Eindhoven University of Technology

Innovation Space project

1ZM150

BlankSpace

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Executive Summary

Who are we?

We are BlankSpace. We fill the gap between satellite data and solutions that exploit this data. We have been working with Jasper van Loon from the Netherlands Space Office in the context of the Innovation Space Project. While working with him we realised that satellite data has a incredibly high potential. Unfortunately, it is very difficult to extract this potential in concrete solutions for the common company. As a consultancy, we want to help these companies in tackling their problems using this awesome source of data.

Our team is made up of Leonardo Remondini, Màrk Sümegi, Mattia Molon, Max Helmes, Mugdha Kashyap and Tommaso Bonomo. We have a strong technical background in subjects that can help in providing these solutions. We have expertise at Master level in Data Science, Physics and Embedded Systems, plus previous work experience in Software Development. We have already built working prototypes that can be considered first steps of complete solutions to solve real problems. In the following Subsections we will go into more detail about our current projects, how we want to grow and what do we see as our future.

What are we doing?

We have found two prime examples of problems that would immediately benefit from a solution that exploits satellite data.

First of all, we spoke with ProRail to understand how they are currently monitoring the integrity of their train tracks. At the moment, they are using trains with dedicated sensors that record information while travelling on the train track. Other options they often use are drones and fixed-cameras that evaluate the integrity of the tracks. We propose a more proactive solution. We intend to use InSAR data to monitor the soil subsidence of the ground underneath the train tracks. We can then understand how the subsidence behaves across time, at precision of a few millimetres. If the ground subsidises very differently in two adjacent points underneath the train tracks, it is likely that the train tracks are affected. Our solution offers much better value: the cost is lower (€8.4M per year instead of the estimated €120M total expenditure in NL in one year); we provide better temporal frequencies (once every few days for any train track segment); we can operate in any weather condition; it is a proactive solution instead of a passive one (warns of possible damage, doesn’t inspect for damage that has already occurred).

Secondly, we talked to Deltares to understand how the process of coastal monitoring is currently handled. Coasts, in the Netherlands and worldwide, provide a natural and effective defensive system against floods from the sea. Coastal erosion is a phenomenon where the sea takes away large quantities of sand yearly. The Netherlands invest a lot of resources to contrast this phenomenon, for example through beach nourishment. To make smart investments and understand their efficacy, a thorough and deep understanding of the coastal development is needed. This monitoring is executed by Deltares. They use drones or in-place cameras to achieve this. We implemented a solution that again provides a better monitoring through the use of satellite data. We analyse a whole time-series of InSAR images, where each pixel contains the elevation of the ground. We are therefore able to provide a visualisation of how the coast has been subsidising, from which we can see how impactful the measures against coastal erosion have been. We are able to provide a our solution at a cost of €500k yearly, while the Dutch government spends around €20M. We also provide a better temporal frequency and detail.

Why are we doing it?

We chose these two projects after several weeks of Divergence-Convergence (a technique from Design Thinking). They both resisted to many cycles of validation. We realised that it made much more sense to keep pursuing both of them rather than choose one of them to drop. It helps our financial calculations, as we share the fixed costs between both projects. We are expecting to turn profitable after one year, mainly because of the finalisation of our two commercial pilots described above. Please refer to Section 3 Analysis for more details.

We also realised that we really wanted to be that middle-company between satellite data and everyday problems. We want to help crafting solutions in various domains, as the opportunity is so large it would be remiss of us to ignore other potential domains. To further expand our operations, we want to first concentrate in expanding within our current domains. This will enable us to have both sustained revenue streams and a portfolio of working solutions. We then want to gradually implement our marketing strategy to target other domains and let ourselves be known to whoever might be interested in our services. We could for example participate in specialised satellite conferences, or rely on word-of-mouth in a local community of entrepreneurs. We feel that the opportunities we could discover are nearly endless. We believe we can participate in revolutionising how satellite data is used in solving real problems. Please read through our extensive report, and contact us if you would like to join us.

1 Introduction

All throughout human history, people have always been fascinated by the idea that we could look down from the skies, and see ourselves from above. Pondering about all the knowledge that we could achieve, by having a bird's eye view of our whole world. This dream became a reality with the invention of earth observing satellites.

Since the launch of the satellites in the 1950s, the space sector has expanded considerably and has now become a global business. Satellites circumnavigate the entire globe and are regularly used to monitor the earth and retrieve important information about the weather, climate change, the right time to harvest or sow, and geolocation. This reflects the growing need for rapidly available information, and this increase in the value of space technology is only set to continue.

But what makes satellite data so valuable? While being able to observe the earth with centimetre precision, satellite data is still able to give you a large scale view, where you can analyse whole countries or continents and extract macro patterns. Moreover, since the satellite is orbiting the earth continually, we can make new observations frequently, and compare it to old data to discover trends. In short, satellite solutions are always up to date, and trivially scalable.

Although this data is mostly available for everyone to use, extracting the necessary information to create business value is not straight forward. First of all, just getting the piece of data you actually need is a very cumbersome process, and there is also quite a steep learning curve when it comes to interpreting it. Thirdly, integrating the extracted information to a business solution also takes time and effort. There seems to be a gap between all the valuable information that satellites can provide, and the people who could benefit from this information.

To fill this gap, we created BlankSpace, a consultancy company that provides tailored solutions to businesses aiming to utilize satellite data. With our experience in the field, our connections to various stakeholders and our knowledge in analytics, we want to make it effortless for businesses to create value by harnessing the potential of this technology.

Figure 1: Blankspace, the connection between satellites and end users

BlankSpace joined ISP and Netherlands Space Office (NSO) challenge at the start of the third quartile. To show how our consultancy will operate, we created two pilot projects that demonstrate our technical capabilities, while also generating immediate value for our first two partners. We developed cost effective monitoring solutions for train tracks with ProRail, and for coastal erosion with Deltares. Both projects deal with the problem of ground deformation (or soil subsidence), but the technology we created can easily be repurposed for various other domains. We hope that these pilot projects will give us an opportunity to educate people about the usefulness of satellite data, and will help us convince stakeholders from other domains to work with us, further utilizing this amazing technology.

