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Title: Design Guidelines for Assessment of Pillar Stability in Underground Room & Pillar Mines from Autonomous Robotic Inspections
Organization: West Virginia University
Principal Investigator(s): Berk Tulu
Partnerships: Virginia Tech, Argos USA, Carmeuse Americas, Lhoist North America, Nyrstar, Vulcan Materials
Focus Area: Health and Safety Interventions - Ground Control

SYNOPSIS

Problem Statement: In 2019 more than 2,000 miners worked in underground stone mining (NIOSH, 2021), and since 2006, approximately 40% of fatalities in this mining sector have been linked to falls of ground from roofs and pillars (MSHA, 2016). The modern pillar and roof span design guidelines developed by National Institute for Occupational Safety and Health (NIOSH) were published in 2011 and have improved the design of stable layouts for modern limestone mines. However, since then, five massive pillar collapses occurred in older workings of active limestone mines, and four out of five occurred after 2020. On January 7, 2022, a massive roof fall claimed the life of a dozer operator in an underground mine operating in the Loyalhanna formation, and reports of extensive regionalized roof falls in other mines demonstrated the potentially severe risk to the safety of miners in underground stone mines. Mine Safety and Health Administration (MSHA) indicated that there is not any design method available to predict when, or even whether, a particular pillar or group of pillars would collapse, but it is possible to recognize hazards that might increase the likelihood of these massive collapses (MSHA, 2021). MSHA listed the following hazards that might cause pillar collapses: (i) irregular undersized pillars due to surveying or blasting errors, and (ii) ignoring or not realizing geological features (joints, weak bedding planes etc.) on the pillars that might reduce pillar stability or induce rib falls (MSHA, 2021). Unmanned Aerial Vehicles (UAV) and Unmanned Ground Vehicles (UGV) can be used to autonomously and safely scan old workings and capture high-resolution 3D maps of these areas that can be used for assessment of pillar and roof damage, and stability.

Research Approach: In 2019, the Alpha Foundation funded a project with West Virginia University entitled "Autonomous Robotic Early Warning System for Underground Stone Mine Safety. In this project, WVU team has been developing a proof-of-concept of an autonomous robotics system for stone mine pillar inspection using LIDAR-based time-lapse 3D imaging from a UAV and a UGV system. Virginia Tech (VT) team has also been developing and applying drone technology for mapping underground mines and has demonstrated the capability of drones to reconstruct digital 3D models of mine pillars that can be used for geotechnical assessment and hazard identification. This collaborative project proposes to collect the necessary data from active stone mines by means of the existing autonomous UAV/UGV technologies and the expertise of VT and WVU teams, while evaluating and improving the field performance of the WVU autonomous systems and integrating the WVU autonomous flight control software and operational sensory subsystems to commercial drones currently used by VT. The ultimate goal of this project is to develop guidelines for stone mine operators to evaluate pillar stability of old workings and roof fall hazards from a UAV and/or UGV captured high-resolution 3D point clouds and geomechanical data. The research to be accomplished in this project will include: (i) Develop a database of mine layout, rock mass characteristics, and high-resolution 3D maps of stone mine pillars and roofs in old workings while evaluating and improving the application of conventional UAVs of VT and autonomous systems of WVU. (ii) Develop guidelines for recognizing hazards that might increase the possibility of massive pillar and roof collapses through the analysis of the database.

Impact of the Research: The development of the autonomous navigation and mapping software for UAVs and UGVs and guidelines to use this software in conventional drones will allow mine operators to integrate the autonomy developed in this project into their own drones for establishing digital inspection missions in their mines. The improvement of the WVU UAV/UGV systems through field tests will provide reliable systems that allow long duration autonomous inspection of pillars and roofs of older sections of mines without exposing mine personnel to ground control hazards. The development of the postprocessing guidelines for recognizing and assessing the hazards that would lead to the potential massive pillar collapses will enable mine operators to respond to the detected hazards rapidly by dispatching support crews to rehabilitate the pillars/roof or evacuating the mine. Successful development and deployment of these systems and design guidelines will improve the safety of the miners working in the underground stone mines. Technologies developed in this project would be adaptable to underground metal/nonmetal mining industries.