Geophysical Software Ergonomics: Objective Measures for Evaluation

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Summary

The ubiquitous use of workstation and laptop -based geophysical applications for seismic interpretation presents a risk for injuries associated with computer use. While work has been done to decrease ergonomic risk for geophysical field personnel (Pearce and Shackel, 1979) the risk to office personnel has not been adequately quantified. In the past few years some geophysical applications have started to utilize ergonomic designs, but these tend to be related to field personnel usage or application in extreme environments.

SEISMIC INTERPRETATION
h – start horizon interpretation
u – set manual interpretation
g – set guided autotracking
a – set seeded 2D autotracking mode
Shift + a – set seeded 3D autotracking mode
r – paintbrush autotracking (resize + / -)
x – active box autotracking
f – start fault interpretation
e – select and edit / add points
Ctrl + z – undo
Ctrl + y – redo
Shift + x – eraser (resize + / -)
o – select composite section
w – draw arbitrary composite section
Shift + w – draw seismic aligned polyline section
PgUp / PgDn – moves seismic section by a given increment

DISPLAY WINDOW
v – viewing mode
p – select / pick mode
s – target zoom
m – manipulate plane
z – magnify
d – measure tool
Mb3 – open item context menu
F3 – change focus to the graphics window
Esc – toggle between view / last mode
Alt – temporary switch to view mode (hold down)
Mouse – rollerball zoom in / out

WELL CORRELATION
a – paint discrete log class
f – flood discrete log class
Shift + s – pick discrete log class
l – create / edit continuous log
Shift + c – create / edit comment log
i – create / edit image control points
t – create / edit well top
s – add new well top surface
PgUp / PgDn – large movement
↑↓ – medium movement
Shift + ↑↓ – fine movement
(+) / (-) – zoom in / out

PILLAR GRIDDING
Shift + a – set arbitrary direction
Shift + b – set part of grid boundary
Shift + i – set I direction
Shift + j – set J direction
n – set number of cells on connection
b – create external grid boundary
i – new I trend
j – new J trend
Shift + p – show points in polygons

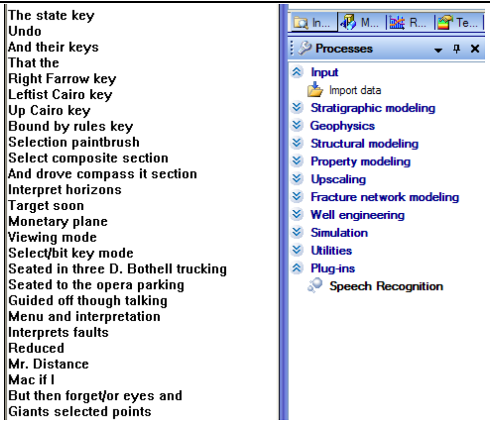
EXPLORER
→← – open / close folders
↑ ↓ – traverse tree
Typed characters – go to next match
Space – toggle display / undisplay item
Enter – toggle activate / deactivate item
Alt + Enter – open item settings dialog
Menu – open item context menu
Esc – close open context menu
F2 – rename item directly in tree

GLOBAL
Ctrl + Tab – navigate windows / tabs
Ctrl + t – focus to input explorer
Ctrl + l – focus to models explorer
Ctrl + r – focus to process diagram
Ctrl + u – view all
F1 – online help
F11 – toggle on full screen

Figure 1: Example set of "hot-keys" for a geophysical interpreation application

At the same time, the incidence of musculoskeletal disorders (MSDs) has been on the rise. An analysis of incident reports verifies that for oil and gas companies, up to 40% of reported lost-time incidents may be related to computer usage (Taylor, 2007), including eyestrain, and the cost for operators in lost productivity and medical costs may be approaching that of more catastrophic and high visibility offshore injuries. The International Association of Geophysical Contractors lists Repetitive Strain Injury (RSI) due to poor ergonomics as one of the potential factors that could adversely affect health and welfare and should be considered in a Company health risk assessment (IAGC, 2004). The physical environment for interpretation can and has been improved to reduce RSI risk through the use of adjustable chairs, tables, keyboards and monitors. However, little research has been done investigating whether remaining injuries are directly associated with the software being used. One reason is the difficulty in measuring muscle strain (a predictor of muscle related injuries).

The degree to which the software being used is "RSI-friendly" may have an impact on software usability, interpretational efficiency, and ultimately an interpreter's health. Strategies to address software-related ergonomic risk can be formulated using standard hazard abatement techniques already established by the Safety, Health, and Environment (SH&E) discipline. In some cases, software design can be adapted to reduce RSI risk, such as by providing configurable "hot-key" setups (Figure 1) or providing interfaces to alternate input devices or voice recognition systems (Bednar and Bednar, 2001).