2 Approach

At the beginning of the project our group started to work without any personally assigned responsibilities, dividing the tasks in an ad-hoc manner where we picked tasks that suited our interests and strengths. As the workload piled up, work kept being shuffled around and deadlines became blurry, so we needed to change the team structure and assign responsible people for given tasks. For this we used SCRUM as a base, whereby we picked and deconstructed two of the original roles: the Scrum Master and the Product Owner

In a software dev-team from where this method was originated, a Scrum Master is the person who is responsible for the SCRUM process. He knows *how* to work in an efficient way and introduces the team to techniques for effective problem solving and communication. He also makes sure that everyone in the team is satisfied with the distribution of tasks, and is a crucial part in handling disagreements. We split the Scrum Master into two roles, The Kindergarten Teacher, and the Process Master.

The Kindergarten Teacher (Leonardo (Q3) & Mugdha (Q4)) is responsible for the overall team well being, and that we work together in peace and harmony. They moderate the feedback sessions, and make sure that the team cohesion and morale is high. This task requires good communication skills and a lot of patience, this is why we named this role the Kindergarten Teacher.

The Process Master (Mattia (Q3) & Max (Q4)) takes the other half of the SCRUM Master role, the one responsible for the working process itself. He is most notably the facilitator of every meeting, and he makes sure that we are utilizing techniques that we learned during the course. These are for example brain storming techniques like the 6 thinking hats method, or ways of analysis like the customer journey mapping.

We quickly realized that properly documenting our work was going to be crucial in order to not lose valuable insights and ideas after our meetings. To make sure that this was handled well, we expanded the SCRUM team roles with a Scribe (Tommaso (Q3) & Mark (Q4)). They are responsible for everything related to documentation, from writing notes during meetings and keeping our shared Google Drive folder tidy, to grammatical proof reading and submitting assignments.

The final role we introduced is the Product Owner. In original SCRUM the Product Owner is representing the stakeholders' point of view. Product Owners have overarching knowledge about the underlying product and it's capabilities, and they also have a deep understanding about the demand of the targeted market segment and the wishes of specific customers. The most important task of this role is the prioritization of tasks to be completed, this way the PO is steering the product towards the customer's needs and towards success.

In a development team there is usually only one Product Owner, since the team is mostly working on one piece of software. In our case however, since the uses of satellite technology are very broad, we managed to come up in the early stages of brainstorming with multiple ideas that all needed further research and validation. This was the diverging phase, where we pinpointed Project Candidates, that were proposed solution ideas for different problems. The original six were:

- Train track monitoring (PO: Max)
- Cultural heritage management (PO: Mugdha)
- Riverbed maintenance and flood prevention (PO: Mattia)
- Solar panel placement and solar energy logistics (PO: Mark)
- Ocean Fishing (PO: Tommaso)
- Economic analysis (shops) (PO: Leonardo)

For each of the candidates we assigned a responsible Product Owner, who manages the project, goes deeper into research, establishes contact with potential customers to validate our assumptions and tries to bring the project to success. By the end of Q3 these had reduced and changed (more on that in the project-wise pivots and stakeholder interactions) and we continued with the converging phase.

Of course working on multiple projects instead of one has a number of drawbacks too. Although we managed to throw out some ideas after one or two weeks, we still had 3 main running projects up to this point, which effectively tripled our workload. This made it harder to rapidly gather information from the industry, since our resources were spread out across different areas. This was also made harder by the 2020 global pandemic, that had a big shock on the people around the world and also prevented us from going out to meet potential customers.

Although the virus was absolutely terrible, we still managed to get some valuable experience that will prove very useful down the road. Remote working, especially in the field of engineering, is a solved problem on the technological level, but it is still a weird thing for people to get used to. As industries shift more and more to an online environment, we think that practicing this type of contactless cooperation is going to be one of the important soft skills of the future.

2.1 Blank Space Company Perspective

From a company perspective, during the first half of the course, we worked at the InnoSpace Project without a clear business structure or marketing idea. At the beginning of the course, we wanted to focus on a single challenge, so that we could focus all of our resources in that domain. Nevertheless, the more we searched for the perfect domain, the more we realized the power and the flexibility of satellite data. After a first brainstorming session, each of us come up with a potential business idea. Initially, the plan was to pick the most prominent and valuable business idea, but then, even after many iterations, three of them were still valuable from a business perspective. From that moment, we started thinking of ourselves as a consultancy agency for satellite data. It means that we could be the ones who help companies to deal with satellite data, providing them more effective satellite-data-driven solutions for their needs. After many iterations and feedback from our coaches, we paid close attention to how we would go about approaching new clients. We lay out those strategies in detail in Section 3, Analysis.

2.2 Train Tracks

At first the idea came to mind when flying from Barcelona to Eindhoven, the initial thought was: is it possible to observe rail defects from space? This thought, in combination with the information provided by NSO on what the possibilities are regarding satellite data usage, quickly grew to a concept. A concept in which the problem of subsidence of railways and their surrounding is defined and after a conversation with ProRail and Ikos Rail the problem was validated. In the search towards a solution to this problem SkyGeo was contacted, SkyGeo is specialized in detecting subsidence with the use of satellite data. After an open conversation with SkyGeo it was determined that radar signals could provide a solution to detect the subsidence of train tacks.

At this point the problem is validated and the potential solution is determined to be technical feasible. This is then followed by a market analysis, in this analysis research and conversations are preformed to pinpoint the pain of this problem. Besides we investigated in the necessity of our solution and what our added value would be to ease this pain. Thereafter we also conducted a small examination of the possible market segments, to determine where else our solution would be applicable.

Finally, it is time to make the solution concrete. The measurement of soil subsidence is done with InSAR, this is a form of radar. With this technique we are able to map millimetre scale deformations of the earth's surface. During this measurement a ton of raw data is obtained, to process this data we investigated a few open source programs. The programs that we considered were; GTMSAR, ROI PAC, and Sentinel-1. After which we have chosen to continue with Sentinel-1 since this was most suitable. After some effort, we managed to create a prototype in which we use the software to analyse any railway in the Netherlands.

