Abstract
In traditional computing, interfaces are designed with the assumption that they are the main focus of a user's attention. In wearable computing, these interfaces are unacceptable; wearable computers are mobile, and often receive far from full attention, while being used in a variety of situations.
The gesture glove is a type of interface with promise as a wearable solution. However, gesture input suffers from user confusion in cases where the user is in a different orientation than expected—particularly, when the user cannot see the relation of the glove to the ground, or the relation of the glove to the body.

Author Keywords
The gesture recognition glove, gesture set, tool grips, environment effect, accelerometers

Introduction
We propose to address the issues of limited user attention, and the difficulty of gesture input as an all-purpose wearable interface due to difference in orientation, through the use of hand-relative gestures and haptic feedback. The context of our project is electrical line work. Workers will be able to use our glove to view manuals on-site, easily, and with little attention paid to the interface.

Context
The selected case study related to electrical maintenance is articulated through two specific scenarios, corresponding to typical maintenance situations:
- inspection of the electrical lines
- troubleshooting
These scenarios represent the background from which the activities of analysis, design and implementation of a suitable wearable application for maintenance support began. Inspection, removal, installation and troubleshooting are all information intensive processes. The maintenance operators have to decide in advance the information/documentation they might need to carry, along with all the tools and consumables they need to use.

Operators are thus normally overloaded with all the information support (usually in paper form) and with all the tools and materials needed for their work, as described in [3]. From this perspective, the main aspects that we have improved in part 2 of docuGest are:
- easy, comfortable and unobtrusive wearable components which work in harsh environments
- developing a gesture set which does not interfere with their work actions
- Allowing tool usage without affecting grip or hand positions

Project Description
The glove and gesture set have been designed for the operation of a document viewer, with four basic gestures—two orientation independent, for selecting a manual and going back to the menu, and two orientation-dependent, for turning to the next or previous pages. The glove communicates with the document viewer wirelessly, using Bluetooth.
The glove will has been modified with conductive patches on the palm, thumb, the side of the middle finger, and the tip of the ring finger, supporting the two orientation-independent gestures. Two three-axis accelerometers have been added to the back of the hand, and the difference of the data between these two accelerometers is used in the recognition of our two hand-relative gestures. In choosing the gestures and designing the glove, our aim was for as few accidental activations of the glove as possible. To that end, our gestures are very distinct.

Implementation
To extend the existing gesture set and to include orientation dependent gestures, we used two 3-axis accelerometers and fixed them on to the glove. These accelerometers were obtained from Arduino and are compatible with the Lilypad. They have been placed on the top part of the glove and are in opposite orientation to each other. Thus, we get two sets of data with values for each of the three axis. Using the two sets of data we are able to find a common set of values which map to a gesture. We are using the GART system (gesture and
activity recognition toolkit) to recognize a gesture based on the pattern of data that we have.

**Construction of the Glove (Modifications)**
The accelerometers have been placed as shown in the figure below. They have been attached (sown) to the glove using conductive thread. The orientation of the accelerometers is opposite to each other. This gives us the option of having a larger space to be mapped with an easy way of differentiating between the values. The accelerometers are small enough to be unobtrusively placed on the glove. This allows for easy movement during work.

**Figure 1: Accelerometers**

**Glove Stitching and Construction**
The complete glove with attached components is as shown in the figure below. It shows the arrangement of the lilypad and the accelerometers. Also, the power, ground and data lines for the accelerometers and the conductive patches have been stitched carefully in a way so as to have the minimum number of crossings between them. The power, ground and data lines are stitched parallel to each other and there is glue attached on joints to prevent stray pieces of thread hanging around. This reduces the potential risk of shorts. A combination of normal non conductive thread and the 4-ply conductive thread has been used, because of which the glove gets a better insulation from external factors such as dust and external particles which can cause shorts. Due to such a stitching pattern used, on the underside only the conductive thread is present and on the top side (exposed side), the normal non conductive brown thread is present. This also provides protection to conductive thread stitching.

