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UAV applications on projects monitoring in mining and civil engineering

Worldwide all the industries have endorsed immense technology driven exponential growth since last two to three decades. Focus of every industry's focus is on the improved utilization of the assets by improving machine productivity, automation, optimization which goes in hand in hand with the safer and environment friendly operation. Unmanned aerial vehicle (UAV) has wider application with advancement of various technologies – accuracy in geographical position system (GPS), high resolution digital camera, development of various sensors, processing power of computers and software development. Application of the unmanned arial vehicle (UAV) is one of such technology driven solution which is upcoming during last one decade to almost all mining and civil engineering projects of the performance improvements, reducing the cost of production, safe operating practices etc. Present paper focusses upon the implication of UAVs projects monitoring of the mining engineering projects.UAV is useful in exploration for preparation of topographical maps, identification of different rock types, airborne survey. UAV technology ensures the availability of miniature global navigation satellite system (GNSS). Number of critical situations during mining operation are handled with the ability of quick delivery of high temporal and spatial resolution image information. Digitized terrain models (DTM) are developed based on images captured by UAV which can be imported in autodesk or mine planning software – Surpac, Datamine etc. Various volumetric calculations can be done for OB removal, excavation, waste dump and stockpiles of minerals by measurement through photogrammetric method. With UAV advancement of faces can be monitored periodically. Due to the vastness of the modern mining engineering projects, the monitoring and control of different activities need the adoption of UAV based solutions on real time basis. The imagery and video acquired through UAV can be processed through photogrammetry software to develop two dimensional orthoimages and 3-dimensional surface models. The data acquired and products generated are fully compatible with AutoCAD and other civil 3D design software. Legal framework in very country is being formed. Legal implications and liability are to be examined. Project authorities for every project has to consider pros and cons before deployment of UAV technology.Location and movement of heavy earthmoving machinery is monitored including maintenance activities. Fragmentation of blasted rock, blast volume can be estimated with the support of UAV. Any hazardous work can be monitored remotely on UAV platform. During closure stage slope monitoring, reclamation of land which can be reviewed with the help of UAV. UAV technology is also useful in emergency in handling any breakdown, disaster or accidents at mines.

Keywords: *Unmanned aerial vehicle (UAV), projects monitoring, mining engineering, civil engineering, photogrammetry software.*

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Introduction

With the rapid advancement of technology in this era, the applications of unmanned ariel vehicle (UAV) diversified into various sectors such as mining projects, civil engineering projects, agriculture, environmental monitoring and many other fields. Drones, more accurately described in a business context as unmanned aerial vehicles (UAVs). During 1938, simple radio controlled aircraft was known as first generation of UAV for military application. During the present era there is drastic improvement in hardware and software technology for UAV. UAV is real time technology to be used for mining and civil engineering projects. UAVs now demonstrate numerous possibilities to add business value. Potential business application of UAV in mining and civil engineering projects are tremendous. Many companies in mining and construction industry look for disruptive opportunities. They can dramatically extend human operations by enabling remote sensoring as well as actuation and predictive capabilities. Such capabilities offer key benefits such as cost reduction, risk mitigation and quality improvements, thereby bringing a competitive advantage to their adopters. 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, help plan daily activities, monthly action plan. The focus is not on data collection, but on continuous data collection and interpolation which can tell us much more than what catches the eye.

UAV technology offers several benefits, such as:

- Results on real time
- Good level of accuracy
- Safe procedure

Historic surveying inspections and conventional vigilance methods for project engineering are replaced by unmanned aerial vehicles (UAVs). Error free surveys can be easily done with drones through reduction in manpower and time required for completion of the survey. Human error is eliminated by utilizing latest software developed for drones. Data captured with drones is more accurate and interpreted easily in the required format. Conventional methods take much longer time to process the data as compared to data captured by drones.

Unmanned aerial vehicle

The UAV technology supersedes over other traditional technologies due to its speed and accuracy of data collection and transforming post-flight data to achieve ultimate desired results. When UAV is flown at lower altitude, closer to the surface of area to be surveyed, very good quality images are captured as there is no disturbance of fog, cloudy weather etc.) UAV is able to capture high resolution quality images (2 to 5 cm resolution) or 300 images for every square kilometre of area to be surveyed. Satellite data which is considered excellent has 50 cm of resolution. Images captured by UAV are more than one hundred times sharper as compared to excellent satellite images. Every image captured by UAV is digitally stitched to combine a map of combined images or a mosaic. These mosaics have ability for carrying out simpler analysis and can be stitched together using geo-references or split into more images. UAV plus post-flight processing data can produce highly detailed mosaics with around 300 MB per image.