2.3 Coastal Erosion Project

The initial challenge of this sub-project was focused on the monitoring, maintenance, and reinforcement of riverbeds and riverbanks with satellite data. Our goal was to create a software that could have improved the time and cost efficiency of nowadays monitoring systems of Dutch rivers and substitute them with satellite data. We first moved to validate those initials assumptions, and to do so, we contacted SkyGeo, which was one of the leading companies in this sector. We found out that the player who is nowadays monitoring riverbeds and riverbanks (Rijkswaterstaat) is already using satellite data and is reluctant to adopt new technologies, as it's satisfied with its ongoing monitoring system. Therefore, our final solution wouldn't have added any additional value. The technology was already there and it was already being used. Moreover, the Dutch river monitoring market seemed to be saturated, reducing the possibility of our start-up to make an impact.

It was clear that we couldn't spend additional time on that challenge, but instead of dropping the idea definitely, we slightly changed the problem-statement we wanted to address since the previous one was a no-go. What we did was to change the focus from rivers to coasts, assuming that satellite images could have substituted and increased the efficiency of coastal monitoring systems, instead of river monitoring systems.

What we needed to verify is that the current technology adopted to monitor the Dutch coasts is replaceable with satellite data without losing efficiency and that this new technology could have reduced the total costs for coastal monitoring and maintenance. Moreover, we needed to understand how this market was moving and who was responsible for what.

Following this mental pattern, we contacted via email various dutch regions and municipalities to understand how they're currently facing coastal erosion and maintenance, and consequently, understand where and how we can stand within the value network. We found out that all regions cooperate at a national level and the main active-player is the Dutch government, which is financing the reinforcement of the coast with sand nourishment through a project called "Delta Program". This project is carried out by the government itself and Deltares, an independent institute for applied research in the field of water and subsurface. Deltares is monitoring the Dutch coasts on behalf of the Dutch government and is providing them an analysis of the Dutch coast regularly.

In the following step, we contact Giorgio Santinelli, a researcher who is involved in the Delta Project and works at Deltares. He validated that nowadays data is not collected with satellite data, but it's collected with drones, planes, and in-place cameras instead. Indeed, satellite data could substitute these monitoring means but we had still to validate if satellite images could have cut costs and if so, in which terms.

To validate this assumption we searched online the annual budget of the Dutch Government for the monitoring of the Dutch coast. We then looked for planes, drones, and in-cameras average rent costs and we compared those costs with satellite imagery costs. It turned out that satellite images are cost-efficient if compared with standard coast monitoring systems and this fact could decrease the national annual budget for coastal monitoring.

At this point we validated two of our main assumptions: satellite data can substitute nowadays coastal monitoring systems and it can cut costs for the Dutch government yearly.

We had then to work on the development of our prototype: Which are the main factors that Deltares is looking for when is monitoring the Dutch coast imagery? Can those patterns be extracted from satellite images? Could Deltares be interested in a possible solution prototype?

To answer these questions we contacted Giorgio Santinelli for a second time. He said that he would have been interested in a working prototype and he explained to us the most useful information that can be retrieved from a coastal data collection. He suggested building a prototype that could monitor the beach soil subsidence over time, together with the concentration of vegetation in percentage, as these are challenges that can be easily extracted from satellite images and match their needs.

At this point, we had validated assumptions and Deltares interested in a potential solution prototype. We worked then on the prototype development. After an intensive coding week we had our working prototype ready to be used, with all the requirements that Deltares was looking for. We didn't have time to validate the prototype with Deltares, but we are looking forward to schedule a meeting as soon as possible. More information about the prototype can be found in Section 4.2.

2.4 Cultural Heritage Project

The approach started with the inclination towards the Art and Culture within the society. Heritage places across the globe and also in the Netherlands are one of the main reasons why people travel. The uniqueness of the sites and the history associated with them are one of the major contributions in the economy of a country. The biggest challenge these days is to preserve and maintain these priceless sites. This was the initial idea, but we were adapted many times along the way.

Initially we started with the problem exploration phase with the help of interaction with associated leads provided by Jasper. The point of contacts and the discussions with explanation are as below:

- To gather information we interacted with Henk Alkemade from Cultureel Erfgoed. Extraction of three main ideas below (included with assumptions):
  - Monitoring of soil subsidence and its impact on cultural assets.
    Assumption: The cultural assets are impacted by subsidence, this was verified with Henk.
  - Undiscovered archaeological sites are at risk of being destroyed by construction work. Assumption: This is happening in the present scenario, verified with Henk.
  - Difficulty of precise exploration of townscapes, landscapes and cultural heritage parks that extend throughout a huge land area. Assumptions:

    * The process is inefficient and costlier with respect to the existing technologies being used.
    * The process is manual and not comprehensive.

- After a few iterations with Henk, we spoke with Jasper to discuss the technical feasibility of solutions we thought of.
- Once we settled on the archaeological domain, Jasper put us into contact with Jochem Lesparre from ARGEOgraph, an archaeological company active in the Netherlands. We were able to retrieve a lot of information from these interactions.

At the beginning of Q4 we incorporated some pieces of feedback we received, namely to improve and go into further detail about the market we wanted to attack. We spoke again with Jochem, who provided us with more information about how the market of archaeological companies worked in the Netherlands. We also further investigated this market through literature research, to try and come up with a number in Euros of the potential value of our innovation. We then set to work on the prototype of our solution. We incorporated feedback through Jochem, who also was a potential user being an archaeologist himself, and started working on the technical aspects of our solution. In the final weeks of Q4, we seriously evaluated the Cultural Heritage project, and acknowledged that there were too many flaws for it to be followed further. We therefore decided to drop the project. More details can be found in Subsection 3.3 in the Analysis Section.

3 Analysis

Satellite data is hard to access and difficult to handle. Nowadays many companies do not engage with this technology only because these main reasons and BlankSpace is going to ”fill the gap” between them and satellite data. BlankSpace is born as a consultancy agency that engages with satellite data on behalf of its customers and provides them satellite-data-driven solutions easily and rapidly.

As a consultancy agency, we will be asked to deal with different and uncorrelated sub-problems, at the same time, and for different costumers. That’s why we chose to show simultaneously three possible business ideas that represent three different customers who have decided to work with BlankSpace.

Ideally, we won’t stick with a specific domain (e.g. coastal monitoring, train track maintenance) as in that sense we wouldn’t exploit the flexibility of satellites data. We will rather stick with a technology that we use to build our solutions and discover other domains where that technology could be exploited (e.g. soil subsidence detection). This could mean either expand our current sub-projects to different countries and companies or dive into other ”soil subsidence domains” like house maintenance market and gas pipe maintenance market From a marketing perspective, we aim to have a Business to Business marketing plan. In order to make ourselves known to the customers, we will approach them by joining satellite data talks and by showing our prototypes during these events. Within the first two years, we will mainly ask directly to selected companies for meetings where we will present ourselves and our projects, exploiting eventual connections that are already present between companies.

