How Will the 4th Industrial Revolution Influences the Extraction Industry?

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Abstract

Even the third industrial revolution has never been officially finished, from some time an expression Fourth Industrial revolution got viral. It has started in 2011 with a project of German government, called Industrie 4.0, which was initiated during the Hanover Expo in 2012. In 2013 an official report on that project was issued.

The article explains the term of 4th industrial revolution and tries to foresee influence of that phenomena on extraction industry. The big challenge of digitalization and cybernetic systems implementation carries a large saving potential, estimated to astonishing 321 Bio. USD till 2025 but also risks and challenges to overcome. Discussion in the paper includes the most important technologies with their state of development and existing implementations including autonomous machines in both underground and open pit mining, technology of self-operating drilling rigs and driverless trucks in open pits.

Briefly description of current situation and a picture of the mining industry after extended automatization is presented. It touches also the challenges of the new industry concept and highlights a road map for the full digital mine.

Introduction

The question about the future is probably one of the oldest the humanity ever asked. People were using various methods to get closer to the mysterious knowledge of the future facts. At the very beginning those questions were rather personal, like "When I will find a husband/wife?" or related to a significant upcoming event of their tribe or nation, like "Will we win the war?". With the development of technology, especially during the second industrial revolution, people started to ask more general questions related also to the technological development in near and far future. That's how science fiction was born. Authors, like Julius Verne started to extrapolate the current development into the future, predicting next inventions or steps in technological journey. Of course, they could not predict facts, like the Hindenburg disaster or I and II World War which kind of derailed the future of the world.

Science fiction is still very popular, as well as fortunetellers, however none of them can accurately predict the future. But we live again in the times of the revolution and the desire to try is too big to resist. Let's think than which influence may the fourth industrial revolution have on the extraction industry.

Industrial revolutions

It is not the first time when the planet experiences the industrial revolution. The first happened in the second half of XVIII, related mostly to mass application of steam and waterpower in the textile industry. Later, growth of steel industry reised demand on iron and coal, causing rapid development of mining industry. As a result, former rural communities changed were urbanized and industrialized alternating life of millions of people. Mining industry was an important part of that changes, generating new workplaces and delivering raw materials, but also using the leverage of new technologies for own growth.

The second Industrial revolution started in 1870 and last till the beginning of the first World War (1914). It was the time of rapid development of mass production, electricity and crude oil extraction and processing. The revolution cut the dominance of steam engines in introducing much more efficient and less cumbersome diesel and electric engines.

Next, third revolution has started in 1980, when computers become small enough to leave large rooms constructed especially for them and entered our houses, where they stayed till today. Thanks to that, industrial digitization become possible. Beside that major achievement, it opened the door for communication technologies development, with its so far most advanced medium – the internet.

Even the third industrial revolution has never been officially finished, from some time an expression Fourth Industrial revolution got viral. It has started in 2011 with a project of German government, called Industrie 4.0, which was initiated during the Hanover Expo. In 2013 an official report on that project was issued. The project considers 4 elements which defines projects aligned with the idea of Industrie 4.0:

1. Interconnection: With wireless communication technology and the capabilities of the IoT, you can now connect machinery, sensors, and other devices to the people tasked with monitoring your process for effectiveness and efficiency.
2. Information transparency: The transparency afforded by Industry 4.0 technology provides operators with vast amounts of useful information needed to make appropriate decisions. Interconnectivity allows operators to collect immense amounts of data and information from all points in the manufacturing process, thus aiding functionality and identifying key areas that can benefit from innovation and improvement.
3. Decentralized decisions: Interconnection and information transparency allow for operators to make decisions both inside and outside of production facilities. This ability to combine local and global information at the same time helps to drive better decision-making and increase overall productivity.

