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REVIEW OF THE DOCTORAL (PhD) DISSERTATION

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ADVANCED AND COMBINED UTILISATION OF GEOGRAPHIC INFORMATION TECHNOLOGIES IN INDUSTRIAL DISASTER REMEDIATION – SIMULATION WITH THE RED MUD DISASTER OF KOLONTÁR

the author's description and official reviews of the doctoral dissertation

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ACTUALITY AND REASONS OF THE THEMATIC CONCEPT

In 2010, on October the fourth Hungary faced the worst environmental disaster of its history. In the surroundings of Kolontár the embankment of an industrial waste reservoir failed and a mixture of red mud and water (more than one million cube meters) was released. The flood affected the lower parts of the settlements of Kolontár, Devecser, and Somlóvásárhely. 120 people were injured and ten people died. The red mud flooded 40 km² of the surrounding area comprising 1017 ha of agricultural land. Remote sensing surveys (LiDAR, thermal, hyperspectral, satellite) were performed immediately after the catastrophe to assess the effects on the environment and assess the stability of the dam structure. The pollution extent and thickness were also mapped and provided to the disaster management authorities. Thus, the accurate and detailed information was not exploited further in the form of digital geographic information during the excavation activities performed during the clean-up phase. My belief is more accurate and probably more efficient work could have been achieved with the appropriate exploitation of the digital information with information technologies.

Thinking about an optimal remediation approach assisted by geographic information technologies I elaborated a new concept I called “precision remediation”. In agriculture, precision farming uses the information technologies (remote sensing, positioning, navigation, GIS) and automation to ensure the minimal use of inputs (fertilizers, energy, pesticides, etc.) and maximal work efficiency. Similarly, precision remediation should aim at using information technologies (GIS, remote sensing, positioning and navigation) automation and adequate field practices to ensure the most efficient work, which means:

- make efficient use of time and energy,
- excavate accurately the planned thickness of the soil,
- do not leave (or leave really the minimal) pollution on the area,
- do not move pollution from contaminated areas into clean area (cross contamination).

I foresee the method to belay on 4 technological pillars:

- Remote sensing (in particular hyperspectral imaging) for the detection and mapping of pollution,
- GIS for remediation planning and spatial operation management,
- Positioning and navigation guidance to accurately implement the remediation plan,
- Automation for the automatic control of grading equipment.

Considering the catastrophe of red mud, if a precision remediation scenario would have been followed it would have looked approximately like:

1/ the catastrophe happen,

2/ from remote sensing approach scientists produce maps with pollution location (extent) and thickness (zonation) - this actually happened,

3/ from the pollution maps, with the help of GIS (and geo-processing tools) the moves of the heavy equipment are planned in detail. This data is converted into navigation lines which can be loaded on navigation system and interpreted by navigation control systems,

4/ bulldozer, wheel loaded (and more generally heavy equipment) are equipped with positioning systems. Drivers implement the remediation plan with the assistance of navigation and control systems, they follow the navigation lines. Automation tackles the grading control issue,

5/ no overcut happen, almost all the pollution is removed in one attempt in the shortest time on the areas where heavy equipment can work.

DESCRIPTION OF THE SCIENTIFIC PROBLEM

Overall, the scientific problem is the development of an approach permitting the complete implementation of precise remediation concept. The method should allow more accurate and faster excavation compared to traditional approaches by the appropriate, advanced and integrated use of geographic information technologies. The scientific problem can be split in several sub-problems targeting the detailed and accurate planning, the implementation of the plan in the field with the help of positioning solutions and grading control. The method is technically constrained by spatial and temporal efficiency objectives. As technical solutions are performing altogether along the processing workflow, filiation and interactions have to be considered carefully.

The scientific problem will be solved by finding answers to the following questions: which technology is adapted to solve each technical problem? How the technology should be used? Is the technology adaptable or should it be modified? How to use the technology to achieve the best efficiency?