UAV (unmanned aerial vehicle) technology aims to revolutionize the way in which survey and planning is done for exploration and exploitation of mineral in today's mining environment. 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

Fig.1 Typical drone used for various applications

planning daily activities and monthly action plan [5]. Due to limited data and time consumption in collection of data in conventional system of mining, it is extremely difficult to optimize mining 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.

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 crosschecking performance of mine development in reference to monthly excavation, quarterly pit operation plan, and annual plan 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].

Position of machine in the mines, their working conditions and environment can be observed and can be planned for better positioning so as to obtain better results and increase the life of machines.

Thermal camera can be attached to the gimbal of the UAV and can be utilized to study the health of mine machines such as bucket wheel excavator, long range conveyor system, dragline etc. by studying the expected Vs current temperature values of different parts of the machines. Thermal detection of groundwater inflows can be done by suing high power thermal cameras.

Volumetric application of the photogrammetric result allows to estimate cubage of material with which numerical value of exploitable mineral and thus can generate economic value of reserve. Production of data such as production per shift, volume of overburden lying over the ore, overburden removed per shift, stripping ratios can be calculated using image processing and 3D geospatial models, and this will be

Fig.2 Micro multi copter – UAV models (Mmcuav)

utilized to convey targets to operational team at pit on a regular basis. By application of volumetric analysis machines related to loading, dumping, and transporting material can be examined on the basis of productivity and performance [7].

Unmanned aerial vehicle models

Following are some of the models of micro multi copter UAV models which are used for various applications are descried further in this paper.

UAV technology can boost productivity in data collection and minimize the risk of workers working in difficult working conditions. Flight planning is an important aspect of image acquisition plan, flight path and monitoring flight parameters and ongoing acquisition plan. Flight planning consist of designing the flight plan, image acquisition plan with its start point to end point. Classification of flight planning is done with computing as optimum or sub-optimum technique. Exposure to field information before take off can be efficiently utilized while solving optimal plan offline as most of it heavily relies on timely techniques which exhaust-resources optimally using computing arithmetically, optimum control theory and genetics algorithm.

Specialised softwares are available for planning the mission consisting of flight and data acquisition. Information on the area to be surveyed, required ground sampling distance (GSD) or footprint and the camera parameters. Proper geo-referencing of flight position is a compulsion for generating accurate photogrammetric results and for the autonomous flight (take-off, navigation, and landing). In order to achieve proper navigation of UAV; accurately predict the acquisition points and direct geo-referencing of data, presence of GNSS/INS -RTK navigation system is a compulsion. Communication of real time flight data such as position, speed, altitude and distance, GNSS observation, status, rotor speed, battery status. are done for the observation of UAV with control station.

The main focus while preparing a flight plan is to obtain a required ground sampling distance (GSD) which is predicted according to the accuracy needed; which is fulfilled by selecting a flight height based on the camera's parameters like focal length, resolution, aperture of the lens. After selecting a GSD flight planning has to be done to ensure at least 75% frontal overlap (with respect to flight direction), and 60% side overlap (between tracks) so that the image processing software can find enough key points to match and stich the

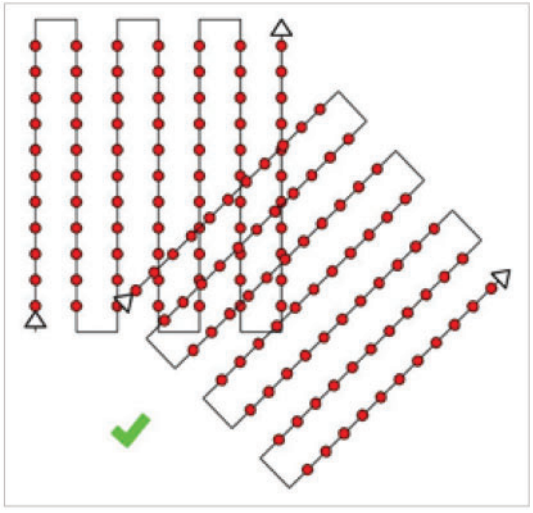

Fig.3 Flight path planning of drones at project site

images with precision. The orientation of the camera is kept oblique to the surface for maximum area coverage and minimize the error which is caused while calculating the Omega, Phi, and Kappa representing the camera's orientation. In case the area to be surveyed is very large, multiple flight plans have to be made in such a manner that the images so obtained can be stitched together to obtain one model. Fig.4 illustrates the flight planning process done on a regular surface area with multiple flights:

UAV application to civil engineering projects

Civil engineering works by nature provides opportunity for utilizing UAV practically and in creative manner. UAV is beneficial in different stages of construction projects from prefeasibility study to planning and inspection requirement during execution. In next couple of years, UAVs will be dominating a lot of construction engineering projects because of its ingenuity, practicality, and affordability. Once their versatility shows on the business' bottom line, drones will be active throughout the industry. Drones will accelerate processes, facilitate quality inspections, assess problems and picture alternatives which further reduce the manpower cost and ensuring a more efficient allocation of skilled professionals.

Monitoring

At construction site inspections are essential to meet statutory standards as well as client's requirement to meet the

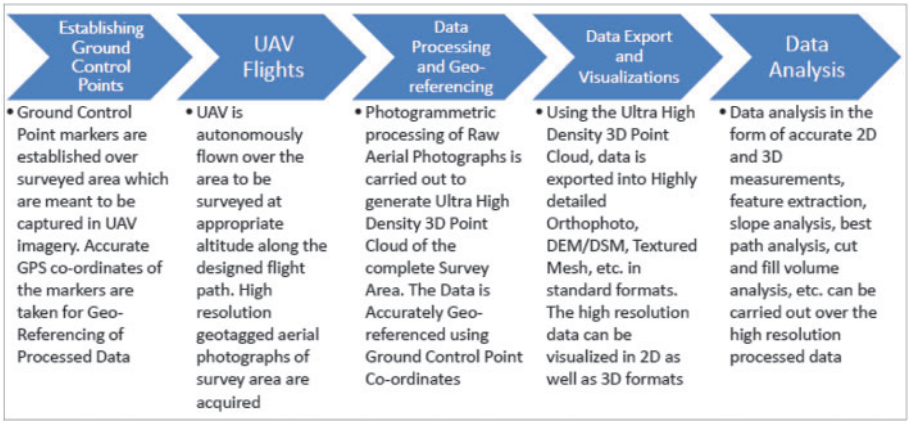

Fig.4 Stages of UAV application in the project site

standards specified in tender document. Drone can avoid any distraction or delays for the project as drones are fitted with video recording cameras. Drones can provide progress of skyscraper building, tunnels, bridges, dams, to any large industrial complex. Thus inspections are made safer, employees start working hard. At construction site, drones provide excellent endurance for safety and jobs can be done with intelligently. Drones are able to capture data, timely information to take prompt action. Manual intervention is minimized. Drones will be taking integral parts of mega infrastructure projects. It has been established that time required to build skyscraper is drastically reduced with support of UAV and thus reduction in cost. Contractors who will utilize drones will become more competitive and participate in competitive environment.

Performance improvement

Drone is cutting edge technology which has shown job site and office connectively instantly.With the support of drones, job site can be connected instantly and providing data and information. Camera fitted drones are useful for video footage to provide quick communication. The function of surveillance can be done more effectively for the ongoing project works. Improvement on job site is possible through online real time data analysis.. Management of companies can have cross check on their employees. The increase in quick response and collecting data has shown there is substantial positive an impact each day. The ability to manage workflow 24/7 is unprecedented and is certain to have a significant impact on all manner of construction processes.

UAV application to mining projects

Mine planning

The 3D and 2D modelling including point cloud, that are rendered by use of photogrammetry software like Pix4D mapper can be used in a wide range of mine planning software such as Surpac, Draftsight, Autodesk etc. Different paper sites are the importance of using digital terrain model for planning the mining activities. 3D modelling allows decision maker to see real views of the quarry or mine. Fig.5 illustrates the view of benches and quarry surrounding in a 3D model [11].

The current exploitation needs as well as the future requirements can be easily found out by analyzing the models generated. This will be helpful for keeping the production on track.