**Figure 3: Stitching pattern on the inside**

There are two main advantages we can get from this technique
a. protection from dust and other external factors in work environment
b. holding tools with different grips without causing any obstruction or problems in gesture recognition.

We conducted experiments with dust namely, saw-dust and dirt from a vacuum cleaner. The glove still works with the same efficiency as in normal conditions.

<table>
<thead>
<tr>
<th>External factor</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saw dust</td>
<td>Works efficiently</td>
</tr>
<tr>
<td>Dirt</td>
<td>Work efficiently</td>
</tr>
</tbody>
</table>

The other potential external factors are oil and grease along with dirt and dust.

**Gesture Set**
The gesture set has been expanded to include two new gestures which are used for turning pages.
The gesture for turning the pages is as shown in the figure below. The gestures for next page and previous page are shown below.

<table>
<thead>
<tr>
<th>Gesture</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Previous page</td>
<td>Turn wrist clockwise with thumb touching middle finger</td>
</tr>
<tr>
<td>Next page</td>
<td>Turn wrist anticlockwise with thumb touching inner middle finger</td>
</tr>
</tbody>
</table>

For example: the gesture of previous page says that the wrist is turned clockwise with the thumb touching the middle finger (this acts like a switch) as it is unlikely that it can get activated unknowingly because the conductive patches are located in isolated positions (back half of the side of middle finger). In this part, we thus investigated the use of haptic feedback. Based on the orientation of the worker, the system will identify if the gesture has been correctly identified or not and it will activate the vibration motors which will be placed in appropriate places on the glove. We have not implemented a haptic feedback system, but it is proposed to be a future enhancement.

### Gesture Data Collection and Analysis

Data was collected following a simple procedure. Each of the project members wore the glove to generate test data. This was done by walking, sitting, and standing while using both hands to do a variety of simple tasks. While one group member wore the glove, another asked the wearer to perform a particular gesture while touching the ring-finger to the palm. The act of touching the ring-finger to the palm signified to the recording computer that the following was to be labeled as a gesture. In this way, a small dataset was created for each member of the team and one volunteer, labeled by whether or not a sampled piece of data was part of a gesture.

![Gesture Data Analysis](image.png)
These datasets were combined and given a time sequence attribute. The differences in the two accelerometers were computed, and the classification of the prior sample was added as a new feature. We used preliminary pattern recognition techniques to verify that a better sequential data prediction model was necessary. These techniques erroneously classified samples, and were found to be unusable; the data cannot be easily classified without a hidden Markov model implementation or similarly oriented model. A summary of the data is shown in Image A. offering a basic distribution of the data with respect to each attribute. The graph colors represent the data labeling: blue for regular activity, red for the first gesture, and cyan for the second. For example, the “xdiff” graph shows the value of the difference of the two accelerometers on the x-axis, and the number of samples that fit within a particular range of x-difference values on the y-axis. It also shows that only data past a particular x-difference threshold was labeled as a gesture, though further significant properties of the data are not so easily intuited.

User Studies
At the moment we are in talks of conducting a user study with workers from the Georgia Power company. A testing proposal has also been developed. The final wearable system will be as shown in the figure below. It shows a worker wearing the glove and a head mounted display with a PDA in the pocket. The PDA contains the documents and the document viewer.

Description of User Studies
1. Conduct Interviews to understand work environment
2. Understand grips and tools being used
3. Go on field to monitor orientations and different work positions (will help in haptic feedback)
4. Find out comfort levels of user wearing the glove over a long period of time
5. Expand gesture set and refine existing gestures
6. Obtain documents and diagrams and modify the software for controlling it accordingly.

Acknowledgements
Thanks to Dr. Thad Starner, Jiasheng He and Scott Gilliland for their valuable inputs and support.

References
1. Thad Starner, DanSiewiorek, Asim Smailagic. Application Design for Wearable Computing
4. Matt Luongo, Sudnya Padalikar, Kedar Toraskar, docuGEST A Gesture Recognition Glove for workers to view Training Manuals, October 2008, MUC Class

Figure 4: Worker wearing the complete docuGest Kit