Beside the correct understanding and mastery on the technical aspects of the three foreseen GI technologies, an underlying scientific challenge is ensuring the integrity of information through a process covering acquisition, planning and implementation phases. The three phases succeed each over and each phase produces input data for the following phase. A key point is to ensure that data quality is sufficient in regards of the technical requirement (accuracy, coherence of the information) of each step. A second key point is to ensure the work is implemented spatially in the most efficient way. Less visible but of the utmost importance as scientific concern is ensuring the data integrity and accuracy all along the approach which should be an integrated approach.

RESEARCH OBJECTIVES

Objective 1: Making a state of the art with the review of the technologies and techniques (remediation, remote sensing, GIS, positioning and navigation) in order to have at hand a "body of knowledge" and up to date information for feeding the technical part.

Objective 2: Identifying the key parameters and metrics of interest for the modelling of the remediation process

Objective 3: Developing a set of tools for the detailed planning and the optimization of planning.

Objective 4: Identifying the technologies allowing the empowerment of the remediation plan in the field, designing technical set-up(s) with equipments and technologies and formulating the field practices associated with the implementation of technologies.

Objective 5: Integrating all the technical solutions into an integrated precision remediation approach that ensures accuracy, spatial and temporal efficiency and data integrity.

Objective 6: Assess the efficiency (timely and qualitatively) of the precision remediation approach (compared to standard approach).

Objective 7: Develop a "generalized version" of the method for its exploitation to most numerous disaster remediation cases.

HYPOTHESES OF THE RESEARCH

The formulation of the hypothesis is organized following my research plan.

Hypothesis 1: I suppose there is some useful information to discover in the literature and this information is relevant for me to develop my approach the best.

Hypothesis 2: I suppose identification of key parameters and metrics is absolutely necessary in such approach.

Hypothesis 3: I suppose GIS technology constitute a reliable solution for modelling and planning of remediation.

Hypothesis 4: I suppose I can use solutions existing in the field of positioning / navigation (agriculture, civil engineering) and in the field of machine control (civil engineering).

Hypothesis 5: I suppose it is technically possible to develop a remediation method based on the combined use of three GI technologies (HS remote sensing (for detection), GIS (for planning) and positioning (for guidance) because these technologies are enough adaptable to handle the different challenges with planning and guidance and their capacities are homogenous and sufficient enough for their coherent integration.

Hypothesis 6: I suppose that the developed solution -making appropriate use of GI technologies- will be more efficient that the approaches presently in use. I suppose the increase of performance can be demonstrated based on: (a) the volume excavated, (b) the work time, (c) the efficiency of the moves.

Hypothesis 7: I consider the red mud disaster can be considered as a typical case of remediation using excavation practices. It is appropriate to use it as a case study. I suppose the approach developed from this case study should be generalizable to other disaster remediation situations where excavation is required.

RESEARCH METHODOLOGIES

Any time technical choices should be done (GIS, navigation and machine control), it is supported by a state-of-the-art review. Several parts are dedicated to it at the beginning of the dissertation (part 1 and 2), then some paragraphs are developed when very detailed and specific complement of information is needed (machine control and guidance in part 3.4).

Geoprocessing tools are necessary for the detailed planning of equipment moves. As those tools are specific, I decided to develop them (with programming). First, the objectives are set, then algorithms are designed, then scripts were written. They are tested and their results are evaluated. The pollution extent and thickness (geographic information gathered during the red mud catastrophe) are used as test data. More generally, the red mud disaster is used as a case study.

Reality should be turned into a data model which can be interpreted by navigation systems. To this respect I used GIS for advanced modelling of the remediation plan.

Regarding the feasibility of the field practices modelling work is done to demonstrate the importance of physical parameters like the overlay and line length in the management of windrows.

The implementation of the remediation plan requires navigation assistance and machine control. A technical set-up is developed. Technical requirements are set, technical capacities are reviewed and evaluated in comparison of the requirements (feasibility study), and then a technical set-up is proposed.