Fig. 1. Drone model of Rzepka Quarry, rehabilitated in a recreational area, mapped using DJI Phantom 4 on 30.09.2018. Field work of approximately 5 minutes and 1 hour of data processing

Rys. 1. Model stworzony za pomocą drona, dla kamieniołomu Rzepka, zrekultywowanego w kierunku rekreacyjnym, zmapowany za pomocą drona DJI Phantom 4 w dniu 30.09.2018. Czaslotuokoło 5 minut, czas obróbki danych około 1 godziny

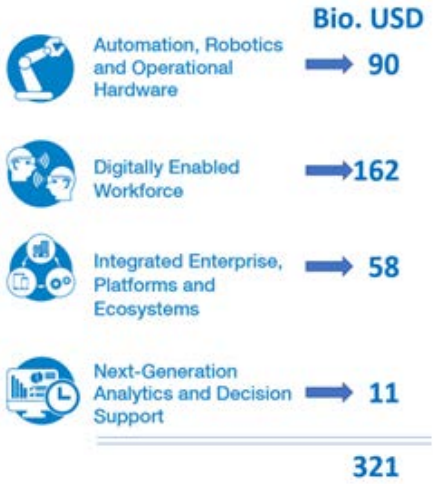

Fig. 2 Benefits of 4th Industrial Revolution according to [7]

Rys. 2. Korzyści z wprowadzenia rozwiązań 4-ej rewolucji przemysłowej wg. [7]

4. Technical assistance: Industry 4.0 shifts the role of humans from an operator of machines to a problem solver and decision maker. Assistance systems are designed to support operators that need to make informed decisions to solve urgent problems on short notice [2]

The above can be summarized by the key words so popular nowadays: Big Data (processing and large data analytics, also Data Mining), IoT (Internet of Things) and AI (Artificial intelligence) including machine learning. Supporting technologies are Virtual and Augmented Reality, which are essential for some applications, but on the other hand stay apart as they are mostly dedicated to people not machines. Machines does not need any visualization.

The term itself, 4th Industrial revolution has been used first during World Economic Forum in Davos in 2016. So, we are just at the very beginning of that journey, which shell change a lot also in the extraction industry. From that moment it caught the attention of all big consulting companies and become priority of all major equipment producers, data safety companies, and even other countries.

How possible is the digitalization of the extraction industry?

Digitalization per se is a part of 3rd Industrial revolution and is happening now and for a longer time. It is without any doubt a first step towards cybernetic systems application. Except from large international corporations, large part of the extraction overslept implementation of modern technologies. Especially in small quarries and pits job is done in the best case like it was 20 or even 40 years ago. Partially we may blame stiff regulations which impose certain solutions and are not open for moderner alternatives, but mostly it is due to people who in that branch are very conservative. As it is said, the good is an enemy of the better. Well, why to change something which works, and proved its reliability?

There is at least one reason. Being stubborn to ignore changing world, one may wake up once in an environment which is not understandable and almost hostile. That happens nowadays to elderly people who are pushed out of the new digital society and suffer trying to live like before. For the companies it is simply a way to become not competitive enough to keep the market share and find itself on the descending ramp. Being a rather basic industry, mining is not

in a situation of for example Blockbuster. This large chain of DVD selling and renting stores, was once the market leader in the US. Somehow, they did not see the upcoming change and didn't react on time. Development of streaming technologies and internet as such, lead them to the bankruptcy. Now their place is filed by Netflix, Amazon or other internet streaming companies. Blockbuster become known only as an example of a company which failed to keep up with the changing world.

Is it a danger for Rio Tinto or KGHM? No, it's not, if there is no alternative for copper or other metals mined by them, but they are in danger to fail in keeping up with their competitors. Those companies as well as many others producing metals, rear earth and industrial minerals may gain a lot on the new industrial revolution, as a supplier of basic raw materials without which, the revolution would not happen.

One of the first thing which has happen when personal computers appeared was the development of modeling and designing packages which allowed using properly the geological data. Software like Surpac, Vulcan, Maptec, or most recently Deswik, open opportunity to store, visualize and use data for deposit modeling. That was the first step for applied usage of created models for the deposit evaluation and production planning and scheduling. Algorithms like Lerchs-Grossmann (LG) become mandatory standards for stock mining companies, to avoid frauds and misinterpretations. Recently, thanks to 64 bits functionality and growing performance of computers, a new method arises -Direct Block Scheduling (DBS). Having its roots in 1960's the method could not get through due to technical restrictions. Nowadays it has a potential to take over the role of LG.