Finally, we developed a very rough prediction of what our cash flow will look like in the next two years. A plot can be found in Figure 2. One of the benefits of being a consultancy with multiple projects is that costs that are common to all projects can be shared. This includes the cost of satellite data itself and the cost of it’s storage and elaboration. We estimate that: we will never have monthly costs of more than €40k/year; we will start having positive monthly cash flow one year in (when the projects with Deltares and ProRail are finished and operative); we never go below €235k of cumulative cash flow.

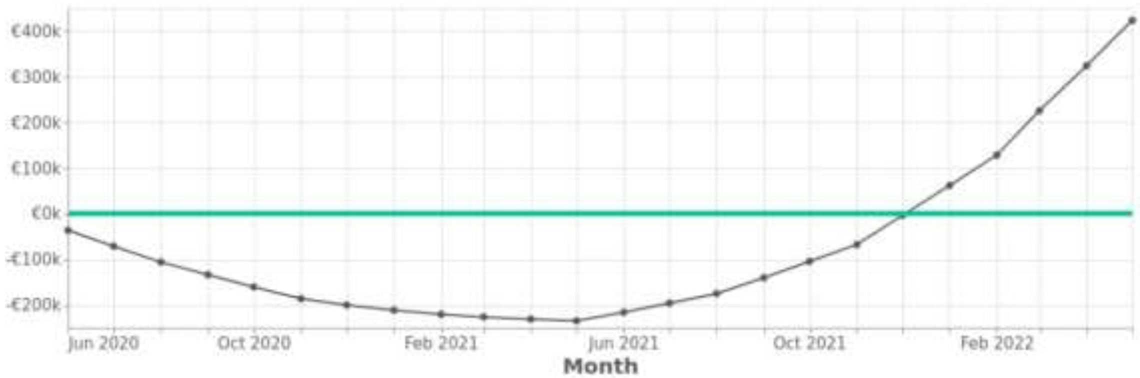


Figure 2: Cumulative cash flow - estimated

3.1 Train Tracks

The invention of the steam engine in 1712 and the utilization in locomotives in the year 1802, revolutionized the transport industry [8]. Rail transport is a cheap and reliable method of transport and therewith launched the globalization of transport. The demand for rail transport exploded in the 19th century, the network of rails had to increase immensely to keep up with this demand and is still increasing to this day. Nowadays, a small country such as the Netherlands has 7000km of rail tracks [11].

As expected, this large infrastructure needs to be maintained on a daily bases, in the Netherlands there are 150 railway constructions daily. One of the major causes of these constructions is the occurrence of subsidence of the rail, figure 3 is an example of such a failure. In this context, the soil below and surrounding the railway is gradual moving downward (in most cases). This process happens over a longer period of time, up to a few millimetres a year. That is why such process usually is unnoticed, until a failure occurs. In figure 4 you can see an image of the Netherlands in which the deformation of the soil is mapped. From this figure one is able to observe two major areas with

Figure 3: Failure of railway due to subsidence in Rastatt, Germany [13].

a lot of movement in the soil; Groningen (upper right corner), this movement is due to extraction of natural gas, and the Randstad (west side of the Netherlands) which is an area of peat soils.

One can imagine that subsidence of 0.5 cm a year that accumulate over the years, will eventually induce problems regarding condition of the railway network. Therefore the entire network is monitored on a regular bases. The process of monitoring this immense network is challenging and also very expensive, this operation is valued at 120 million euros a year, for which the municipality of infrastructure together with ProRail is responsible [11]. In this monitoring process they use manned helicopters, drones and measuring trains to actively measure the 7000km railway on a regular basis. We think that satellite technology can replace a part of the monitoring process. The satellite data freely available in the Netherlands and therefore we estimated that this solution can

reduce cost to less 10 million euros a year [3]. These measurements can be preformed under any weather condition, are updated (bi)weekly, and during this measurement transportation can keep on going.

This progressive solution will increase the efficiency of the monitoring process, making it cheaper than the existing methods. Apart from the efficiency, the regularity of the measurement makes the examination more reliable and with that reducing risk.

Figure 4: Map of ground subsidence in the Netherlands, acquired with satellite *technology [1].*

3.2 Coastal Monitoring

If the world continues on current path of high greenhouse gas emissions, scientists predict that oceans could rise more than six feet by the end of this century. Large parts of the Netherlands are below sea level, protected against floods from the North Sea by a coastal flood defence system consisting of dunes and dams. The extremely high safety standards of the Dutch flood defence system are unique worldwide, but investments are needed to maintain this high safety level. These include the constant monitoring and analysis of the coastlines, and the sand that makes up its geological structure. Currently 12 million m^3 of sand is replenished annually by the Netherlands, and managing this requires a deep understanding of the geological dynamics of the coastline.

With the disappearance of sand the industry also faces a problem when it comes to manufacturing goods. Industries like glass or concrete production require a specific type of quartz based sand called silica sand, which can not be mined from the desert. Because of coastal erosion, mining silica sand in the Netherlands requires a close collaboration between the industry players, the Dutch government and the scientific community. It’s important to know where building a sustainable and profitable sand mine is possible, and also to make sure that the regulations are enforced to prevent illegal mining or the disposal of polluted sand.

One of two ways the Netherlands is fighting coastal erosion is called beach nourishment. An example for this is the sand motor developed in Delft. This type of nourishment produces quick results and it’s an efficient way of replenishing a damaged coastline. This sand motor is extremely expensive to build, and also require constant monitoring, most of which is done currently by drones with cameras. This data is then, in most cases, processed manually.

A second one is underwater nourishment. This involves building an underwater dune-structure along the coastline, which over time with the help of the ocean currents slowly replenishes the coast. This is a more sustainable method, but it produces slower results.

From a managing perspective, coastal erosion and coastal monitoring is tackled by the Dutch government with the assistance of Deltares, an independent institute for applied research in the field of water and subsurface, through a project called ”Delta Program”. Deltares is sporadically (2/3 times per year) monitoring the Dutch coast on behalf of the Dutch government, providing them an analysis of the Dutch coast. The results are then discussed from the government in a meeting with all regions, deciding what it has to be done.