Last a precision remediation approach is consolidated (generalization of the method) on the base of the technical solutions identified in the different technical parts. Emphasis is put on the feasibility, efficiency and accuracy of the approach and on data integrity.

THE CONCISE DESCRIPTION OF THE RESEARCH CONDUCTED

In the first chapter I examine the remediation topic first with a general bibliographic review about the remediation methods. The review helped me to know the vocabulary, the techniques, the strategies and the practices. It widened my field of view about remediation approaches and the diverse alternatives existing out of the excavation. In a second part I examine what happened during the Kolontár red mud disaster (depth of excavation, type of equipment used) so as I can have all information at hand for the later developments. This chapter is concluded with the examination of dam failures and remediation statistics worldwide and also the examination of the situation with other red mud storage sites in Hungary.

I demonstrated that dam failure disasters have frequently happened worldwide; that excavation remediation is the most employed practice even if it is not the less expensive; and that remediation business grows in Europe because of the industrial sites that should be restored. I finally conclude the precise remediation approach is of high interest as it should improve a method already largely employed; it will make excavation work more competitive – *answering hypothesis 1 partly.*

In the second chapter I deal with a general review about the technologies using geographic information: I sorted out the important capacities useful for my demonstration. Additionally, I took care to make the link between the capacities offered by these technologies and the advantages they can constitute in disaster remediation effort. I first examine the remote sensing technologies (aerial imagery, LiDAR and hyperspectral, then space imaging). How it can support the collect of information for the preparation of the disaster response phase. I examine the reliability of these techniques and for some the alternatives. Then I examine how geographic information systems work and how data model are used. My concern is identifying the important concepts and data model for the proper and efficient use of GIS with modelling and remediation plan design. Two concepts retain my attention: accuracy and data integrity. I decided that accuracy and data integrity should be the thread of this study. Last the positioning and navigation technologies are reviewed. The goal here is to examine the different technical solutions and conclude about the advantages, disadvantages and accuracy reached.

Closing this chapter, I conclude about the usefulness of the technologies and techniques for the disaster response in general, and for solving every of my single technical problems in particular. I also conclude that no example was found worldwide with the integrated use of the technologies as I visualize it.

In the third chapter, I develop solutions which constitute the pillars of the approach which are: 1/ *geoprocessing tools* for automatic planning, 2/ the optimization of the planning (for individual equipment and also the cooperation between equipment).

With each of the two solutions, I had to think at two different levels. One level is answering the technical requirements corresponding to the single technical challenge itself. The second level is having the solution fitting into the information workflow next to the other solutions, i.e. assuring it will properly integrate into the global schema.

With the development of the *geoprocessing tools* for the automatic planning equipment moves I had to identify the data model appropriate for the modelling of the detailed moves. That's how I identify rectangular polygon to model the footprint of equipment passage and lines to model the path to follow (for navigation). I also demonstrated how the footprint geometry can model the equipment characteristics. The blade capacities are represented and modelled with the footprint length and width. My intuition leads me to test the effect of the orientation of the footprints. I was almost sure orientation has an effect on the efficiency of the spatial coverage by the footprint. I demonstrate my intuition was true; I demonstrated the footprint orientation has some consequence on efficiency of the planning by developing and testing it with geoprocessing tools. I also demonstrated that scale issues play a role, in particular when the footprint area becomes bigger in comparison of the AOI to cover. Last I tested the effect of vertical and horizontal shift with the footprint pattern and demonstrated that the effect on number of lines is limited. These demonstrations were done by algorithm development, then geoprocessing tools development, then tests with a test dataset from the survey made on the red mud disaster. Based on the number of footprints I got after running a tool, I was able to conclude if tools increase or decrease the number of footprints to cover a fix area. By this process I demonstrated it is possible to perform automatic and detailed planning of the moves of the equipment using two parameters: footprint length and footprint width. The geoprocessing tool is designed to solve the orientation issue so as it has the highest efficiency. This first step was a good start but it is incomplete to model properly what happen in the field. During the geoprocessing tools development I had in mind that "somehow" the tools should allow to input a third physical parameter: an overlay between the footprint. In practice with programming, I did not have to modify my scripts to integrate this additional parameter as it can be input just by giving a larger width integrating half of the required overlay.

