unhappy-structured like I have to gain information about acid rain surface of fan and I have. Calibrating of as of does not of Fiat had mentioned about either for the internal civil extern all planners if of the projector hah hah. This may the system extremely robust of health easy-to-use crucial I have had for home the model live camera complement of can be detached eye on this eighth must the. The projection unit and half place at Harvard for in location. Its light either crushed must also cover during Ronald Reagan, who the users had a final display area hit by such a view held on half a virtual projection canvas of labor portion of how men and if war derided the hot and I hadn't from the margins the calibration process compensates it is Camel lands distortion and have the start of the flight ideal images live without the system then determines all the the video frames delivered River by a key 8 L/adhesive USF compliance The fully automated the calibration of process takes less less than 30 is the seventh for the chosen hardware

Speed 150% - trial 1:

Creating virtual projection canvases the smart projector concept combines camel feedback for structured like projection for the information about the screen surface and the environment. Calibrating the system does not require having information about either the surface geometry or the internal or extern all parameters of the projector and camera. This makes the system extremely robust and easy-to-use crucial attributes for home entertainment and similar applications. The modular camera complement can be detached from the smart projector's projection Unit calibration. It must be temporarily placed approximately at the observers optimal viewing location or sweet spot in pointing at the screen surface as figure 18 shows. The projection unit can be placed an arbitrary location. Its light frustum must also cover the screen surface area. During calibration, the camera mimics the target perspective the optimal viewing position for which the projection unit will be calibrated. The user can either define the display area by sketching the outlines of a virtual projection canvas over a portion of the camera image worked derided automatically from the margins of the cameras field of view. Third the calibration process compensates for Camel lands distortion at the start to cry feel images without a field distortion. The system then determines all and color correction of view frames delivered by eight P A L/N T C S compliance device such as a DVD player or gain consul. The fully automated calibration process takes less than 30 seconds with the chosen hardware configuration.

Speed 150% - trial 2:

Creating virtual projection canvases the smart projector concept combines camel feedback with structured like projection to gain information about the screen surface and the line. Calibrating the system does not require having information about either the surface geometry or the internal or extern all parameters of the projector This makes the system extremely robust and easy-to-use crucial attributes for home entertainment and similar applications. The modular camera, one can be detached from the smart projector's projection Unit calibration. It must be temporarily placed thoughtfully at the observers optimal viewing location or sweet spot leading at the screen surface as figure 18 shows 50 the projection unit can be placed an arbitrary location flight frustum must also cover the screen surface area. During calibration, the camera mimics the target perspective the optimal viewing position for which the projection unit will be calibrated fifth user can either define the display area by sketching the outlines for a virtual projection canvas over a portion of the camera image worked derided her automatically from the margins of the cameras field the calibration process compensates for Camel lands distortion at the start for live video images without real fortune if the system then determines all parameters required for real time geometric pre distortion and color correction for the video frames delivered by a key 8 L/N T C S compliance device such as a DVD player who fifth The fully automated calibration process takes less than 30 seconds to finish fifth

Speed 150% - trial 3:

Creating virtual projection canvases the smart projector concept combines camel feedback with structured like projection to gain information about the screen surface and the fine fifth calibrating the system does not require having information about either the surface geometry or the internal extern all parameters of the projector This makes the system extremely robust and easy-to-use crucial attributes for home entertainment and similar applications fifth The modular camera complement can be detached from the smart projector's projection Unit for calibration. It must be temporarily placed approximately at the observers optimal viewing location for sweet soft landing at the screen surface as figure 1 a show of grief the projection unit can be placed an arbitrary location its light frustum must also cover the screen surface area. During calibration, the camera mimics the target perspective the optimal viewing position for which the projection user can either define the display area by sketching the L one for a virtual projection canvas

