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Mining Automation: The Future, and an Excavation Automation Example

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Extended Abstract

The success of automation applications in the Mining Industry has traditionally not been good. In many of these cases the benefits of automation have been advertised (or sold) as the definitive solution to a wide variety of problems faced by the mining industry, such as increased safety and improved productivity. However, these applications have in many cases been introduced prematurely without adequate consideration of the rigors of the mining environment, an appropriate field testing regime to ensure robust operation and most importantly without developing a culture at the mine that understands the operational requirements for implementing automated systems.

As a result, effective technology has often been labelled as a failure before it has had a chance to demonstrate its true capability. Therefore, I believe that a major requirement for automation technologies developed for mining systems or sub-systems is transparent operation with minimal operator input required. This can be achieved in several ways. First, by narrowing the domain in which the automated mining system must operate such that less complex automation technology can be applied robustly. However, this approach severely limits the possible mining operations where automation can be applied and more importantly the applications where automation can have the greatest payback. Alternatively, more sophisticated control technologies are required that can react to the wide range of operating mining scenarios resulting from an uncertain, dynamic and very unstructured geologic environment, where conditions are highly variable and unpredictable. These conditions make autonomous control of mining machines extremely difficult since conventional control technology that uses mathematical models and then generates precise output from the model is impractical if not impossible to use.

As an example, automating the digging cycle of mining excavators has all the characteristics of the latter control problem. In particular, excavators such as wheel loaders (front-end-loaders) are currently used for rock and earth moving tasks in mining, construction, roadwork and many other excavation applications. Over the past ten years we have developed and implemented a control approach for automating the dig cycle of wheel loader used in mine conditions. Our approach uses feedback from bucket force/torque measurements to control excavation motions by sensing and reacting to interactions with rock particles during the excavation task. This intelligent control approach utilizes fuzzy behaviors with a goal-directed situation assessment and behavior arbitration configuration to control bucket and machine motions for autonomous excavation. The system makes control decisions based on subjective inference using imprecise and uncertain knowledge.

Thus this system requires no input from the operator related to characterizing digging difficulty. In general the digging difficulty is most strongly affected by the subsurface characteristics of the material to be loaded and its potential interactions with the bucket. Since, human operators cannot see below the surface and no practical sensors currently exist to do so the automated system must adjust its digging trajectory by reacting to perceived changes in digging conditions. This paper presents details and results of implementing this control approach on a CAT 980G wheel loader (a 70,000lb, 7.5yd^3 bucket) at the University of Arizona San Xavier Mining Laboratory. Extensive tests at local surface copper mines have also been completed. These results clearly demonstrate the abilities of the system to complete autonomous digging tasks in a wide range of material types and configurations.