2/ In the field happen what is called "windrows" when blade is filled to capacity. Concretely blade start to be filled to capacity and incoming material is ejected on each side. The windrows are the reason why overlay should be integrated in the approach and modelled. I had no clear idea about how windrows work; I had no clear idea about the relationship between blade capacity, the excavation thickness and the "time" when the windrows start. My intuition was the relationship should exist but I have to show it. I demonstrate how it works and quantify it. That's the reason why I built a dozer scaled model equipped why a U blade and started experiments. First, I started by the examination of the windrows, quantifying it along the carriage. The experiments showed a bladed can store without windrows for a certain distance of carriage, then windrows grow, then windrows are stable when all the material coming in front of the blade is ejected on the sides. The next experiments demonstrated I can use the overlay between passages to be able to carry material on a longer distance without apparition of windrows. A modified version of this experiment definitely set the correlation thickness <-> maximum distance without windrows for a certain overlay with a certain blade. At that point of my demonstration I knew a field calibration similar to the experiment could provide the relationship between overlay and maximal distance at a given excavation thickness for given equipment (blade). At that point of my demonstration I realized different kinds of equipments cooperate and I have no idea about the relationship between the duplet {max line length; overlay} and the efficiency of the planning in the field. Inspired by the bibliography I realized, I use linear computing to solve this last issue. I Finally had the capacity to model (and plan) in detail the move of the equipment, avoiding the leftovers with overlay and optimizing the use of diverse equipment. The conclusion of this part is the demonstration of the feasibility of automatic planning, the demonstration of the feasibility of optimization - answering to *hypothesis 3*.

In the fourth chapter, having the detail and accurate planning, I should use the available technology to implement it with similar level of accuracy. I examined the problem and split it into two problems: a) navigational support for accurately following the navigation lines and b) vertical control of blade for excavation of the proper thickness; because vertical and planimetric dimensions does not have the same effect and technical solutions. Some additional questions rise up: does equipment already exist to perform that? Can it be used as is? I decided to examinate extensively the equipment proposed by the most renowned market brands in agriculture, civil engineering and land survey segments. I also reviewed the patents existing on the topic. To perform the review, I stated on the requirements. I was able to sort out what is useful and what is not. With x,y dimensions precision farming systems offer 1-2 cm accuracy, which meet the requirements. With z dimension bibliographic research reveal grading controls system will be adapted with accuracy up to cm, even mm with the appropriate technical set up. In depth examination of these grading control solutions revealed that they work base on a provided DTM. My further analysis of error propagation with the vertical reference revealed 3D grading control system would not be appropriated to guaranty the centimetric vertical accuracy. Finally I decided to look for a direct measurement in the the field with sensors and found the sonic sensor solution.

Getting the appropriate equipment is no sufficient, it should be operated properly. The last part is all dealing with the analysis of what happen in the field and how the difficulties should be solved. I defined practices for any type of equipment and any step of the collect.

The conclusion of this part is the demonstration of control system assistance, and the applicability of the approach with the support of adapted field practice – *answering to hypothesis 4*.

In the fifth chapter, following the data integrity and accuracy threads I demonstrated that the individual solutions I developed (planning, optimization, positioning and guidance, grading control) efficiently integrate in a coherent, global and complex approach – *answering to hypothesis 5*.

I investigated how the remediation approach can be generalized to be applied to a larger number of disaster management situations and I propose a generalized version with some recommendations for its implementation. In this part I conclude the method is feasible, coherent and conform to the accuracy objectives set. In conclusion the larger exploitation of the method is possible and recommended – *answering to hypothesis 6*.