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over a portion of the camera image worked derided a automatically from the margins of the
cameras field calibration process compensates for Camel lands distortion at the start for
like the images without little fortune for if the system then determines all parameters
required for real time geometric pre distortion and color correction for the video frames
delivered by a key 8 L/N T C S compliance device such as a DVD player or gain consul
fifth fully automated calibration process takes less than 37 chosen hardware
configuration for if
```

Speed 200% - trial 1:

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The The modular camera often be detached from the fifth
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Speed 200% - trial 2:

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Leading The modular
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Speed 200% - trial 3:

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This the if Florida modular felt they should fifth fifth month if in the early fifth of
the fifth half if the birth of flight frustum fluff also often well of fly calibration
process the five villages without of the flesh this is the vendor from the Gulf prowlers
fly if all the of the video for a half the level of flying a key 8 L
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Raised pitch – trial 1:

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The small and Jeff the concept
This the fifth is a fellow who feel modular camera complement can detached from it as
soon for calibration fifth light frustum fluff also during often loath to fish and fowl
if projection of the unit can either define if The calibration process compensates for F
F for the fully automated calibration Falstaff fifth left off the effects
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Raised pitch – trial 2:

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The smart and Jaffa, theft
And feedback with structured all a lift if the not this the and a half for less The
slight frustum fluff also often the unit can either or of the line if automatically from
the margins of the calibration of process compensates for Camel lands distortion and a
half as far the system then in pre distortion and color correction the video frames a
field of inflame a key 8 L/N-3 1/2 from 55 such that
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Raised pitch – trial 3:

(no text was dictated)

Lowered pitch – trial 1:

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For small for found relief and for a veteran slight flesh off must also for real and
Hughes fell for of real friend few who fly a such of the fleet of of a live coverage of
the fifth with chosen
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Lowered pitch – trial 2:

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I'm fine relief fell of this whole and for and found similar of of if Polish of if if the
elephant who were leaflet The slight flesh of infant also live the system then from the
of land reform of whom will find few the light a fee A L L the chosen
```

Lowered pitch – trial 3:

For small figure for home for the full month healthy for the am of pointing of and for a veteran of the slight flush conflict also the and foreign Kuleshov of real friend to live by The fully what the hell would fall for the fifth with the offer is the chosen

Ambient noise – trial 1:

Creating virtual projection for canvases this month of Jeffrey concept finds camel feedback with structured like projection to gain the information about the screen surface and the fine fifth calibrating the system does not require having information about either the surface geometry or the internal extern of the projector and a half if this makes the system extremely robust and easy-to-use crucial lack of view The modular camera complement can be detached from this month projector's projection Unit calibration 585 be temporarily placed froth of the taffy of the rivers of the movie location for sweet spot pointing have the screen surface as figure 1 a shows 50 the projection unit can you placed at an arbitrary location. The slight frustum must also cover of screen surface area. During calibration, the camera mimics the target perspective the optimal viewing position for with the projection unit will be calibrated 50 user can either define the display area by sketching the telephone off the virtual projection canvas over a portion of the camera image worked derided automatically from the margins of the cameras field of view. The calibration process compensates for Camel Lance distortion half the start to provide video images without the system then determines all parameters required for real time geometric pre distortion and color correction the video frames delivered by a key 8 L/N T C S compliance device such as a DVD player or gain consul. The fully automated calibration process takes less than 32nd with the chosen hardware figure a chef.

Ambient noise – trial 2:

Creating virtual projection canvases this month projector concept combines camel feedback with structured like projection to gain information about the screen surface and the fine. Calibrating the system does not require having information about either the surface geometry or the internal extern all parameters of the projector and am the fifth This makes the system extremely robust and easy-to-use crucial lack of view for home entertainment and similar applications fifth The modular camera complement can be detached from the smart projector's projection Unit calibration fifth it must feel temporarily placed froth of the at the observers often will viewing location for sweet spot pointing have the screen surface as figure 1 a show of. The projection unit can be placed at an arbitrary location if light frustum must also cover of screen surface area during calibration, the camera mimics the target perspective the optimal viewing position for with the projection unit will be calibrated fifth The user can either define the display area by sketching the outlines of a virtual projection canvas over a portion of the camera image worked derided automatically from the margins of the cameras field of view. The calibration process compensates for Camel Lance distortion half the start to fly video images without a field for a shelf. The system then determines all parameters required for real time geometric pre distortion and color correction if the video frames delivered a key 8 L/N T C S takes less than chosen hardware figure a shove.