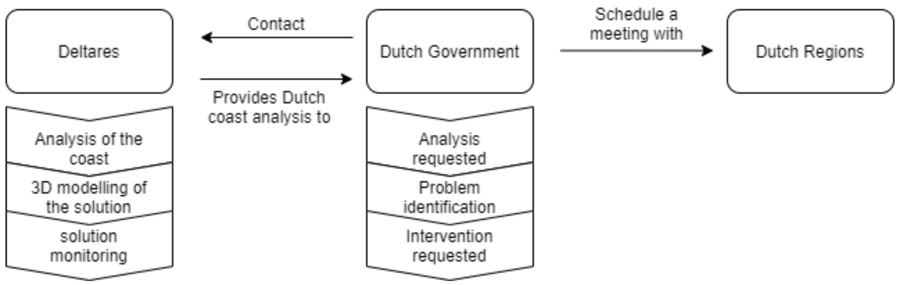


Figure 5: Visualization of main actors and their role in the Dutch coastal monitoring process.

However, Deltares is not providing the solution efficiently. After an interesting discussion with Giorgio Santinelli, a researcher who works in Deltares, we figured out that the company is providing solutions by gathering the data with drones, planes, and in-place cameras: a monitoring system which is less time and cost-efficient if compared to satellite data. Indeed, satellite data can be used by every company with a monthly subscription of a maximum of €1000 to SentinelHub [6], a European engine for the gathering of satellite data. Moreover, satellites can capture every type and size of zones of the Earth without any additional cost. SentinelHub lets every user request a maximum of 500000 images per month, which can guarantee a daily update of the Dutch coast with a precision of 30 centimetres. On the other hand, the management of drones and planes have higher costs.

- Drones are being sold up to €25k and the hiring of a pilot is needed for the gathering of the data [2]. They can cover only small areas.
- Planes cost up to €300k per unit [2], they can cover medium size areas, and the precision depends on the sensors that have to be applied on the plane. A pilot and maintenance costs are needed.

To cover the Dutch coasts as a whole, costs increase exponentially, which brings the Dutch government to invest approximately €20M to coastal monitoring yearly.

From an analysis that we conducted, a satellite data solution for coastal monitoring could cost €400k yearly instead, which includes software, hardware, and maintenance costs. Moreover, satellite data guarantee a daily update of the Dutch coast, whilst the current monitoring system can not.

After this analysis and the calls with the stakeholders, we decided to address the following problem statement: Coasts nowadays are monitored by the usage of drones, airplanes, and in-place cameras, and analyzed by humans. Furthermore, the data is retrieved sporadically and cost-inefficiently, and that could limit the user to have a clear and global vision of the whole situation. We aim to find a product that could provide real-time data and increase the time and cost-efficiency of the analyses, by the usage, of satellite data.

3.3 Cultural Heritage

UNESCO quotes: *“Heritage is our legacy from the past, what we live with today, and what we pass on to future generations. Our cultural and natural heritage are both irreplaceable sources of life and inspiration.”*. This quote signifies the existence of Cultural Heritage across the globe. There were two fields which we wanted to address: respond to existing concerns related to current heritage sites and protect undiscovered sites, which are yet to be explored.

Making using of the approach in the initial phase of our project, we were able to come up with a clear problem statement:

Problem Statement: Undiscovered archaeological sites are often inadvertently destroyed during construction operations. Archaeologists could also consult remote sensing data to avoid this phenomenon, but this is a difficult, manual process that many don't bother with.

Solution: We propose the following solution: use dimensionality-reduction techniques (such as PCA) on N images to obtain a single image. This would mean that the archaeologist conducting the desk research must look at only one image instead of N, where N can easily scale to around 1000.

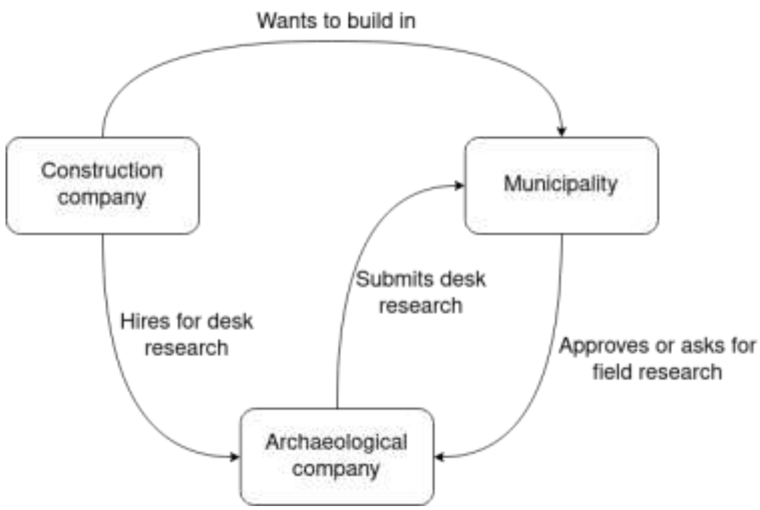


Figure 6: Diagram of the archaeological market in the Netherlands.

Market: Figure 6 represents the current state of the market between the construction company, municipality and archaeological company. Developers and construction companies want to build something and in order to get things done they need permission from the government authorities (mostly the municipality) as they are obliged to do an archaeological investigation. For this, the construction company hires a commercial archaeological company (like RAAP or ARGEOGraph) to do desk research. The construction company is not interested in archaeology, only in keeping the cost of the investigation as low as possible. Therefore commercial archaeological companies compete on price and try to do the absolute minimum only. The report of the desk research needs to be approved by the municipality and for this to happen the research has to obey the specifications of the official quality norm Kwaliteitsnorm Nederlandse Archeologie (KNA). The obligation to check aerial and satellite imagery is in the KNA, but this isn't mentioned in a very specific way and in practise it is mostly done by just having a quick glance at the imagery of Google Maps. The report of the desk research could recommend a fieldwork. In that case the municipality will probably demand the construction company to hire the same or another commercial archaeological company for the fieldwork, often first by drilling and possibly later a full excavation. It will be specified exactly where to drill or dig, so the remote sensing data needs to be used in the desk research to be useful. Commercial archaeological companies will only use remote sensing if they are forced to do this by the municipality.