Conscious that an approach has interest only if it demonstrates its usefulness, I have demonstrated the efficiency of the precision remediation approach – *answering hypothesis 7*. By making a detailed and accurate modelling of the remediation, it is possible to estimate the time necessary for implementing the operation. This information is essential for the dimensioning of a disaster response and mobilization of equipment (require international cooperation for example). I conclude the method is efficient in comparison of excavation made without GI assistance – *this answer to hypothesis 7*.

SUMMARISED CONCLUSIONS

Overall, this research work made feasible and demonstrated the applicability of precision remediation for pollution excavation on contaminated sites. To make the concept applicable, geo-processing tools, calibration protocol, the design of technical set-ups and the development of appropriated field practices were necessary. The applicability was assessed with diverse modelling. On a theoretical basis it was demonstrated that employing this approach allows achieving higher efficiency and accuracy.

I demonstrated accurate and extremely detailed planning can be achieved with the help of geoprocessing tools especially designed for the specific scopes of the remediation planning – *validating hypothesis 1*. The input data which is necessary for the planning consists of the pollution extent and thicknesses in the form of digital maps. A recommended option for the acquisition of such data is using remote sensing approach. The geo-processing tools outputs a remediation plan within the form of straight lines (which are navigation lines) and polygons (which represent the footprint of passage of the equipment following the line). An important discovery of the research work is the geometry of the planning should be determined by two critical parameters. The first one is the maximum length of the navigation lines. This parameter should be adapted to the capacity of the blade employed and the targeted thickness to remove. The goal is to adapt line length to the blade capacity. The second parameter to consider is the overlay between the navigation lines. The modelling of the excavation work has demonstrated some windrows inevitably happen along the lines and the overlays between the passages allow correcting this effect. Line length and overlay are critical parameters to the spatial efficiency of the work and they are necessary to consider for achieving a realistic planning. Last, I also demonstrated that the orientation of the parcels also has an effect on coverage efficiency. Those concepts were developed for this scope specifically they are not employed in the classic civil engineering approaches. My identification of these parameters the demonstration of the extent of their effect validates my assumption with *hypothesis 2*.

Observation of earthwork operations, manipulations of models and sand material helped me to figure out how the relationship between maximum line lengths, overlay between passages, blade capacity and excavation thickness works. I concluded overlay and line length correlate; and this pair can be optimized for the pair {blade capacity ; thickness}. The modelling and tests allow the development of calibration protocol which can be implemented in the field for collecting the values (blade capacity, line length and overlay) that are later on used as input parameters for the planning done with the geo-processing tools. Formulating *hypothesis 3* I did not expect I should go so far with modelling and I did not expect I should deal with optimization. So, optimization work was an add-on part out of my hypothesis formulation only targeting GIS). Nevertheless, the correlation between maximal line length and overlay falls under the umbrella of *hypothesis 2*.

My research work showed that guidance equipment and machine control equipment could efficiently assist the implementation of the detailed remediation plan in the field – *hypothesis 4*. My analysis of the earthwork practices showed the work should be split into two stages: the bulking of the dirt and the collect. Additionally, I demonstrated each stage requires specific equipment setup assistance. The most efficient solution for bulking consist in a kinematic DGPS assistance for ensuring the accurate positioning in x,y while using automation guidance for the grading control (in the z dimension) via the use of sonic sensors mounted on the blade. The collect phase can be assisted by radar guidance and masts or 2D grading guidance.

Inseparable from the equipment are the field practices. Adequate equipment with inappropriate field practices would lead to a lack of accuracy and efficiency. My research for the highest efficiency has led to proposals for fundamentals and equipment configurations. A first fundamental is to minimize the overlay between passages so as to ensure the highest efficiency with spatial coverage with the earthwork. This fundamental lead to the design of a remediation plan with parallel lines and parallel overlays. Another fundamental is to avoid cross contamination, and has a determinist effect on the freedom of the moves of heavy equipment. Last depending of the thickness of the excavation, the resistance of the ground and the remediation objectives different configurations were formulated with diverse type of heavy equipment in order to ensure the highest efficiency.

