Fourth Quarter Technical Report For
A Real Time Coal Content Ore Grade (C²OG) Sensor

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Abstract

This fourth quarterly technical report discusses the progress made on a machine vision technique for determining coal content and ore grades. Work done this quarter has been primarily devoted to improving the apparatus and data collection system. This includes a totally new optical setup, continued development of a new imaging spectrometer, and software improvements. Additionally, interest from other mining operations has arisen and sample of titanium and talc have now been obtained for preliminary analysis. Work is ongoing with coal samples, although it appears a more diverse sampling may be required. With the improvements now being made in the system, much faster and more user-friendly data collection and analysis will result in faster and better turn-around for sample analysis.

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1. Introduction.

The purpose of this effort is to develop a machine vision system for visual coal and/or ore grade evaluation. In many instances, trained eyes can evaluate coal and ore, often by utilizing the distinctive colors of small particles within the sample. To mimic this capability, a machine vision system based on an imaging spectrometer has been developed. With the spatial and spectral resolution provided by this instrument, data is provided that allows standard remote-sensing software to classify objects of interest.

Much of the fourth quarter has been devoted to improving the data collection and analysis system. This has resulted in a more stable platform and faster turnaround. This will take much of the drudgery out of data collection, thereby allowing the collection of more data for better statistics as well as allowing more experimentation with lighting and different samples. Because much of the effort for this quarter has been devoted to apparatus and system improvement, there are fewer images than with the previous quarter, much of what came from a Masters this for Mr. Brock Bolin [1].

The bulk of the previous work on this effort was devoted to platinum/palladium ore from the Stillwater Mine in south-central Montana. Our attentions are now turning to the analysis of coal, and we have also been provided samples from a talc mine and from a titanium processing plant. These additional opportunities provide unforeseen avenues to development and deployment of the machine vision technology.

The technical portion of the report below is organized into subsections as dictated by the DoE contract for this effort. These sections are: Experimental Apparatus, Experimental and Operating Data, Data Reduction, and Hypothesis and Conclusions. Partners in this effort are: Montana Tech of the University of Montana, Stillwater Mining Co., Western Energy Company A Westmoreland Mining Company, TIMET Inc., Barrett's Minerals Inc., and the Montana Board of Research and Commercialization.

EXPERIMENTAL

2. Experimental Apparatus.

Hardware improvements. As noted above, much of the fourth quarter was devoted to improving the experimental apparatus. The experimental apparatus used for the previous parts of this effort is shown in Figure 1. Note that the sample sits on a simple wooden table and the camera is mounted on a rather flimsy rail system. Although this apparatus is sufficient, it requires considerable care to use. Ultimately, this decreases the utility of the instrument and also decreases the amount of data that can be obtained. Consequently, a complete upgrade of this system is being made.

Figure 1. Pictures of the formerly used experimental apparatus. The imaging spectrometer was mounted on a simple clamp and pole system above a stepper motor driven translation stage. The sample was placed on the translation stage sitting on a wooden table. This apparatus was located at Montana Tech.

A new standard optical bench has been purchased. This bench has $\frac{1}{4}$ -20 holes spaced every inch, providing a much better surface for mounting apparatus. A dedicated aluminum tower is also being constructed. It will have translation stages mounted to it to allow easy positioning of the camera. The tower is mostly complete and only a few mounting brackets still need to be machined to complete the system.

Software. Previously, approximately 20 minutes were required to collect data for a single scan and two computers were required to collect and analyze the data. This cumbersome process greatly limited productivity. Consequently, effort has been devoted to streamline the software. A C++ program is being written that will eliminate the need for one of the two computers and also speed up the scan rate. Preliminary results indicate the scan time will be reduced to under one minute, a huge improvement.

Imaging spectrometer. A second generation imaging spectrometer is now being developed. This camera is constructed with Thor Labs' SM series tube and rail components, which greatly decreases the development time, although some of the components require modification and others must still be custom made. The new camera will have an increased spectral range as compared to the previous design and is expected to have less optical distortion. Progress has been somewhat slower than expected for the imaging spectrometer, but it should be completed and in place before the end of next quarter.

3. Experimental and Operating Data.

A Masters thesis that utilized the imaging spectrometer was completed last quarter [1]. This provided considerable experimental data. Now that this thesis is complete, as noted above, the emphasis for this project has been redirected to improving the apparatus. Consequently, there has been very little data collection this quarter.

Platinum/palladium ore was used primarily for the initial portion of this effort. Now more effort is being devoted to coal and other materials. Coal samples have been examined with the system, but results from are not yet available. One difficulty was noted however; the coal samples were apparently taken directly from a stream that had already had most of the impurities separated from it. Consequently, the samples are not providing the impurities needed for analysis. Additional coal samples will be collected to remedy this problem.

In addition to coal, samples of talc from Barrett's Minerals have been obtained as have samples of impurities in titanium sponge from TIMET. In both cases, the samples obtained have undesirable impurities that need to be identified for removal. This is a particularly difficult problem for titanium processing where they currently use manpower to pick through the sponge samples to remove defects.

Once the machine vision system has been fully upgraded, additional measurements on coal, talc, and titanium sponge will be made. Further investigations on platinum/palladium ore may also be pursued, depending on the interest from Stillwater Mining Co.

RESULTS AND DISCUSSION

4. Data Reduction.

With the efforts devoted to device improvement, no significant data reduction has been done this quarter. Preliminary work has been done on coal samples, but nothing conclusive has been discovered.

CONCLUSION

5. Hypothesis and Conclusions.

Results from the previous quarters, most notably the third quarter, indicate that a machine vision system based on an imaging spectrometer and remote sensing software can be used to classify ore. A serious drawback with the apparatus used for the first portion of this effort is that data collection was slow and awkward. This has led to an effort to improve the data collection system in several ways, including the mounting, the imaging spectrometer itself, and the software for data collection. All three of these directions are proceeding and it is anticipated this will greatly improve the system for ongoing work that will be devoted to instrument fabrication and deployment.

REFERENCES.

1. B.J. Bolin, "*Sulfide detection in drill core from the Stillwater Complex using visible-near infrared imaging spectroscopy*," unpublished Master's Thesis from Montana Tech of The University of Montana, Department of Geophysical Engineering; 1300 West Park Street; Butte, MT 59701.