The state key
Undo
And their keys
That the
Right Farrow key
Leftist Cairo key
Up Cairo key
Bound by rules key
Selection paintbrush
Select composite section
And drove compass it section
Interpret horizons
Target soon
Monetary plane
Viewing mode
Select/bit key mode
Seated in three D. Bothell trucking
Seated to the opera parking
Guided off though talking
Menu and interpretation
Interprets faults
Reduced
Mr. Distance
Mac if I
But then forget/or eyes and
Giants selected points

Figure 2: Examples of voice recognition interpretation of common geophysical commands.

This approach may be limited by the specialized terminology used in geophysics (Figure 2). The potential for improvement in the ergonomic computing environment also depends on the degree to which the ergonomic fitness of individual applications and/or workflows can be measured. The software development industry has for many years routinely applied standard usability criteria to improve their products, but an accepted framework for assessing software ergonomic fitness is lacking. This paper is based on a multi-company effort to develop a tool for the purpose of quantifying an application's ergonomic risk. This tool is being tested and benchmarked to compare geophysical interpretation tools and identify areas for ergonomic improvement (Bishea, Wood and Muddimer, 2007).

Geophysical Software Ergonomics: Objective Measures for Evaluation

This paper presents results from a study on the relationship between objective and subjective measures of muscle strain during computer use by geotechnical professionals, based on pilot data investigating whether self-report measures of strain can approximate the actual muscle strain of software users.

Introduction

Software use is seismic interpretation can facilitate the accomplishment of many types of tasks. However, it also has the potential to cause injuries. Populations such as SEG members who spend many hours a day working on software that requires intense mouse usage have a high incident rate of Musculoskeletal Disorders (MSD) (Silverstein et al, 2000). These MSDs result in discomfort and pain for individuals and lost productivity for the companies who employ them. They also burden oil and gas employers with remediation and treatment costs. The annual costs to all U.S. employers are as high as twenty billion dollars (Brisson et al, 1999). In 2006, the Bureau Labor of Statistics (BLS) reported that MSDs accounted for 30% of total workplace injuries and illnesses. Workers who operate Visual Display Units (VDU) are one of the occupational groups with a high incidence of upper limb MSDs (Szeto and Ng, 2000).

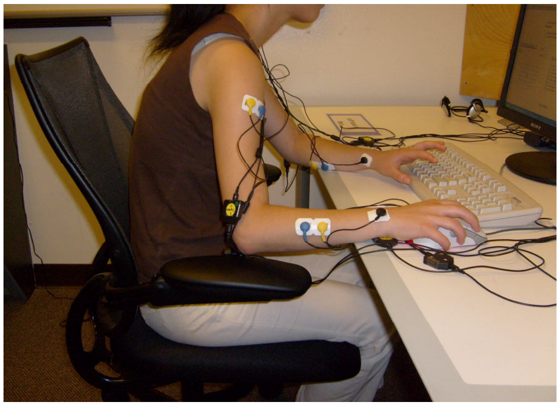


Figure 3: SEMG sensor, computer keyboard, and monitor placement used for the study.

Much of what we know about remediating these injuries is focused on ergonomic workstation adjustments to reduce injuries for the employees. Although these solutions are often successful, they have not eliminated the occurrence of these types of injuries (Ferreira and Saldiva, 2002). Further solutions are necessary to improve worker health and reduce the costs of MSDs. A potential solution is to change the design of software to reduce strain. A substantial amount of work has been done on ease of learning and use of software (Hornbik, 2006) but these usability goals do not address the muscle strain associated with software use. Usability professionals need to explore how software design can help in the effort to reduce injuries in the workplace.

Two important variables in the study of software ergonomics are objective and subjective measures of strain. One of the most predictive measures of MSD is muscle activity in the hands, arms, and shoulders. Increases in the duration and amplitude of activity in these muscles may increase the likelihood of MSDs. An objective method of measuring activity is through Surface Electromyography (SEMG). This technology measures the electrical activity of muscles through electrodes on the surface of the skin. Although SEMG is widely used and reliable, it is time intensive and requires expensive equipment. User surveys as a subjective method of measuring workload have been developed that do not require equipment or much time. These measures have been used in a variety of domains to measure physical and mental workloads, but little research has been done to examine if they can be used to measure physical workload for software use. The current state of technology thus does not allow a full investigation of the ergonomic impact of software design. The more reliable measurement system (SEMG) is expensive and time consuming and the more practical measures (short surveys) are not validated for these investigations. A positive correlation between the two would allow for efficient measurement of ergonomic impact. The preliminary results of this study indicate such a correlation.