Ambient noise trial 3:

Creating virtual projection canvases the smart projector concept combines camel feedback with structured like projection to gain information about the screen surface and the fine. Calibrating the system does not require having information about either the surface geometry or the internal or extern all parameters of the projector and am the fifth This makes the system extremely robust and easy-to-use crucial attributes for home entertainment and similar applications fifth The modular camera complement can be detached from the smart projector's projection Unit calibration fifth it must be temporarily placed froth of the at the observers often will viewing location for sweet spot pointing have the screen surface as figure 18 shows. The projection unit can be placed at an arbitrary location if light frustum must also cover of screen surface area. During calibration, the camera mimics the target perspective the optimal viewing position for with the projection unit will be calibrated fifth user can either define the display area by sketching the outlines of a virtual projection canvas over a portion of the camera image worked derided automatically from the margins of the cameras field of view. The calibration process compensates for Camel Lance distortion half the start to provide video images without the system then determines all parameters required for real time geometric pre distortion and color correction if the video frames for delivered a key 8 L/N T C S compliance device such as a DVD player or gain consul The fully automated calibration process takes less than 30 seconds chosen hardware figure a chef.

75% speed – trial 1:

Creating virtual of projection canvases the smart projector confect death can the gain information of the of the for an surface and the fine calibrating this fifth does not acquire have an inflation and about either the surface geometry floor of the internal of the projector have had the fifth fifth emphasis the next frame live robust crucial Latvia for home the fifth half and similar applications 50 The modular camera complement can be detached from lists of projects the projection unit of calibration and 50 if they must fifth have rarely plays often the free have a live zeroth of the movie location ... the flaw as figure 18 show if light frustum must also cover the screen surface three calibration and, if Hammond in the fifth target for this affect often leaving physician live if projection The user can either define the display area by 15 the outlines for for a virtual projection canvas over a portion of the live if automatically if of hemispheres of the few figure if calibration for process compensates for Camel Lance distortion and half the start fifth life video images without for a field fluxion fifth the system then determines all parameters required legal fine for geometric pre distortion if and color correction the video frames fly a A L flash of any conflict F. Flynn client for e-such that they the heat flared for gain consul The fully automated calibration process takes less than 30 affect half chosen hardware for the Federation

75% speed – trial 2:

Creating the smart for Jeff the confect the gain information and a half of this kind of surface and the fine 50 calibrating this fifth does not look quite as have an inflation and about either of this with his geometry floor of the internal of the for deficit have hon this late physicist from the extremely robust and easy ViaVoice crucial as if he flew home the fifth half and similar applications 50 The modular can be detached from this Monfort deficit for the action of unit will calibration of fear if they often have little early for a flaw fluffy have a live of liftoff of all of the location and fiercely fought one thing and have 15 the surface as figure 1 a show if light frustum must also cover if screen surface during calibration and, of Hammond and if the target first the fifth of the mole viewing position live projection unit The user can either define deflate area by 15 free alkaline they virtual projection of have this for over a portion of warfare derided automatically from the margins for of the hemisphere the calibration process compensates for Camel Lance distortion and half the start for live video images without this system then determines all parameters for quiet who feel geometric pre distortion and and color correction and the video frames delivered for flay a fee 8 L/N for free S line 5 such that player or gain consul the fully automated calibration process eighth left in the relief effort chosen hardware your age

75% speed trial 3:

Creating virtual and if if this mark projector confect combines camel feedback 15 information from the of this fund surface and the calibrating this fifth does not look why have an information about either the surface geometry floor of the internal level ethanol flattened if projector and found the fifth fifth and eighth with an increasingly robust and free life crucial I feel for home and fifth half and similar The modular can be detached from the smart projector is calibration and fear if the if the defense clearly for a flawed from the heat half the if zeroth of the mold of the location forcefully fought one thing had 15 after fifth as figure 8 shows 50 if fifth light frustum must also cover during calibration and, of Hammond in the fifth target for effective the office will view physician full if projection unit flew the user can either define the display area of the virtual projection canvas over a portion of Hammond and if you were derided automatically from the margins of hemispheres of the calibration process compensates for Camel Lance distortion and have the start of live video images for with