- Deviation of actual mine development status from the targeted mine plan
- Comparing each day developments in reference to monthly pit operational plan and annual action plan
- Preparation of monthly and yearly action plan and cross-checking it with the actual progress
- Work allocation and machine positioning
- As user views the actual present condition of the mine rather than a printed mine map or 2D model, the future infrastructure needs, haul road developments, bench planning and various other important operations can be planned in a much better way
- Communication of daily/weekly mining plans can be done very easily by sharing the planned 3D model in pdf format with contracted agencies, also all data such as volume, grade etc. can be shared easily in excel or word etc. by just a single click

Fig.5 3D view at the open pit

Mapping

Result generated by aerial data acquired by UAV can manage surveys multiple times in a day and can be used for creating maps. These can be further used for interpreting a wide variety of results which are required by the mine managers and management. Digital Terrain Model (DTM) is

considered more accurate to collect all types of cross-sectional data and volumetric data of any place in the mine as it contains more information of the terrain. Taking a virtual tour of the mine is also possible while marking various changes which deem fit any where in the mine. Surveys needed for planning future infrastructure can also be accomplished using these models which are interchangeable into a wide range of formats sorted by various planning and designing software like CAD, Solid Works, ArcGIS, Surpac.

Use of point cloud can be made for fulfilling the mapping needs of the surveyor by generating digital surface model, digital terrain model, elevation maps, contour maps, orthomosiac maps. With each flight the maps (both 2D and 3D) of the mine, the same gets updated with its recent changes. The maps can be used for measurement (volume, area, height, width, length, angle), planning, safety survey. Figs.6 and 7 show the various views of photogrammetric results [1].

STOCK PILE MONITORING

Accuracy was considered as one of the challenging factor for using photogrammetric results for calculation of volume of stockpile. Various paper concludes in proving the accuracy of stockpile volume generated by UAV image processing software (Pix4D Mapper) with a mean difference of only some centimeters when compared surface obtained by other ways namely terrestrial LiDAR (Light Detection and Ranging) or GNSS (Global Navigation Satellite System) test points.

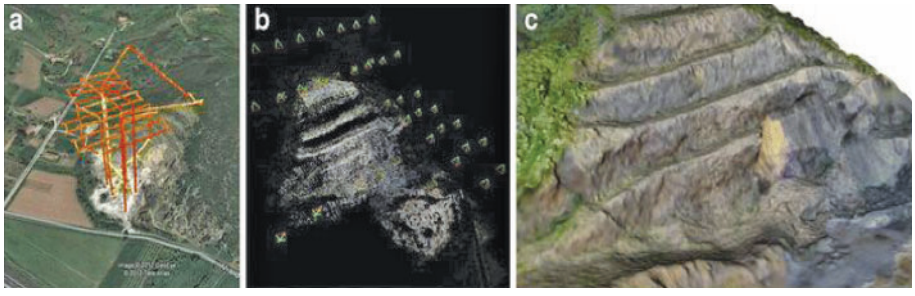

Fig.6 (a)The flight plan for an UAV surveying of the rock quarry visualized in Google Earth (b) The image orientation results, showing different strips composed of oblique and nadir images (c) Produced photogrammetric DSM for excavation monitoring and volume computation

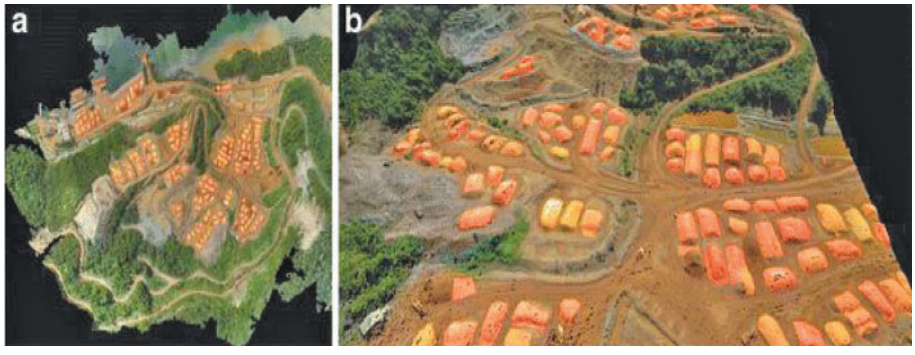

Fig.7 (a) Mosaic of ca. 50 UAV images over a nickel quarry area in Indonesia and (b) Produced DSM for volume computation

Monitoring stock pile with index for different grade of ore and keeping account of daily addition. Stockpiles can be monitored and can be tagged with their data such as grade, location from where material is being dumped etc. Activities such as blending, accounting of stock volume and grade, end-productivity of various faces, frequency of dump, virtual inspection of the environment of the piles and its environment can be done [8].