Already from 2006 most of the OEM (Original Equipment Manufacturers) install telematic systems on their machines. The origin of that solution lays in the desire to acquire operational data for better storage and maintenance planning. With the time those systems evolved into more operations focused. Simultaneously the market complimented some solutions like CAT ProductionLink, Komtrack of Komatsu or Caretrack of Volvo with independent solutions, universal for all the machines, like Polish TMS MES which has a large market share among quarries in Poland. The main task of all above listed systems is to gather vital production data as a decision base for mobile fleet management. As a back site, the full utilization of the system capabilities requires a person who is almost fully dedicated to that task. Many smaller quarries cannot handle that, thus focuses only on the most important part. In many countries it is simply diesel consumption and thief avoidance. In the best-case idle time is also followed.

Recently a new technology appeared got warmly welcome in the industry. Drones are used more and more often, but mainly for topographical situation update. They can save time and money, but like in case of telematic system, deliver more information than the mine operators can process.

Those examples show, that digitalization simply happens. There are well developed, robust, commercial solutions which are in the reach of once hand. The only thing to do is to reach for it and establish a system which will take an advantage of acquired digital data. And it is not an easy task, at least not for humans…

The mine of the future

Before we get to the technical part, let's set an important benchmark. The one sure thing is, that the mine of the future will be green. Of course, not in the meaning of the color, but its impact on the environment. One may say it is a truism but lookat the following examples.

Jura Cement operates a small very compact and extremely clean plant in Wildegg, Switzerland. The limestone quarry delivering materials for cement production is located close to the plant and extremely well design and operated. Like in any case Jura needs to renew their mining lease which among others is a subject of extensive community consultations. And here is the problem. Having already the governmental clearance, the plant cannot agree with the local community which is opposing blasting as an extraction method. It does not matter that they do the blasting better than required, being below vibrations and airblast limits. Alternatives? There are a few but none of them will be as economically efficient as explosives [10].

In 2010's Holcim demolished an old cement plant in Miskolc, Hungary, planning to replace it with a new, modern one with marginal environmental impact. Mining strategy was prepared accordingly. At the end, the extensive community protests and never-ending negotiations pushed the company to abandon the investment. Simultaneously Hungary suffered a deficit of cement and needed to import it from Slovakia and Romania.

The last example is from the Netherlands. This country with 26% of land below the sea level is almost without any mineral resources but sand and gravel. Those commodities are extracted from below water level, creating water reservoirs which are anyway common in the landscape of the country. It should not be a problem to get a license though. The company Royal Smals, one of the biggest sands and gravel producers in the area waited 25 years to get a clearance for a new extraction area… Negotiations included extensive environmental impact assessments, community consultations and even resettlement of a beaver family which costed some million Euro.

This happens now and won't be any better in the future. Thus, if the new operation is not in the middle of nowhere, like Kamchatka in Russia or Australian Interior, it will need to be environmentally friendly, or will not exist.

Economic impact of the 4th revolution

In 2017 the consulting company Accenture published the report prepared for World Economic Forum (WEF) [7] stating that mining and metal industry globally can save till 2025 almost 321Bio. USD , out of which 189 Bio. USD the mining separately. It is equal to 2-3% of annual revenue .

Moreover, the report states, that thanks to digital solutions 1 000 fatalities and over 44 000 injuries can be avoided. Next to heavy social and private impact of that events, each fatality or lost time injury is a subject of high cost related to legal, compensation, medical and other expenses. According to [3] average cost of a fatality in US amounts to no less than 2.5 Mill. USD and non-fatal injuries around 50 000 USD. Assuming the above values and earlier stated number of accidents, it gives an additional value of 4.7 billion USD in next 10 years![6]

The report of Accenture divides sources of savings into four groups, let's check which technology in every group have the potential of the highest impact.