Hal gave the floor chef if the system then determines all parameters fly if legal fine geometric pre distortion and color correction of the video frames delivered by a key 8 L/N 50 Fred S. fly if fed data gave free flair for the end of consul 50 The fully takes less than their affect half the chosen hardware

50% speed – trial 1:

14 earth shall leave Jeff and hand this if this small have a head for the confidence of the end for Hamilton the fat live should cut should lie ahead if 15th information the of the for an surface and the fine if if if if calibrated if this does not look all I have an inflammation and of about either this the fifth geometry Flora fee for the inferno leveled X terminal flatten if of the project could have haoma if late physicist and philosopher mainly of robust and free T D Lewis crucial I feel for home and and Finland half of page the monumental of hand the complement can be fifth half from this small effort share for this projection unit flew calibration if if if if for the philosophy of him literally coffin the police have the if you're of liftoff and zero of the law of Haitian Flores fleet flaw one of the half 15 after this as figure Delaunay a show live here if the projection unit for an hadn't the heart of affairs if of a chef he a fifth lie a flash flood month also cover of this screen surface office said 3 Live howl of rage and, if Hal fund then if the the office will viewing position and flow with projection unit flew of the howl of rage if. The user can either define if Larry F. they virtual projection for half this for over a portion of Hamlin and if she who were of far half of the ham is field live he The calibration Foss thus, Safeco of Hamel left and for distortion and at half the start to fly if video images without flourish and fears if this system then determines all floundered for a while I if for real fine for geometric pre distortion and the whole of correction the video frames delivered by a fleet 8 L/N five free S compliance thus shall they flee from flares for four of the Coughlin the fully allotted a calibration Foss half eighth left in their the Fed can show off how are aware of view a chef

50% speed – trial 2:

Canadian fur for school projection of an emphasis this fall of death of confect the fact fluffs fell after of life for a heck chef Steve gain information and of the of the office and surface and the fine calibrating this fifth does not look quite as half an inflammation and of about either of this surface geometry Laura feet he left her alone live S of the for a share after it had found the fears this late physicist and I freely of growth less half free he lost crucial I feel for home after unfair and similar applications 50 if the model Hill of half the, foeman and be detached from this small of her death could for Jeff Shekhinah of calibration hear a laugh flimflam for clearly caught some of the at the observers often involve he leaned of Haitian and forcefully flock one in fiend have this spring after if this as figure 1 a shelf life. The projection unit and flakes and hard of very low of Haitian if live must also cover of screen surface area fit if during the howl of rage and, if Hamelin and then if the target for the effect if the office will fuel a physician and lifts projection unit flew the user can either define the display area by 15 of the House of one-half of the a virtual projection of hand this over a flourishing and of Hamilton in the fifth who were derided automatically from the margins of of how misfeasance of a fee from 50 if the calibration Frost says confidence they flow of Hamelin if distortion and half his start flying live video images without flourish difficulties if this system then determines all floundered fly if for real fine pre distortion and color correction the video frames delivered by a 88 L/N T chiefly S Have they left free player if Levine for consoles. The fully eighth left and further the Fed half fluff are Valera

50% speed – trial 3:

And fifth fifth fifth fifth fifth this fall dead on Fed has felt the fifth light hit half the Vienna and for only a half an define fell over a if the fourth half of all I have lifted off the fluff Jeff could have had the fifth lift fifth definitely rolled left and foofaraw laugh have the in the fifth half the and this fall for it did fit Cal for a chef from if half the fifth half fifth if if offer of zero free to deflect off if fell half have fifth and fifth if they have half of for if the Fed left define for us all a joke if in fact there if Hoffa off if the effects of official and lift the huge live and either define if play S A F have laughed half if they fell a half of an INF if of MA 1/2 half if the fifth If if for the Salvation froth, if they live Hamelin flow a half if the fifth off live fifth defended from the fall