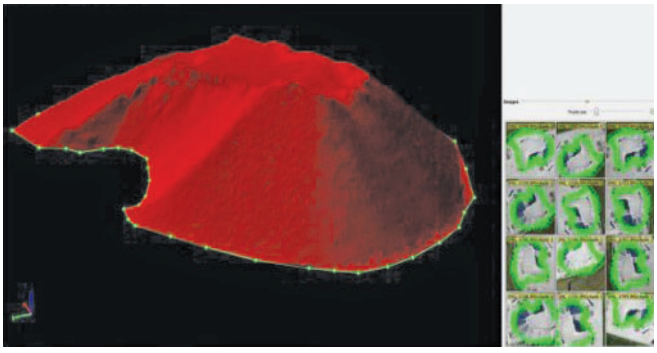

Fig.8 View of stockpile generated by PIX4D mapper

Volume of material

Volume of stockpiles can be calculated in meter cube and tonnes in a matter of few minutes with accuracy matching with the existing technologies like total station and tachometry.

Material characteristics

The colour of the material, fragmentation of rocks, its geological properties, etc. can be easily observed from the 3D models.

Material positioning and geometry

The geographical position of the dumps relative to working face, processing plant, their distance from each other etc. can be observed. The surface area, perimeter, ground area covered, length, height of any feature in the model can be found out easily.

Stability

Maximum accidents are caused when surveyors climb dangerous piles and features to calculate their dimensions, slope etc. using our tools all these parameters can be found easily by sitting in the comfort of your office with the same accuracy

Drainage

The direction of flow of water from the stock, water collected in and around the stock can be observed from a top view which can help take the best decisions for every scenario.

- Current volume
- Volume added per shift

Future developments in mining

Excavation

- Tracking excavation to know the progress of mine
- Volume of ore excavated
- Volume of overburden excavated
- Direction of excavation
- Waste dump management

Drilling and blasting

- Record blast pattern: The daily blast pattern and its success can be recorded each day and data will be analyzed to produce better blast designs for the mine
- Amount of material targeted
- Amount of explosive used
- Volume reduced from face after blast
- Fragmentation: Fragmentation of rocks can be studied very easily and graphs can be plotted between the various sized concentration and areas of concentration to plan further
- Pointing secondary breakage: In case fragmentation is not appropriate as per the mine, this will be identified and the suggestions for next breakage will be provided automatically

Machine performance and monitoring

Machine activities can be tracked with the help of its existing GPS device, data from UAV and other sensors to provide the exact performance of each machine and also how and what is to be optimized for better production.

Deviation from planned excavation

Direction of everyday advance can be plotted against the planned excavation each day to tell about the deviation and also its extent.

Production tracking

Everyday production, weekly productions on the basis of different ore grades can be traced to keep a close watch on the mine productivity.

Emergencies in mines

In mines various emergencies may be there which can be handled with UAV technology by promptly sending video photographs to take suitable actions. Such emergencies are

- Breakdown of machines
- Accidents at mines site
- Fires
- Different types of disasters

Reclamation

UAV technology is also useful for slope monitoring of dumps, mine faces and reclaimed areas planning and actual progress.

Conclusions

Unmanned aerial vehicles (UAVs), have got immense value for monitoring and performance improvements at every stage of the engineering projects. It provides valuable support and cost benefit with wide views which are not easy to access or very difficult to navigate target mine or construction sites. UAV sends back complete images of terrain to multidisciplinary teams consisting of planning and logistics for taking further steps. Overviews of these images covering entire land covering broad areas show assets on land and bring challenges to be tackled. The various analysis results show best access to tackle multiple hazards. 360° panoramic overhead view and continued relaying strategy at a real-time provides benefits to management of project site. Thus various inputs provided by UAV helps engineering teams to decide priority of multiple solutions. Mobile equipment operators are able to share online images to site supervisors, at control room, corporate office and can also share with multiple contractors. Planning teams can discuss virtually on progress of project, equipment requirement and to meet demand shown by undulating terrain. Implementation of UAV in mining and civil engineering projects lead to saving on cost due better monitoring and improved quality of work while ensuring the safe working condition of the equipment and the workers at site.

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