Theory and Method

For this study, users completed sets of tasks and SEMG muscle activity was recorded for the muscles associated with using a keyboard and mouse. After each task set, users completed surveys asking them to quantify the level of strain they experienced during the tasks. Correlations between the measures indicate that subjective measures can provide reliable information regarding the muscle strain associated with software use. These easily obtained subjective measurements could assist in producing software interaction designs that are better for users, and in making specific design recommendations at the hand-action level. This is especially important for geotechnical applications in the oil and gas industry that require successive multiple mouse clicks and dragging the mouse.

University of Houston-Clear Lake students participated in an experiment in which SEMG output and observations were collected. The computer equipment and workstation furniture were set up according to current ergonomic guidelines (Figure 3). Participants completed three surveys asking the amount of strain they experienced during the task sets. The surveys provided a single score on the NASA

Task Load Index (NASA-TLX), the Busiest Hand Activity Scale (Latko) and the BORG Scale of Perceived Exertion (BORG). Participants had SEMG electrode sensors placed on four muscles (Extensor, Flexor, Deltoid, and Trapezius) used during typing and computer mouse movements. Participants completed tasks in five counterbalanced “command method” sections such as “find” and then “bold” a word using the keyboard, icon, mouse right-click, or mouse dragging. Another section involved the participants playing a web-based game called “Hit-the-Dot” which is a good approximation of tasks involving the use of successive multiple mouse clicks such as those required in geotechnical applications.

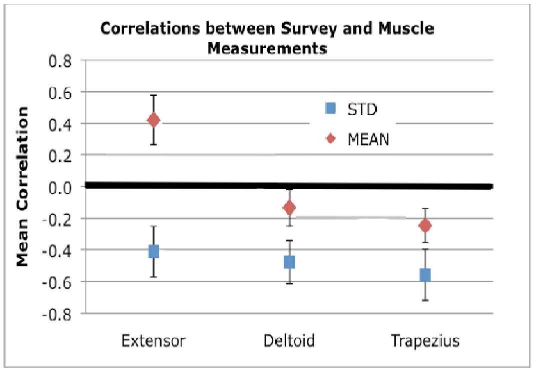


Figure 4: Mean Fisher’s Z for the MEAN and STD by Muscle. Error bars represent standard error of the mean.

After each command section, participants verbally reported their responses. For each task section, the mean (MEAN) and the standard deviation (STD) of the RMS-SEMG readings was calculated. The mean SEMG is an approximation of the exertion level for each muscle and the standard deviation provides the level of static activity for each muscle. The dependent variable was the correlation between each participant’s SEMG measures and self-report measures, resulting in eighteen correlations. A Repeated Measures Analysis of Variance (RMANOVA) was used to examine differences in the relations for the muscle and self-report.

Examples

Two correlations between the self-report measures were found to be significant. They were both with the Latko survey, one for the Extensor muscle and the other with the Trapezius muscle. The three self-reports were equally correlated with SEMG readings (Figure 4), but correlations with STD were stronger than those with the MEAN. There was also a difference in the correlations for the three muscles, with the Deltoid and Trapezius muscles having stronger correlations than the Extensor. This is likely due to the MEAN resulting in positive correlations for the Extensor and negative values for the other muscles.

Conclusions

These analyses support the position that self-report measures can approximate muscle strain associated with software use. The single question measures (BORG and Latko) were equally reliably as the more complex NASA-TLX measure. Although the relation between subjective and objective measures was different for the three muscles measured, this may be due to the polarity of the correlations for the Extensor muscle. There was a positive relation between the MEAN and self-reports of strain but a negative relation between the STD and self-reports of strain. It is reasonable to expect that as exertion increased, self-reports of strain would increase, while as STD increased (reflecting less static activity) self-reports of strain would decrease.