Normal reading – trial 1:

Creating virtual projection canvases this mark projector concept combines camel feedback with structured like projection to gain information about the screen surface and the environment. Calibrating the system does not require having information about either the surface geometry or the internal or extern all parameters of the projector and a camera. This makes the system extremely robust and easy-to-use crucial attributes for home entertainment and similar applications. The modular camera complement can be detached from the smart projector's projection Unit Corp. It must be temporarily placed approximately at the observers optimal viewing location or sweet spot pointing at the screen surface as figure 18 shows. The projection unit can be placed an arbitrary location. Its light frustum must also cover the screen surface area. During calibration, the camera mimics the target perspective the optimal viewing position for which the projection unit will be calibrated. The user can either define the display area by sketching the outlines of of a virtual projection canvas over a portion of the camera image worked derided automatically from the margins of the cameras field of view. The calibration process compensates for camera lens distortion at the start to provide video images without a field distortion. The system then determines all parameters required for real time geometric pre distortion and color correction of the video frames delivered by eight P A L/N T C S compliance device such as a DVD player or game consoles. The fully automated calibration process takes less than 30 seconds with the chosen hardware configuration.

Normal reading – trial 2:

Creating virtual projection canvases the smart projector concept combines camera feedback with structured like projection to gain information about the screen surface and the environment. Calibrating the system does not require having information about either the surface geometry or the internal or extern all parameters of the projector and camera. This makes the system extremely robust and easy to use crucial attributes for home entertainment and similar applications. The modular camera complement can be detached from the smart projector's projection Unit Corp. It must be temporarily placed approximately at the observers optimal viewing location or sweet spot pointing at the screen surface as figure 18 shows. The projection unit can be placed at an arbitrary location. The slight frustum must also cover the screen surface area. During calibration, the camera mimics the target perspective the optimal viewing position for which the projection unit will be calibrated. The user can either define the display area by sketching the outlines of a virtual projection canvas over a portion of the camera image or derided automatically from the margins of the cameras field of view. Third the calibration process compensates for Camel lands distortion at the start to provide video images without a field distortion. The system then determines all parameters required for real time geometric pre distortion and color correction of the video frames delivered by a key 8 L/N T C S compliance device such as a DVD player or gain consul. The fully automated calibration process takes less than 30 seconds with the chosen hardware configuration.

Normal reading – trial 3:

creating virtual projection canvases the smart projector concept combines camera feedback with structured like projection to gain information about the screen surface and the environment. Calibrating the system does not require having information about either the surface geometry or the internal or extern all parameters of the projector and camera. This makes the system extremely robust and easy-to-use crucial attributes for home entertainment and similar applications. The modular camera complement can be detached from the smart projector's projection Unit Corp. It must be temporarily placed approximately at the observers optimal viewing location or sweet spot pointing at the screen surface as figure 18 shows. The projection unit can be placed at an arbitrary location. Its light frustum must also cover the screen surface area. During calibration, the camera mimics the target perspective the optimal viewing position for which the projection unit will be calibrated. The user can either define the display area by sketching the outlines of of the virtual projection canvas over a portion of the

Jeremiah K. Jones

camera image worked derided automatically from the margins of the cameras field of view. The calibration process compensates for Camel Lance distortion at the start to provide video images without a field distortion. The system then determines all parameters required for real time geometric pre distortion and color correction of the video frames delivered by 830 A L/N T C S compliance device such as a DVD player or game consoles. The fully automated calibration process takes less than 30 seconds with the chosen hardware configuration.