While further investigating the market, we understood that the price for a desk research is around €750 per km ^{2} [9]. This includes all aspects of a desk research, not only the satellite data usage. We estimate from the same source that around 5% of the price of an archaeological company service is what the desk research costs. We discovered that in 2006 the total yearly expenditure on archaeological companies in the Netherlands was around €66M [10]. Assuming a constant level of expenditure and adjusting for inflation, we take the 5% share of the €66M, obtaining a rough estimate of €4M spent on archaeological desk research per year.

We realise that is therefore a domain with limited possibilities. The *desirability* of our solution is called into question: why would a market where limited spending is happening and where incumbents are competing on the price of archaeological desk researches invest in a solution that does something that is not needed? To make this solution desirable, the KNA guidelines should change and include some more stringent requirements for satellite data. But this is a political and long process that cannot be relied upon to make the solution desirable.

Please also refer to Appendix A.1 for a complete description of the solution devised for this project.

4 Solution and Prototype

4.1 Train tracks

A solution to monitor the soil subsidence of the tracks and the surroundings is to adopt satellite technology. In particular Interferometric Synthetic Aperture Radar (InSAR) technology, which measures millimetre-scale deformations of the Earths surface with radar. The satellite measures both phase and amplitude of the reflected radar signal, the essence of this measurement is show in Figure 7.

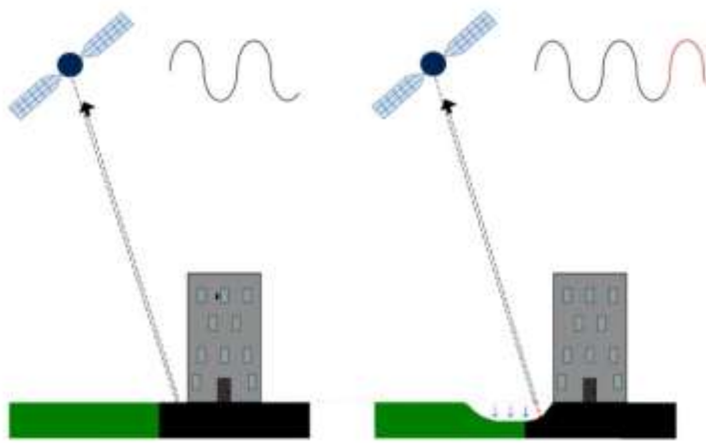


Figure 7: Schematic overview of InSAR measurements before and after subsidence [7].

After subsidence occurs the path length of the radar signal has increased, this then results in a phase difference (show in red). The deformation of the Earths surface is therefore based on this phase difference and is determined with Bragg's law

$$2d\sin\vartheta = \lambda. \qquad (1)$$

In which d is the deformation of the Earth's surface, ϑ is the angle reflection and λ the wavelength of the radar signal [5]. The wavelength of the radar signal is in order of a few centimetre and therefore the deformation of Earth's surface is determined with mm precision. It's possible to track the deformation of a particular location over time, by combining a set of radar measurements.

4.1.1 Prototype

In the final pitch we made use of two types of prototypes; one to demonstrate the seriousness of the problem on a fun and amateurish manner Figure 8. The other that demonstrates our capability to provide a solution to this problem.

Figure 8: Problem ”prototype” derailed lego train.

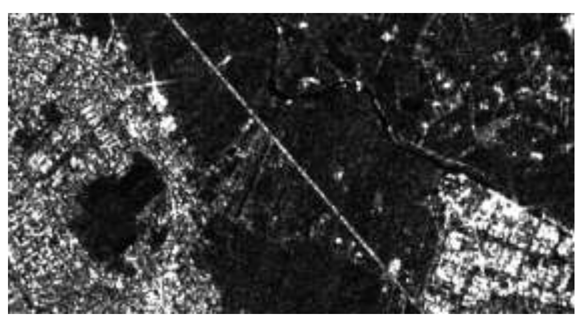
The problem ”prototype” is intended for the spectators of the final pitch, it’s used as encouragement to enjoy our pitch and to brighten up their morning with something fun. The solution prototype is intended for the client (end user), it’s used as a tool to transfer our knowledge of satellite technology to the client.

The solution prototype is demonstrating a working technical solution, that tackles a specific problem from the industry, and also gives an idea about how the user will interact with the finished product. Here we will show an implemented version of the train track monitoring system using satellite radar data.

The first problem we face is acquiring this data. We are using the Sentinel 1 project’s elevation measurements, and even though this data is freely available, it is quite cumbersome to access and get insights from it. Instead of downloading the whole database, we are utilizing Sentinel hub’s API to query the data, this way we access the information needed dynamically.

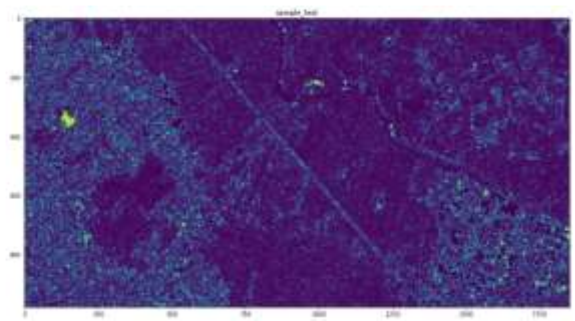
We also wanted to make the demo interactive, so we found a way to mock the user interface through a website named bboxfinder.com. The user can select an area on the map with a train track to inspect, and then feeding the coordinates to the software it calculates the deformation of the ground in a given time window. Let’s see an example from a dutch train track running near Kleine Melm.

(a) Interface for selecting the area to analyse

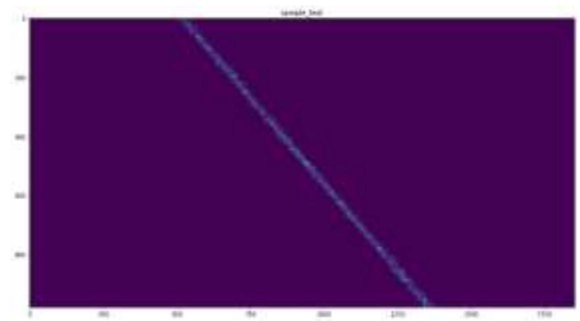


(b) The corresponding elevation data from Sentinel 1

To observe the ground deformation over time, we are also downloading the measurements form a given earlier point in time, so we can compare the two by calculation their difference. When we do this, the resulting image will highlight the areas where there was a large elevation change (which could mean potentially dangerous ground deformation). We are only interested in the area where the train track runs, so we use a mask to visualize only the meaningful parts of the image. This process is done manually, but integrating it with an open rail map data is a low hanging fruit that will be implemented in the production software. If we take a look at the image where the train track runs, we can see that there are no crucial deformations.