Accuracy is a leading thread of the “precision” remediation study. The thread was carefully unwounded looking at how accuracy works for any individual step. I also carefully assessed the continuity (via the inheritances thought the geographic features) of the accuracy thread and I secured it all along the workflow. This study has showed how the different pieces match each over and how they should be designed to work with each over. The planning strategy has inherited from (1) spatial coverage efficiency analysis, (2) the results of the modelling (windrows, line length, overlay). The navigation and grading control equipment set-up is influenced by the vertical and horizontal accuracy achievable, deriving from the result of the planning. Finally, the approach proposed is "integrated" and the integration of the technologies was a success – *as supposed in hypothesis 5*. This success is explained by the homogeneity of the accuracies associated to each individual the technical solution on one hand, and the care taken to develop compatible individual solution on the other hand.

I proposed a generalization of the method in order first to provide a one view over the whole approach for experts, and secondly to broaden the possible exploitation of the approach. I this respect I was true with *hypothesis 6* because I built a stereotype which should be employable in various cases of disaster where excavation is the recommended technical approach.

Finally, I assessed the approach technically in comparison with the requirements I set and in comparison with the situation with a classical approach not using GI. I demonstrated the designed workflow allow the increase of spatial efficiency by factor of two at least which result in decreasing expenses at least by half, validating completely *hypothesis 7*.

NEW SCIENTIFIC RESULTS AND THESES

- 1. Thesis

  Based on **research, I deepened knowledge** on disaster management, remediation practices, disaster response (in particular in Kolontár) topics. This **knowledge strengthens** and **sustain** the development of the remediation approach.
- 2. Thesis

  Based on **desktop research** I **gathered references** and **knowledge** about GIS, remote sensing, navigation, positioning, machine control, industrial disasters and remediation practices. My **examination** of the relevant literature **put into evidence** that the "precise remediation" approach was neither developed nor considered at national or international level. **My examination** also **demonstrated the usefulness of developing a more efficient excavation approach** based on advance GI technological support.
- 3. Thesis

I investigated the effect of the key parameters on the modelling of the equipment moves. This was done with geo-processing and scale modelling. **I demonstrated footprint orientation and the duplet** (maximum line length/overlay between footprint) **has effect on spatial efficiency** of the planning. My observations and conclusions led to the **development of geo-processing tools** for planning and linear computation tools for the optimization of the remediation plan. With the set of tools I developed, **planning** is **made automatically**, is **detailed** and **spatial efficiency** is **optimized**.

- 4/. Thesis

  I **reviewed** equipment for navigation and machine control. I **identified** appropriate equipment for the accurate implementation of remediation plan in x,y and z dimensions separately. **I proposed** one **set up for** supporting **navigation** (planimetric) and a **machine control set up** for the grading guidance (z). **I** also **demonstrated** that only remote field measurement of terrain elevation (with a sonic sensor) is relevant for acquiring valuable elevation data. This development **empowers** the **accurate** and **efficient implementation** of the remediation plan in the field. I designed field practices for the appropriate and **efficient use** of the equipment/technologies.
- 5. Thesis

  I **integrated** the different technical elements into a coherent approach; I **ensured the accuracy** of the remediation approach, the **data integrity** and the **applicability**.
- 6. Thesis

  I demonstrated how -by its build up- the method leads to the accurate implementation of the remediation objectives, resulting in spare of dirt move (only the targeted dirt), in an efficient spatial coverage, in almost no pollution left overs, and in an increase comfort for the operator, all leading to spare of energy, costs and time. Additionally, **I demonstrated** how rationalization can be done by adding time dimension to the project metrics (into the bulking phase and excavation phase) **leading to** an **accurate** estimate of operation time. By varying the equipment mobilization scenario, the operation time can be decreased and the project performances can be increased.
- 7. Thesis

  I designed a **generalization** of the **method.** for a remediation supported by integrated geo-information technologies for the accurate excavation of polluted soil (relevant for on-site and on-site ex-situ remediation approaches). R7/ **I designed** a **generalization** of the **method** for the remediation for on-site and on-site ex-situ remediation approaches. It makes the precise remediation approach usable in **wider** disaster remediation **context** or **situations.**