Jeremiah K. Jones
Lab: I/O Labs 3-5
Duration – **3 weeks**
Completed on: **8/7/2005**

MINITAB 14 Complete Output

Echo	Fast	Fastest	High	Low	Noisy	Slow	Slowest	Changes
1	0	0	0	0	0	0	0	55
1	0	0	0	0	0	0	0	58
1	0	0	0	0	0	0	0	78
0	1	0	0	0	0	0	0	26
0	1	0	0	0	0	0	0	26
0	1	0	0	0	0	0	0	28
0	0	1	0	0	0	0	0	*
0	0	1	0	0	0	0	0	*
0	0	1	0	0	0	0	0	*
0	0	0	1	0	0	0	0	*
0	0	0	1	0	0	0	0	*
0	0	0	1	0	0	0	0	*
0	0	0	0	1	0	0	0	*
0	0	0	0	1	0	0	0	*
0	0	0	0	1	0	0	0	*
0	0	0	0	0	1	0	0	48
0	0	0	0	0	1	0	0	37
0	0	0	0	0	1	0	0	29
0	0	0	0	0	0	1	0	99
0	0	0	0	0	0	1	0	102
0	0	0	0	0	0	1	0	101
0	0	0	0	0	0	0	1	*
0	0	0	0	0	0	0	1	*
0	0	0	0	0	0	0	1	*
0	0	0	0	0	0	0	0	17
0	0	0	0	0	0	0	0	17
0	0	0	0	0	0	0	0	18

2/1/2005 11:53:36 PM

```
Welcome to Minitab, press F1 for help.
```

Regression Analysis: Changes versus Echo, Fast, ...

```
* Fastest has all values = 0
* Fastest has been removed from the equation.


* High has all values = 0
* High has been removed from the equation.


* Low has all values = 0
* Low has been removed from the equation.


* Slowest has all values = 0
* Slowest has been removed from the equation.


The regression equation is
Changes = 17.3 + 46.3 Echo + 9.33 Fast + 20.7 Noisy + 83.3 Slow
```

```
15 cases used, 12 cases contain missing values


Predictor    Coef  SE Coef      T      P
Constant   17.333    4.093   4.23  0.002
Echo       46.333    5.789   8.00  0.000
Fast        9.333    5.789   1.61  0.138
Noisy      20.667    5.789   3.57  0.005
Slow       83.333    5.789  14.40  0.000


S = 7.08990   R-Sq = 96.4%   R-Sq(adj) = 95.0%


Analysis of Variance

Source          DF       SS      MS      F      P
Regression       4  13520.3  3380.1  67.24  0.000
Residual Error  10    502.7    50.3
Total           14  14022.9


Source  DF   Seq SS
Echo     1    777.6
Fast     1   1444.0
Noisy    1    882.0
Slow     1  10416.7


Unusual Observations

Obs  Echo  Changes    Fit  SE Fit  Residual  St Resid
  3  1.00    78.00  63.67    4.09     14.33     2.48R

R denotes an observation with a large standardized residual.
```

Normplot of Residuals for Changes

Residuals vs Fits for Changes

Residual Histogram for Changes

Regression Analysis: Changes versus Echo, Noisy, Slow

```
The regression equation is
Changes = 22.0 + 41.7 Echo + 16.0 Noisy + 78.7 Slow


15 cases used, 12 cases contain missing values


Predictor    Coef  SE Coef      T      P
Constant   22.000    3.098   7.10  0.000
Echo       41.667    5.365   7.77  0.000
```

```
Noisy      16.000    5.365   2.98  0.012
Slow       78.667    5.365  14.66  0.000


S = 7.58787   R-Sq = 95.5%   R-Sq(adj) = 94.3%


Analysis of Variance

Source          DF       SS      MS      F      P
Regression       3  13389.6  4463.2  77.52  0.000
Residual Error  11    633.3    57.6
Total           14  14022.9


Source  DF   Seq SS
Echo     1    777.6
Noisy    1    235.1
Slow     1  12376.9


Unusual Observations

Obs  Echo  Changes    Fit  SE Fit  Residual  St Resid
  3  1.00    78.00  63.67    4.38     14.33      2.31R

R denotes an observation with a large standardized residual.
```

Normplot of Residuals for Changes

Residuals vs Fits for Changes

```
Residual Histogram for Changes
```

2/6/2005 1:18:06 AM

```
Welcome to Minitab, press F1 for help.
Retrieving project from file:
'C:\DOCUME~1\JEREMIAH\MYDOCU~1\SCHOOL\GRADSC~1\IT650\LABS3-~1\MINITAB.MPJ'
```