UAV Application for Blast Design and Fragmentation Analysis

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Abstract
With the advancement of various techonlogies during last two decades, processing power of computers and software development, accuracy in Geographical Positioning System (GPS), photogrammetry with high resolution digital camera, cloud computing, application of Unmanned Aerial Vehicle (UAV) in mining application is providing benefits. Blasting is one of the critical operation in any excavation system in mining, was dependent on conventional methods of analysis till new technologies made in-roads in last few decades period. Digitised Terrain Models (DTM) are developed based on images captured of mine terrain and mine faces(as a part of pre-blast and post-blast situations). With mobile phone application vis-a-vis App based, real charge per hole, 2D/3D view of borehole patterns, geometric paramters, real coordinates of blast location and boreholes and presence of water in individual borehole can be recorded. For measurement of blast fragmentation, UAV is flown on blasted muckpile with video recording of images. Blast fragmentation photographs are analysed using image analysis software. Photographs are useful to calculate blasted rock volume. This paper describes two case studies. In one of aggregate (granite) quarry in Malaysia, with the help of UAV aerial phographs were obtained to identify rock types and geological structures which improved blast design. In another case study, in photgrapghs of blasted muckpile are taken manually in limestone quarry. Results of blast fragmentation prediction by software Vs image analysis are discussed in this paper.

Keywords: Digitised Terrain Models (DTM), Geographical Positioning System (GPS), Geological structures, Image analysis software, Unmanned Aerial Vehicle (UAV),

1. Introduction

In the past, the development of UAV systems and platforms was mainly motivated by military goals and applications. Unmanned inspection, surveillance, reconnaissance and mapping of inimical areas were the primary military aims[1]. UAV photogrammetry indeed opens various new applications in the close-range aerial domain, introducing a low-cost alternative to the classical manned aerial photogrammetry for large-scale topographic mapping or detailed 3D recording of ground information and being a valid complementary solution to terrestrial acquisitions (Fig.1) [2.3]. Advancement in UAV technology ensures the availability of miniature global navigation satellite system(GNSS), inertial measurement units (IMU), consumer grade digital cameras and photogrammetric process, which will help mines to keep all updates of the exploitation done up to current stage of mine, maintain a continuous flow of precious data to figure out problems in stage prior to exploitation and take an economic viable decisions by planning daily activities and monthly action plan [4,5]. Due to limited data and time consumption in collection of data in conventional system of mining, it's extremely difficult to optimize blasting operation.The focus is not on one time data collection, but data collection on continuous basis and analyze data through interpolation which can tell us much more than what catches the eye.

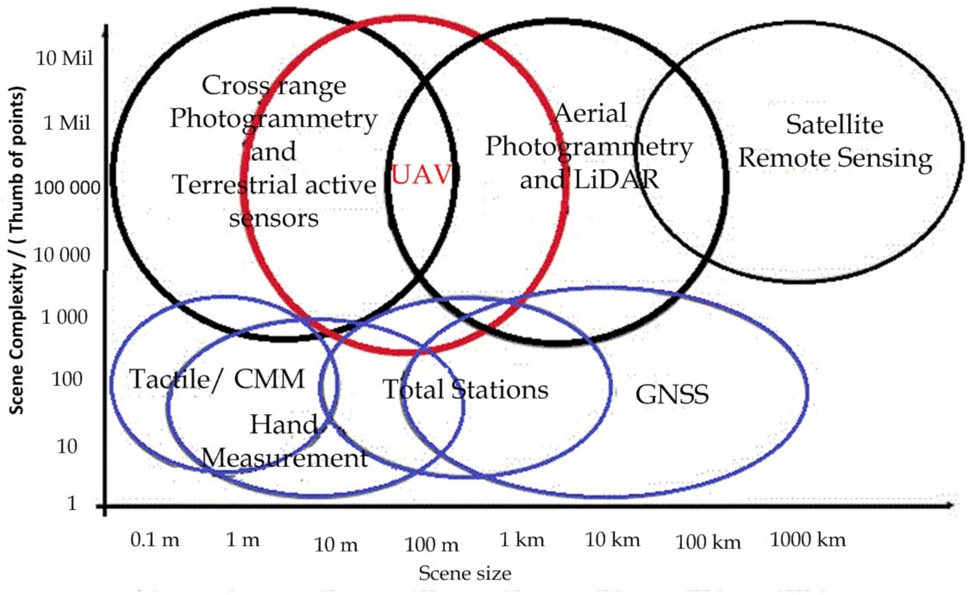

Figure 1: Comparision of UAV with Geomatics techniques, sensors and platforms for 3D recording purposes [1]

With the ability of quick delivery of high temporal and spatial resolution image information and flexibility of availing a rapid response in number of critical situations such as blasting crosschecking performance which can be done at different level of the mining hierarchy. The data obtained from aerial survey generates access to 3D geo-information and analysis is friendly. Operations such as blasting, loading and transporting can be tracked and optimized by analyzing the huge data that was obtained from the past operations. Machine learning algorithms will make the results of these studies much more precise [6,7].