Automation and Robotic

Automation and robotic has a potential of 90Bio. USD savings in the global scale. The key technology in that group is autonomous vehicles and machines. Two group of machines has the larger potential for automation: drilling rigs and loading and hauling machines. Both on surface and underground there are thousands of loaders, excavators and dumpers hauling extracted material every day. This work, especially in underground mines is one of the most dangerous, and a subject of many injuries. Out of 12 fatalities in US surface mining, according to MSHA 6 were related to haulage. Similar values are reported in Australian mining (42% vehicle collisions, according to [1]). In case of autonomous machines, not only those fatalities could not happen, but most likely many of accidents would not have a place. It is due to the nature of autonomous vehicles, which are equipped in multiple sensors and able to handle information coming from all of them in a fraction of a second. Those technology is already tested by many automotive companies, just to mention Volvo and Tesla in a normal street traffic, much more demanding environment than isolated roads of open pit or corridors of underground mining. Thus, that technology is already used from many years in underground mines and enters in open pits as well.

First report on autonomous underground loaders are dated on 2004, so are more than a decade old! Underground mines are favorable environment for autonomous machines, as a large part of their cruise happens on a fixed and not changing tunnels. It gives an opportunity to place reflectors or other localization supporting devices on the fixed areas and limit number of sensors on the machine itself. Beside rare events of inspections or natural phenomenon's, almost nothing disturbs their travel. Additionally, it increases the safety!

Open pits are here slightly behind, due to more complex environment, but slowly catching up. Rio Tinto uses 80 autonomous Komatsu dumpers, in their Australian operations. Those trucks, which are 20% of their fleet delivered 25% of production showing 15% lower costs than maned ones [8]. That convinced Rio Tinto to double their autonomous fleet till the end of 2019.

Another interesting project has been recently undertaken by Volvo. The project called Free from emission quarry, considers not only autonomous dump trucks but also electric or hybrid powered machines. The project is in the early stage (started in August 2018) but considers at least 25% operational cost reduction. Beside emission reduction, the important part of the project is to prove, that autonomous concept make sense also in case of smaller operations [4]. Since then, the press releases on autonomous mining and construction equipment pops-up every month (eg. [9])

If we take an average quarry production limestone for cement production, with an average cost of 2 USD/t and production of 1.5 Mio. t (the Author has reliable data about that sector of extraction industry), it would result in 750 thousand USD per year, which scaling up to a multinational concern with 100 operations worldwide gives astonishing 750 Mio. USD!

Drilling in underground is more complex, but open pits mastered already also this activity. BHP Billiton and Rio Tinto use autonomous drill rigs since 2014 and basing on the experience decided that it is the way to go. O-Pitblast the modern blast design platform has capability to export designs into Hole Management System (HMS) of Epirock drill rigs. The system is available also on the small, quarry rigs. The machine equipped with the HMS system gets the design from O-Pitblast and can position itself over a future blasthole. It is not autonomous yet, but already close.

There is also one more economic aspect of autonomous or remote operations. Many big mines located either underground or in the remoted areas must transport and encourage employees to accept this demanding lifestyle. Working on the base of fly in, fly out (FIFO) is difficult, usually very few accepts in a long run. Cost related are not only higher salaries but also cost of camp and transport, often imposing private planes, airports and all the related infrastructure. If the mine won't be fully autonomous, a part of that cost needs to be paid, but there is a large optimization area.

Touching the topic of fully autonomic mine, Syama gold mine in Mali, which is being constructed by Australian Resolute Mining will be the first fully autonomous underground mine. Secluded location in unstable politically country encouraged the company to use recent technological novelty. The main should be fully operational till the end of the year! [11]

Digital enable workforce

With 162Bio. USD saving potential digital enabled workforce is the most promising out of 4 sectors. In the other words we can talk about the connected worker, an employee who all the time has access to work relevant data, like production, safety, environment and many more.

Imagine that there is no need to train the new employee, who during his task gets online support from augmented reality-based platform. Using a googles or another device, platform recognizes machine and task to be done and guides the employee in each task.

From the safety point of view, it is be possible to localize every employee. It would avoid traffic accidents, as connected machine could see the employee, as well as help to control access to areas of a plant. Preheater tower is an area of a cement plant, which is especially dangerous. It contains preheaters, high temperature gases installation and supports flow of tones of hot raw materials. Entering there is restricted and limited to the employees who have special training and authorization. Simply beacon based system may warn, once somebody enters the area without permission, as well as warn the employee that he is trespassing border of a dangerous zone.