APPLICABILITY OF THE RESEARCH RESULTS

Remediation

The parcel and line design geo-processing tools can be employed for the planning and guidance of any machine work that should follow a remediation approach parcel per parcel and segment the field of work. Chemical remediation approaches require this segmentation of the field in unitary parcels. Parcel size and number of lines per parcel could be design so as to use the content of one tank. It is more efficient to proceed with rectangular parcel shape come to a close by refill station then doing long lines till the full consumption of the chemical material and travel longer to refill.

Because of the case study framework, I have considered the excavation of red mud pollution caused by a flood after a dam failure. The generalized method presented in chapter VII is designed to be applicable for the excavation of biological, chemical or nuclear contamination. Moreover the equipment selection allows the complete automation of the excavation work if required in the case the material to excavate is dangerous.

Automation and artificial intelligence

During the search for solutions for the control and navigation assistance I many times got in connection with the fields of robotic, automation and artificial intelligence. Then I realized the research work done could find much larger field of application than what I first figured out. This rises some opportunities for application of part of the method in these fields.

Military

My approach for the design of the geo-processing tools was basically an optimization of the efficiency of the spatial coverage of some field operation. Considering the numerous military operations requiring the optimization of spatial efficiency coverage, potential fields of application and extension exists there. I think in particular about decontamination, de-mining, reconnaissance, research in the field. The geo-processing tools could be added to spatial analysis tool box and then used in integration with other tools.

As mentioned above, important fields of research/ developments are robotic, automation and artificial intelligence. Whatever the military operation is, the robot or the operation control centre has to manage the efficiency of the spatial coverage of the robot in his environment. The cooperation and coordination of the robot fleet or groups should similarly be managed. The geoprocessing tools can also be used in this matter. The developed algorithm can be further developed so as to cover new challenges or different application. The optimization of the spatial efficiency for coverage finds applications whether with UAV or with terrestrial robots.

Industry

Part of the method can also find some application in the field of mining and landfill management as the operations there are very similar to the one of excavation for remediation. Oil spill remediation around pipeline is also a concrete field of application[1].

More particular but with a lot of importance, the industry of rare metal extraction could also find some interest. Polymetallic modules lying on the sea bed contains rare metal of strategic interest. Who master the technology allowing the collect of the raw material will have a strategic advantage in a technologic world where rare metal are strategic resource. Under the conditions an extraction machine with capacity to work under water (electrical dozer already exists) and the positioning under water could be solved then the geoprocessing tools, navigation and control approach can similarly be implemented.

PUBLICATIONS OF THE AUTHOR

Articles issued in international peer reviewed journals in English:

1. Lucas, Grégory: Development of Method and Tool for Optimizing the Earthwork with Ex-Situ Remediation of Polluted Soil, *Global journal of computer science and technology*. 2017, 17 : 01, pp. 16-36. Paper: 0975-4172
2. Lucas, Grégory ; Lénárt, Csaba ; Solymosi, József: Development and testing of geo-processing models for the automatic generation of remediation plan and navigation data to use in industrial disaster remediation, *Open Geospatial Data, Software and Standards*. 2016, pp. 1-13. Paper: 2363-7501, 13 p.
3. Lucas, Grégory ; Lénárt, Csaba ; Solymosi, József: Development and testing of geo-processing models for the automatic generation of remediation plan and navigation data to use in industrial disaster remediation, *International Archives of Remote Sensing*. 2015, (2002-) XL-3 : W3, pp. 195-201. , 7 p.
4. Lucas, Grégory. Considering time in orthophotography production: from a general workflow to a shortened workflow for a faster disaster response. *International Archives of Remote Sensing*. 2015, (2002-) XL3 : W3, pp. 249-255. , 7 p.

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[1] I had a discussion with a disaster management specialist dealing with oil spill remediation at the ISPRS Montpellier in 2015.