(a) Ground deformation map, the yellow highlights indicate large changes in elevation data.



(b) The same deformation map, only showing the area where a train track is running.

4.2 Coastal Monitoring

With the previous analysis of the coastal monitoring project, we have identified the following customer pains:

- The technology currently used for coastal monitoring like drones, planes, and in-place cameras is not cost-effective.
- The costs derived from the usage of these technologies limit the amount of data collected every year. For instance, the altimetric profile of the coast is measured twice a year.

Hence, the usage of satellite data either in addition to or as a substitution of the current technologies would result more cost-effective and provide better spatial and time coverage of the coast.

We propose a software-based solution to alleviate the aforementioned pains. BlankSpace wants to develop software capable of retrieving raw satellite data, process it, and generate interactive maps of specific areas of the coasts. The given view would be an image of the interested area divided into cells, which are color-coded according to the value of a required metric in the highlighted locations. The metrics will vary concerning the needs of the clients and the sensors of the satellites available. Some examples are the altimetric profile of the coast trough InSAR technology, the amount of vegetation trough the infrared spectrum of colors, or the salinity of the water. Alongside the map, statistics on the viewed area is provided together with a forecast of the metric. All the data is presented and analyzed according to a certain time span requested by the user. For instance, InSAR data is available daily from the year 2018. Together with this visual representation, we also want to provide access to the raw satellite data to the final client such that it can be easily accessible in case of further analysis.

The described solution has multiple advantages:

- The cost of the examined data does not depend on the amount of data retrieved. The coasts of satellite data remain always the same as long as the API requests remain below the threshold dictated by the SentinelHub subscription.
- Multiple metrics are handled in the same place. Nowadays, the usage of different technologies in the monitoring framework adds additional difficulty to the analysis of the retrieved data. Indeed, metrics collected from multiple sources are difficult to merge into a single solution.
- The analysis of time series is already implemented in the solution and it is easy to analyze. The software is capable of providing trend analysis and forecasts.
- The frequency of the analyzed data is dictated only by the satellite orbiting around the globe. Therefore, the frequency of the data is greater than the one that the current technologies provide.
- Satellites can provide metrics that are not available with currently used solutions or that are difficult to retrieve. For instance the vegetation quantity estimation.

With the solution we propose, we want to fit into Deltares' analysis and monitoring steps of the process loop illustrated in Figure 5. First, we will help Deltares during the analysis phase. We will drastically facilitate the data collection process and its analysis. Second, we will help in the monitoring phase. Once again, the software would facilitate Deltares job in collecting data and to have a better view of the coast in its entirety. In case we would expand to other countries, the client would always be the agent in the process that already deals with coastal monitoring. Indeed, we don't aim to substitute them. On the contrary, we want to become partners and support them.

As the reduction of the costs is one of the main generated values of our solution, we list all the costs we need to face to develop it:

- Storage costs. To keep all the requested satellite data safe and ready for analysis, we need lots of storage capacity. Given the dimensionality of the data and the length of the Dutch coast, we would easily need hundreds of TeraBytes. The Amazon Storage Service [4] comes in our help here. 500TB of fast cloud storage would cost us around €100'000.00 per year [12].
- Computational power. The analysis of time series is a heavy computational task and requires great computational power. We have counted around €30'000.00 in hardware expenses [12].
- SentinelHub subscription [6]. In order to collect data from the Copernicus satellites, we need an enterprise subscription to SentinelHub. It costs €5000 per year.
- Software development. The development of this software is going to take a long time and a great effort from all the members of the team that need to be considered in the costs.

Summing up all the expenses, we reach an upper bound of €500'000.00 for the complete solution development, maintenance, and deployment for an entire year. This quantity takes also into consideration a margin of profit for the company. The cost is not high considering that the Dutch coastal monitoring annual budget is almost twenty million euros per year.

If we analyze our solution in terms of desirability, feasibility, and viability, we conclude that the proposed solution fits perfectly the sweet spot between the three. The solution is desirable because it alleviates the current customer pains by being more cost-effective than current technologies, simplifying the analysis process, and providing additional data over time. The software is feasible. We will describe the developed functional prototype in the following subsection 4.2.2. This prototype already implements the first iteration of some features of the solution. Therefore, it represents proof of the feasibility of the solution proposed.

Finally, the solution is viable. As already discussed, in a cost-effective package we manage to sell the product and generate profit for the company.

4.2.1 Problem Prototype

The problem prototype was reserved for the spectators of the final presentation. The main aims were to show the problem we want to tackle clearly but at the same time funnily, and to help the presenter retain the attention of the audience. Our model consists of a toy simulation of the sand disappearing phenomena. The camera is placed on top of a plastic box containing sand and water, which represent the coastline and the sea respectively. During the simulation, the box is shacked to resemble waves on the shore. Wave after wave, the sand starts disappearing and the coastline to shrink. We believe that even though the prototype is simple, it is very powerful. It manages to show at a high level and in an uncomplicated way a problem that could be hard to understand if explained otherwise. Some snapshots of the simulation are shown below.