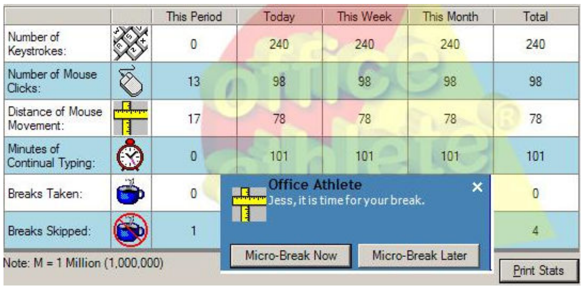
The more surprising finding was that this relation did not hold for the other muscles. For these muscles, as exertion increased, self-reports of strain decreased. An explanation for this is that participants responded to the survey based on their overall strain for the task set, not for a particular muscle group. Thus for a task set intensive for the Extensor and did not use the Deltoid and Trapezius, the participant would still indicate high strain on self-reports, resulting in a positive relation for the Extensor and a negative relation for the other two muscles. Future analyses on these data will investigate whether readings from all muscles can be combined into a general muscle strain measure.. Regardless of the muscle, self-report measures have stronger and more reliable relations with the STD than the MEAN SEMG, indicating that static tasks result in more perceived strain for all muscles. This indicates software designers should avoid operations that require users to maintain static muscle activities for extended periods of time such as dragging with the mouse.

Future study

The results are encouraging for the use of more practical measures such as short surveys and self-reporting to measure workload associated with computer use, instead of expensive and time consuming SEMG studies. Although not complete, the results of this investigation are nevertheless compelling. They provide insight into how self-report measures can be used to measure workload associated with computer use. This will allow practitioners to assess a potential ergonomic impact score for software their company is considering purchasing. Companies could also monitor usage of applications that have a poor ergonomic impact score. Self-reports will also facilitate field research by scientists interested in the impact of software ergonomics on overall usability and muscle strain.

The data collection for this investigation is ongoing and for future analyses we will include the Flexor muscle to explore the relation with this muscle and the self-report measures. There are several other analyses we will explore to identify additional relationships in the data. For instance, we will explore whether a multiple regression of the self-report measures on the SEMG measures is informative to a predictive model of muscle strain. Additionally, we will investigate the correlations of SEMG with measures of keyboard/mouse activity. This will tell us two things; what impact does the keyboard/mouse activity ratio have on muscle strain, and do different interaction techniques result in more muscle strain? This will allow us to make specific design recommendations at the hand-action level.

Current methods of reducing RSI include a focus on improving the ergonomic qualities of the workstation and hardware environment (desk, chair, monitor placement, etc.), the type of input devices being used (mouse, trackball, etc.), and an emphasis on taking frequent "micro" breaks (short breaks during computer use over long intervals), which may be even be prompted and or enforced by "rest break" software (Figure 5). A number of companies are adding this feature to their computing environments. However, a software tool which is poorly written from an ergonomic perspective may increase the risk of incurring further RSI despite the best hardware configuration and frequent rest breaks.



	This Period	Today	This Week	This Month	Total
Number of Keystrokes:	0	240	240	240	240
Number of Mouse Clicks:	13	98	98	98	98
Distance of Mouse Movement:	17	78	78	78	78
Minutes of Continual Typing:	0	101	101	101	101
Breaks Taken:	0				0
Breaks Skipped:	1				4

Note: M = 1 Million (1,000,000)

Office Athlete

Jess, it is time for your break.

Figure 5: Mini-rest break software display and ergonomic analyis in place for geotechnical professionals at a major oil company.

With human-computer interfaces evolving dramatically over the past few years, devices such as touch screens and touch tables, and pointing devices that originated in the gaming industry will continue to enable improvements in the ergonomic computing environment. Universal software drivers that work with an entire suite of devices can also result in improved efficiency and reduced RSI risk. Pen-based displays are becoming popular, with significant potential for improved efficiency in workflows such as seismic interpretation. Many senior interpreters began their careers using colored pencils and paper seismic sections, so the transition to pen-based screens for interpretation can be accomplished relatively easily by these users. More sophisticated approaches such as eye tracking may become more prevalent as the human-computer interface evolves in parallel with the complexity of applications and the increasing expectation of improved effectiveness and efficiency. Although these devices are useful, additional equipment should be viewed as the last resort for ergonomics intervention, with the preferred option being improvement of design features for ergonomic fitness in the software. Advanced input methods may still increase the risk of RSI if the underlying software is inefficient and requires excessive work by the end user. We can expect the current trend of increase in RSI incidence to continue as the age of the oil and gas technical workforce advances (Juliano, 2007). With the current economic downturn and reductions in force already occurring, a new problem has also started to appear among the smaller group of available experienced geophysicists. This has been identified as "binge computing", the phenomenon of working for an extended time under pressure without a break, with an unreasonable deadline, to produce large reports, presentations or documents. Studies have shown an even more increased risk of injury under these circumstances (Amick et. al., 2004).

These data are part of a larger investigation on identifying software interaction techniques that result in higher levels of muscle fatigue (e.g., dragging the mouse) than others (e.g., using the keyboard to issue commands). When the impacts of these techniques are better understood, this information can be used to design geophysical software that will be less likely to cause injury.

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