Articles reviewed and published in professional periodicals in English:

5. Lucas, Grégory; Solymosi, József, Lénárt, Csaba: Review of remote sensing technologies for the acquisition of very high vertical accuracy elevation data (DEM) in the framework of the precise remediation of industrial disasters (1), *HADMÉRNÖK*. 2022, 17 : 1 pp. 155-170., 16 p.
6. Lucas, Grégory; Solymosi, József, Lénárt, Csaba: Review of remote sensing technologies for the acquisition of very high vertical accuracy elevation data (DEM) in the framework of the precise remediation of industrial disasters (2), *HADMÉRNÖK*. 2022, 17 : 2 pp. 147-158, 12 p.
7. Lucas, Grégory; Solymosi, József: Preliminary study on the detection of radioactivity with airborne remote sensing systems. *HADMÉRNÖK*. 2015, 10 : 3 pp. 137-155., 19 p.
8. Lucas, Grégory ; Halász, László: Review of airborne laser measurements of chemicals and radiations. *HADMÉRNÖK*. 2014, 9 : 3 pp. 61-79., 19 p.
9. Lucas, Grégory ; Halász, László ; Solymosi, József: Exploring the capacities of airborne technology for the disaster assessment. *HADMÉRNÖK*. 2013, 8 : 3 pp. 74-91., 18 p.

Lecture Held in international professional conference:

10. Lucas, Grégory. Application of remote sensing technologies for the prevention of risk, the monitoring and the restoration of industrial sites. **In** : A A, Abdykalykov (szerk.) Proceedings of the Sixth Central Asia GIS Conference - GISCA'12 : Geoinformation for land and resource management. Bishkek, Kirgizisztán : Austria-Central Asia Centre for GIScience, (2012) pp. 58-65. , 8 p.

Lecture held in a Hungarian professional conferences:

11. Lucas, Grégory ; Solymosi, József ; Lénárt, Csaba: Development of geo-processing models for the automatic generation of navigation data used for precise industrial disaster remediation. **In** : Boda, J (szerk.) Az elmélet és a gyakorlat találkozása a térinformatikában : Térinfomatikai Konferencia és Szakkiállítás VI. Debrecen, Magyarország : Debreceni Egyetemi Kiadó, (2015) pp. 155-162. , 8 p.
12. Grégory, Lucas ; Solymosi, József ; Lénart, Csaba: Using hyperspectral imaging in nuclear radiation aerial reconnaissance?: a preliminary study. *REPÜLÉSTUDOMÁNYI KÖZLEMÉNYEK*. 2013, (1997-TŐL) 25 : 2 pp. 644-656. , 13 p.

SCIENTIFIC CURRICULUM VITAE

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2022-2012	Aerial photography expert at Envirosense Hungary Ltd.
2007-2012	Coordinator of Educational and research project at the University of West Hungary, Faculty of Geoinformatics.
2005-2007	Civil servant (as a research assistant) at the Caribbean Agronomy Research Centre (Martinique) on the topic of GIS and watershed management

Academic activities

Publications: 17

Participation in research of university and projects:

(2016-2022) Production of Orthophotography RGBNIR maps for research projects

(2016-2022) Assessment as external expert of 17 research and development projects for the Slovak Research and Development Agency.

(2012-2015) Mapping of several Danube floods (acquisition and processing)

Conferences	(2016) Invited as keynote speaker at the Leica airborne user conference, presentation about the advantages of advanced camera calibration and the use of direct geo-referencing.
	(2015) Two papers presented at the ISPRS conference, La Grande Motte, Montpelliers, France
	(2015) One paper presentation at the Geospatial Conference and Exhibition in Debrecen
	(2013) One paper presentation at the Conference on Aeronautical Science in Szolnok,
	(2012) Moderator at the GIS for central asia conference 2012, Bishkek, Kyrgyzstan.
Distinction/nomination	(2016) Nominated as an international peer review expert by the Slovak Research and Development Agency in the field of aerial radiation survey.