3D Real-Time Stockpile Mapping and Modelling with Accurate Quality Calculation using Voxels

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In loving memory of my grandparents …

Declaration

Originality

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Shi Zhao
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Publications

Journal

1. Shi Zhao, Tien-Fu Lu, Ben Koch, Alan Hurdsman, "Automatic quality estimation in blending using a 3D stockpile management model," Advanced Engineering Informatics, Volume 29, Issue 3, August 2015, Pages 680-695, ISSN 1474-0346, http://dx.doi.org/10.1016/j.aei.2015.07.002.

2. Shi Zhao, Tien-Fu Lu, Ben Koch, Alan Hurdsman, "Stockpile modelling and quality calculation for continuous stockpile management," International Journal of Mineral Processing, Volume 140, 10 July 2015, Pages 32-42, ISSN 0301-7516, http://dx.doi.org/10.1016/j.minpro.2015.04.012.

3. Shi Zhao, Tien-Fu Lu, Ben Koch, Alan Hurdsman, "Dynamic modelling of 3D stockpile for life-cycle management through sparse range point clouds," International Journal of Mineral Processing, Volume 125, 10 December 2013, Pages 61-77, ISSN 0301-7516, http://dx.doi.org/10.1016/j.minpro.2013.09.009.

Conference

1. Shi Zhao, Tien-Fu Lu, Ben Koch, Alan Hurdsman, "3D stockpile modelling to improve the quality control in iron ore handling," Proceedings of the International Conference on Mining, Material and Metallurgical Engineering, Prague, Czech Republic, 11-12, Aug., 2014.

2. Shi Zhao, Tien-Fu Lu, Ben Koch, Alan Hurdsman, "Stockpile modelling using mobile laser scanner for quality grade control in stockpile management," 12th International

Conference on Control Automation Robotics & Vision (ICARCV), Guangzhou, China, 5-7 Dec., 2012.

3. Shi Zhao, Tien-Fu Lu, Ben Koch, Alan Hurdsman, "A simulation study of sensor data fusion using UKF for bucket wheel reclaimer localization," 2012 IEEE International Conference on Automation Science and Engineering (CASE 2012), Seoul, Korea (South), 20-24 Aug., 2012.

4. Tien-Fu Lu, Shi Zhao, Shihong Xu, Ben Koch, Alan Hurdsman, "A 3DOF system for 3 dimensional stockpile surface scanning using laser," 6th IEEE Conference on Industrial Electronics and Applications (ICIEA), Beijing, China, 21-23 June, 2011.

Poster

1. Shi Zhao, Tien-Fu Lu, Ben Koch, Alan Hurdsman, "3D real-time stockpile modelling and voxelization to estimate quality during blending operation, " 11th South Australian Exploration and Mining Conference (SAEMC), Adelaide, Australia, 5 Dec., 2014.

Abstract

Stockpile blending is widely accepted as an effective method to reduce the short-term quality variations and optimise the homogeneity of bulk materials, such as iron ore. Currently, both industry practice and academic research focus on planning, scheduling and optimisation algorithms to stack a stockpile that meets the predefined quality requirements. Namely, using 'selective stacking' algorithms to optimise the quality of a stockpile and improve the operational efficiency. However, it has been identified that stockpiled products are currently being reclaimed at approximately 50% of their potential engineering productive rates after applying such 'selective stacking' methods at most iron ore loading ports in Australia. There is an evident lack of solutions to this issue in the literature. This study focuses on stockpile modelling techniques to estimate the quality of a stockpile in both stacking and reclaiming operations for consistent and efficient product quality planning and control.

The main objective of this work is to build an up-to-date geometric model of a stockpile using laser scanning data and apply this model to quality calculations throughout the stacking and reclaiming operations. The significant elements of the proposed research are to: (1) upgrade a stockyard machine used to stack or reclaim the stockpile (i.e. a Bucket Wheel Reclaimer) into a mobile scanning device using Kalman filtering to measure the stockpile surface continuously; (2) build a 3D stockpile model from the measurement data in real time using polynomial and B-spline surface modelling techniques and use this model to calculate the quality of a stockpile with a great degree of accuracy when the quality composition is available; (3) associate the 3D model with the reclaiming machine model to achieve autonomous operation and predict the quality of the reclaimed material through voxelization techniques. In order to validate the developed techniques, several experimental tests were conducted using simulation and real scenarios. It was verified that the proposed 3D stockpile modelling algorithms are adequate to represent the real geometric shape with great accuracy. The percentage error in volume is better than 0.2%. Therefore, the combination of stock-

pile and BWR (Bucket Wheel Reclaimer) models enables the reclaiming to be conducted automatically.

To the best of author's knowledge, this is the first time that a stockpile is modelled automatically in real-time and the integration of the stockpile and BWR model generates a novel stockpile management model allows true reclaiming automation. Thus, the quality of material composition after every stacking/reclaiming operation is calculated from the geometric shape/volume, density and quality assay results.

Through accomplishing this project, the quality of a stockpile and its distribution inside the stockpile can be tracked continuously and the stacking/reclaiming trajectory of the machine can be controlled precisely. By making available such information, it is then possible to develop proactive stacking or reclaiming pattern strategies with more accurate product quality grade planning and control. Therefore, the workload of current selectively stacking and reactive reclaiming algorithms can be relieved, and the production rates can be improved with good output product quality control.

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List of acronyms

BW	Bucket Wheel
BWR	Bucket Wheel Reclaimer
CAD	Computer Aid Design
DCM	Direction Cosine Matrix
DGPS	Differential Global Positioning System
DOF	Degree of Freedom
ECEF	Earth Centred Earth Fixed
EKF	Extended Kalman Filter
FIFO	First in, First out
GA	Genetic Algorithm
GP	Goal Programming
GPS	Global Positioning System
GPU	Graphical Processing Unit
KF	Kalman Filter
LiDAR	Light Detection and Ranging

LRF	Laser Range Finder
LTP	Local Tangent Plane
MSE	Mean Squared Error
NED	North East Down
PF	Particle Filter
QMC	Quasi-Monte Carlo
QVO	Quality Volume Object
RMSE	Root Mean Square Errors
SSE	Sum of the Squared Error
UKF	Unscented Kalman Filter
UT	Unscented Transformation
UWB	Ultra-wide Band
VRR	Variance Reduction Ratios