But why at all go into a dangerous zone or perform a dangerous task if a machine can do it instead? The problem is, that not always autonomous machine would be able to do it alone. Here come the remote-control capabilities. Again, it is a technology already used in many operations, especially underground. LHD's and Jumbos are already for years operated remotely. The operator located on the surface has a direct control over machine which is underground. Beside obvious safety related benefits, it influences also an effective working time of

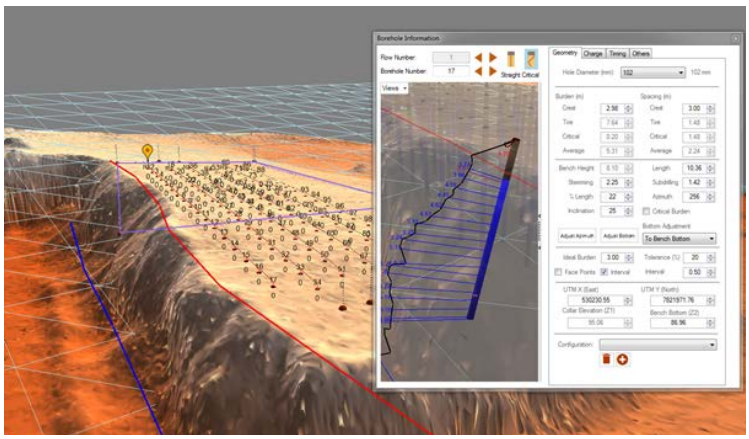

Fig. 3. Blast design using O-Pitblast, model created following [4]

Rys. 3. Projekt robót strzałowych z zastosowaniem O-Pitblast

Fig. 4.AugmentedQuarry – project of Kawalec Consulting GmbH

Rys. 4. AugmentedQuarry – project autorski Kawalec Consulting GmbH

the machine and the operator, who does not need to get underground. Recently there are investigations on remote or autonomous solutions for long walls and other coal mining systems.

Remote control would be also a solution to attract more people to work in mines in the future. Youngsters prefer to do other jobs, which are not really exposed to harsh weather conditions or dangerous confine space of underground mines. Additionally, it gives a potential for gamification – the operator may have an option to gain batches and is informed about his achievements, like in a computer game. Looking at popularity of different simulation games it shells significantly change the perception of the mining jobs, but also have a direct influence on the working performance. Many operators nowadays are just train to do a job safely and without damaging the machine, while work performance is far behind. Gamification would foster continuous development without expensive trainings.

The last to mention is the author's project related to Virtual and Augmented reality for quarry planning and operation support. It is partially connected with decision support platforms, but still more in connected employee. The project is on an early stage, with a major idea to create VR and AR platform which eventually will replace paper maps in normal quarry operations.

Integrated enterprises, platforms and ecosystems

This block of actions with the value over 58 Bio. USD is mostly about connecting and improving business processes and technological operations. Taking as an example an open pit mine, in case of overload on the crushing system, the connected trucks can be either sand on standby, or reassigned to transport overburden. The system would also have capacity to learn and adjust number of vehicles to optimize crusher throughput considering the distance to the crusher, road conditions or even weather or time of the day. With the scope to be as close to the nominal output or the best demonstrated practice, system would shuffle reevaluating options and strategies.

Another possibility is to shorten the distance between the producer and a final client. Using internet purchasing platforms big foundries and steal plants would be able to cut some middle levels of the supply chain, which would be beneficial for both sides.

Similar solution is used already by the OEMs like CAT or Komatsu, which use their telematic systems to predict possible breakdowns and supply spear parts on time, avoiding unnecessary stocks at the client, but also in the regional distributor.

The area covered by that block is wide, starting from internal processes optimization to Social Media application for company image improvement.

Special place is reserved for cybersecurity solution, which do not cut costs, but help to avoid loses related to cyberattacks and other kinds of cybercrime.

Next generation analytics and decision support

Already now each mining operation or any other industrial object collect vast amount of data, which very often are not properly analyzed and rarely used for process optimization. It is mostly due to the large amount of data which are collected. To make a proper decision we need to analyze the right data in the right time, which is hard being overflooded with the data waterfall. It requires extensive data analytic capabilities and won't be done without a person or a team dedicated to do that. A solution would be to delegate that task to AI which unlike people can work 24/7 and analyze more data per second than even the best trained human brain.