For any blast design important paramters are topography, type of rock or geology at the face, borehole location with geometry etc. Based on face geometry and borehole location, explosives charging pattern can be designed. Initiation can be planned by various combindation of detonators and ground vibration can be predicted with the support of software. There are several blasting softwares now available, which have different modules which can import data related to drilling and blasting via mobile phones, UAV, total station etc. Various digital information can be easily compared with planned blast design with topography of blasting face and blast design can be modified to achive desired blasting results. Blasting software has also the ability to predict blasting results based on planned and actual data collected.

2. Blasting Software

2.1 **Software Modules** There are major 6 modules which are shown in figure 2 and described below[8]:.

- **Topography module** can import and export topography, edit terrain. Georeferenced digitised terrain can be developed with data obtained from drones. Terrain can be viewed with different options and can be expaned. There is a provision to expand bench bottom as blasting face advances. Digitised Terrain Models (DTM) are developed based on images captured of mine terrain and mine faces.
- **Borehole module** can import and create pattern. Borhole geometry can be adjusted and hole type can be adited. It is possible to incorporate presplit design in blasting pattern. Actual burden and spacing can be calculated based on face topography. Real deviation for each hole can be recorded. Thus borehole position can be changed prior to drilling. Number of rows can be edited.Type of borehole such as pre-split, contour or production boreholes can be defined.
- **Charge Module** can define charging rules consisiting of bulk explosivs, catridge explosives, booster, ANFO. Hole to hole can vary charge increase / dcrease by manually feeding. Prior defined charging rules can be modified.
- **Timing Module** is for the design of delay timing for nonelectric or electronic detonators. Contour lines and movement direction can be simulated. Histogram can be created for charge per delay It is possible to adjust MIC. This has options to add surface and in-hole detonators. Multi-decks option is suitable geologically disturbed strata. Time tool option can generate various reports with alternative dely timing of detoantors. Initiation hole can be compared with various combinations.
- **Blast Result Module** can predict rock fragmentation due to blasting based on input parameters. Blast optimization can be carried out either with blast pattern expansion

or frag mentation adjustment. If quality of mineral data is fed, quality assurance data can be generated.Blasting cost can be compared.

- **Vibration Module** is useful to predict ground vibration around blasting area using google maps. Critical structure can be added into the map. Attenuation law can be incorporated. This module can predict PPV and generate picture with different vibration level contours.UTM correctios can be done..

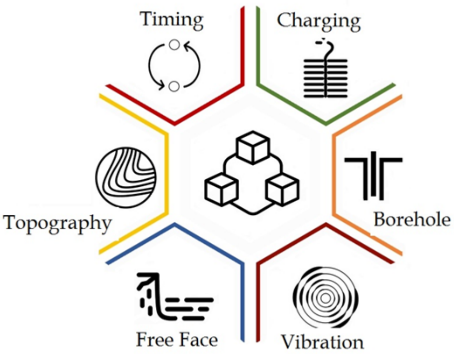

Figure 2 : Blast software modules [8]

2.2 Cloud computing architecture

Cloud computing architecture is shown in figure 3. Cloud is the area where the user can, for example, send blast reports to others users, upload new blasts and invite new people for a project. In this area, the user can reload projects lists, check details from some project. It is also possible to invite other users and create a new project or delete an existing project.. In the blast area the user can download the selected blast pattern, download the QAQC information, copy the selected blast to another project, plan and report by e-mail, update, delete or upload the selected blast. The user can download the QAQC information to compare the theorical values with the real values. The user can updload excel and CSV files [6].

Figure 3 : Cloud computing architecture [8]

2.3 Mobile Application

Various information related to blasting can be collected using aneroid mobile phone. (See Figure 4) All projects related to individual blast can be accessed or created.Boreholes can be viewed in 2D/3D View pattern.Geometric paramteres can be recorded and kept in the register. Real GPS coordinates can be recorded. Presence of water hole observed during charging can be recorded. Real charge per borehole can be recorded in individual blast.

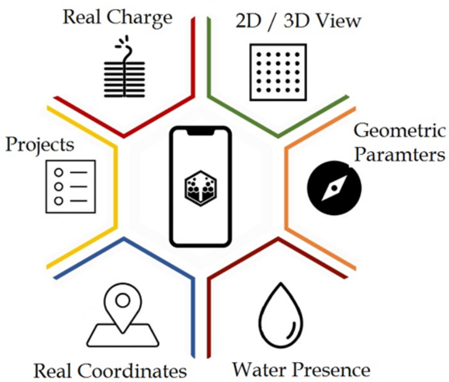

Figure 4: Mobile application in blasting[8]

3. Case studies on blasting

Two case studies on blasting are discussed for application of UAV..