Following that idea, simple or routine decisions can be done without human intervention and validated through so popular recently block chain.

On the other hand, visualization capabilities for both data and spatial information would efficiently support any interdisciplinary discussions and decision-making process.

Challenges and risks

Many of the above was about autonomous, automated, faster and easier processes. The first risk which is coming to once mind is no doubt related to the workforce which will face the danger of being unemployed. According to Accenture report, estimates the number of so-called displaced jobs to approximately 313 thousand. Among those are mostly the most risky and dangerous jobs, which requires the lowest skills and education.

Simultaneously the demand for data scientists, programmers, analytics, engineers and other highly educated specialists will rise drastically. Paradoxically the demand may rise faster than their training which will create lack of workforce as oppose to unemployment generated by jobs displacement.

Here the solutions described above may help as well. To reeducate a low skilled employee, it's possible to use augmented reality and gamification.

Another great risk is the safety of data transfer and protection of connected production lines against terrorism, sabotage or any other kinds of hacker attacks. Up to date it has been frequently done by creating an internal isolated network, which in the era of 4th revolutions does not look like a feasible solution anymore.

Talking about the safety it is also necessary to find a way to control the AI itself. The scenarios from movies like Terminator or Matrix looks very unlikely, but the rapidly developing new technology must not get out of control…

On the other hand, a great challenge lays in front of all the regulatory bodies and controlling institutions, as well as governments of countries, which will need to create a legislative environment capable to handle the new challenges.

Conclusions

Several interesting and ready to implements technologies is just waiting to be wider implemented. The ball is on mineral industry side and waits for initiative. Like in case of all other innovations, ore mining takes the lead but with high probability, others will follow soon.

The road to full digitalization contains two phases:

1. Preparation
   a. Digitization
   b. Data gathering (IoT)
2. Digitalization per se where advanced AI will start to take some decisions without human influence.

Change is inevitable, it happens all the time and cannot be ignored. It fosters an idea of continuous development. In our times, nobody can just simply finish education graduating college or university. It is a process which last through our entire life. Using the quote of marvelous American author:

"you got to figure out which end of the needle you're going to be, the one that's fastened to the thread or the end that pierces the cloth."

— Sue Monk Kidd, The Invention of Wings

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Jaki wpływ na przemysł wydobywczy będzie miała 4-ta rewolucja przemysłowa?

Mimo że trzecia rewolucja przemysłowa nigdy tak naprawdę oficjalnie się nie skończyła, od jakiegoś czasu określenie Czwarta Rewolucja Przemysłowa jest na ustach specjalistów branży technologicznej. Początków tejże upatruje się w projekcie rządu republiki Federalnej Niemiec, nazwanego Industrie 4.0, zainicjowanego podczas Hanower Expo w 2012 roku. W roku 2013 opublikowano oficjalny raport na temat ww. projektu.

Artykuł wyjaśnia pojęcie 4-tej rewolucji przemysłowej i podejmuje próbę przewidzenia wpływu tego fenomenu na przemysł wydobywczy. Olbrzymie wyzwanie jakim jest cyfryzacja i wprowadzenie systemów cybernetycznych do górnictwa niesie ze sobą ogromny potencjał ograniczenia kosztów, który ocenia się na 321 miliardów USD do roku 2025, ale także liczne wyzwania. Artykuł przedstawia najważniejsze technologie oraz ich stan rozwoju i istniejące już wdrożenia, uwzględniając maszyny autonomiczne w kopalniach podziemnych i odkrywkach, samosterujące maszyny wiertnicze czy pozbawione kierowcy samochody technologiczne w górnictwie odkrywkowym.

Prezentowany jest krótki opis bieżącej sytuacji oraz obraz górnictwa po wprowadzeniu pełnej automatyzacji. Poruszone są również zagadnienia związane z wyzwaniami związanymi z nowym konceptem przemysłu oraz nakreślona zostaje mapa drogowa dojścia do w pełni zautomatyzowanej kopalni.