3.1 Granite quarry, Malaysia

The granite quarry is situated in Johor Bahru. As the topography of granite quarry was very steep, geological study was undertaken using UAV [9-10]. With the support of UAV, aerial phographs were obtained and rock types identified were biotite granite (95%), pink granite (2%), microdirite enclave(1%), andesite dyke (1%) and microgranite (1%). Geological features include faults, joint sets, slicken side surface and mixing of magma. Geological structures identified are enclave zone, andesite dyke and fault zone. This information is useful for planning blast design at this granite quarry..

3.2 Limestone Quarry, Thailand

The aggregate quarry under this study had an annual production capacity of 2.5 MTPA and has expanded its capacity to 5 MTPA. The existing quarry uses 76 mm diameter DTH drills, 2.2 cum back hoe excavators and 25 t dump trucks. The feed size to the primary crusher is 800 mm. The objective of the study was to improve rock fragmentation to improve productivity of mining equipment.

UAV was deployed to study rock faces The limestone rock is classified into four types -- blocky, very blocky, blocky/seamy and disintegrated limestone -- supports blast design based on observation of blasting face

- Input parameters consisting of mean block size (X_B), RQD%, powder factor, maximum charge per delay (MC), (BD) burden to hole diameter ratio, (SB) spacing to burden ratio, stiffness ratio (i.e. ratio of bench height to burden (HB), (TB) stemming height to burden ratio, played significant role in predicting mean fragment size. Further, it was observed that Excavator output improved from 200 tph to 245 tph when mean fragment size was reduced from 0.27 m to 0.13 m and percentage of large fragements (boulders bigger than 0.8 m) was reduced from 12 to 4 per 100 t of primary blast.[11]

3.2.1 Fragmentation Analysis

An object of known size was kept at blasted muck pile for comparsion of size of rock fragments. Blasted muckpile photograph is taken with mobile camera as shown in Figure 5 (a). The same photograph is subjected to blast image analyses software as illustrated in Figure 5 (b). Blasted block size distribution with RR is shown in figure 5 (c). Thus for every blast, images are taken for further analysis through image analysis software.

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Figure 5 (a) Input image of blast muck pile from mobile camera

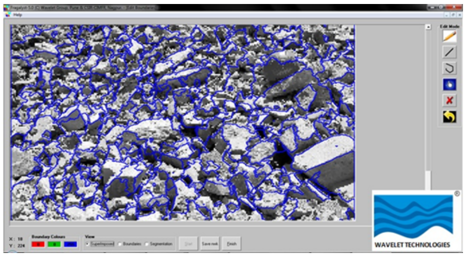

Figure 5(b) Fragments imags as observed in software

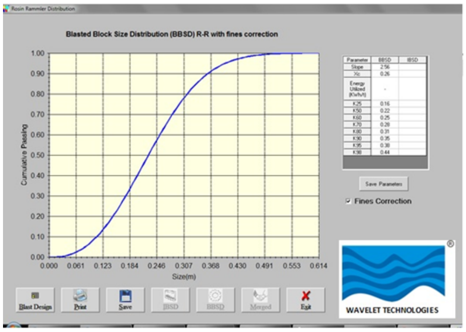

Figure 5(c) Blasted block size distribution with RR

4. Discussion

With recent development of technologies, it is possible to capture blasting input data using UAV and maintained in digital form. In the case study of granite quarry, different rock types and geological structures were identified. The same information is useful for blast design. In the case study of limestone quarry from Thailand, photographs from UAV were useful for classification of rock types and the same was useful for blast design.UAV has capability of video recording. However, in the case study of Thaland quarry, photographs of blasted muckpile are taken with mobile camera and image analysis was done with blast fragmentation software.. Further technique needs to be developed for fragmentation analysis similar to Point Cloud Based Aerial Fragmentation Analysis [12].

5. Conclusions

(i) With emerging technologies such as UAV, Mobile phone App (application) and cloud computing, it is possible to design a site specific blast design.

(ii) It is possible to make changes in blast design based on topgraphic survey and face survey using blasting software

(iii) Blasting information can be viewed seamlessly using various platforms of UAV, mobile phone, laptop/PC and virtual reality using cloud computing.

(iv) Results of fragmentation analysis are comparable with actual results. However, further research is required for fragmentation analysis of smaller fragment size using image analysis software..

(v) Big data of blasting can be captured and analysed to get cost benefits with blasting software.

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