(a) Start of the simulation, coastline is not effected by coastal erosion

(b) During simulation, the waves are changing the coastline line

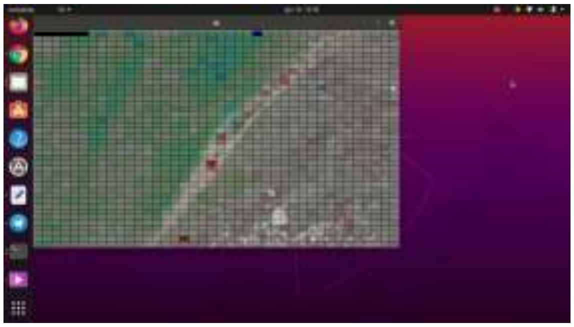
(c) End of the simulation, the coast has been affected by coastal erosion

4.2.2 Solution Prototype

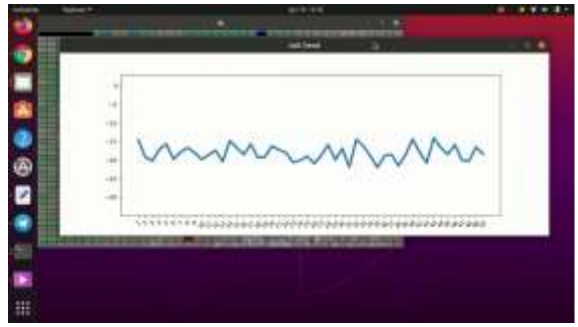
The solution prototype is intended for the final user and has the aim to show the feasibility of the project. Regarding coastal erosion, we have implemented a python framework that implements some of the features discussed in Section 4.2.

The implemented software is already capable to show the grid and to compute statistics for each of its cells. The user can decide which part of the coast to visualize, select a satellite from which to get the metrics and decide the time span from when to get the data and with which frequency. The software automatically generates the view and color-codes the cells according to the trend of the metric chosen. When a cell is clicked, related statistics are shown in a pop-up window. The resolution of the grid, such as its number of rows and columns is also customizable by the user. The metrics implemented by now are soil subsidence and vegetation quantification.

The software shows how with a little amount of code and short development time, BlankSpace is capable of developing a working solution, and that we have the capabilities to implement the technology described. All the additional features, which are not implemented in the current version of the software, can be added with relatively little tweaks to the code. Part of the prototype is shown below. The software is completely open source and can be found at https://github.com/tommasobonomo/BlankSpace.



(a) The interactive grid is shown, it is color-coded by the values of the metric trends in the cells



(b) Trends for a cell is shown when we mouse-click it

5 Conclusion

The section is divided into two categories, the first one reflects explanation in terms of the business model and added value created for the two projects, Train Track Monitoring and Coastal Monitoring. The second is the aspects learned by the team to meet the objectives of the Innovation Space Project.

Blankspace targets to work in collaboration with ProRail and Deltras expanding the business model for the first year as in Figure 13.

- Business Model and Roadmap:

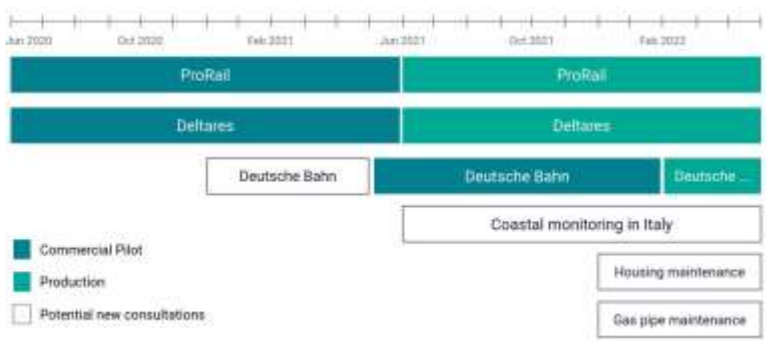


Figure 13: BlankSpace Roadmap

Train Track Monitoring: The InSAR technology is a good and reliable technique to monitor the Dutch railway network and could replace the current technology. Moreover, it could reduce costs and be less expensive. This is validated in the Q4 and the solution will cost €8.4M per year as in contrast to the existing spending of €120M per year. The solution is also automated and will work under any weather condition. Apart from ProRail, target in the next year of business is accommodating other customers, like Deutsche Bahn of Germany.

Coastal Monitoring: Satellite data can replace the current equipment used to monitor the Dutch coast. Monitoring the coasts with satellite data does not reduce the quality of the analysis. The solution provided is cost-effective, as in the current spending it is €20M euros per year, in contrast to our spending of €500K euros per year. This is accounts for the reduction in the budget of planes and drones as used in the existing technology.

- InnoSpace Objectives and Team Learning:

As a team, we learned from scratch to start on different ideas and then convolution into a concrete business model. The collaboration within the team and different cultures gave us a sense of how the business startups work. This was 6 months of the project, with coaching and support provided by the InnoSpace to reach a feasible and viable business model. The inter-disciplinary work culture is also one of the leanings as a team we nurtured. We stood as the runner up in the final pitch presentation, reflecting the high-spirited and enthusiasm of the team throughout Q3-4. The project helped us to adapt challenged based learning as a team, with several tools and business skills that we adapted to change the course of a business model in accordance with the market needs.

6 References

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A Appendix

A.1 Cultural Heritage - Solution and Prototype

The experimentation was performed on a particular crop field near Kortgene, Zeeland. In the summer of 2018, a pattern was very visible, as can be seen in the Figure 14. The speculation was that the visible pattern is where water once flowed.

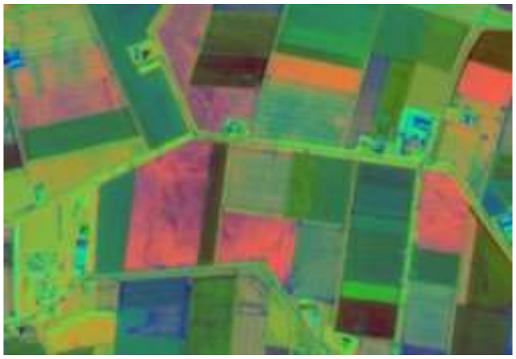
Next step was to collect data. The multiple-band images from the Sentinel2 satellite, consisting of 6 bands: red, green, blue, near infrared, aerosol optical thickness and water vapour pressure was used for the prototype. The last two bands might not bring a lot of information, but then it is used for the experiment in order to ensure that the technology is working as expected. All bands have 10m resolution. The PCA decomposition of the bands was computed, and so reducing the dimension of each pixel from 6 dimensions into the 3 dimensions that most explain the variance between bands. We can then compute the dimensionality reduction with PCA (Figure 14) with the 1st, 2nd and 3rd principal component matched to red, green and blue respectively.

The pattern selected is the expected behaviour to see through PCA, but this doesn't really have any advantage against the normal RGB viewing. This procedure is repeated on a secondary date, and the PCA visualisation does not give any indication of the underlying pattern.

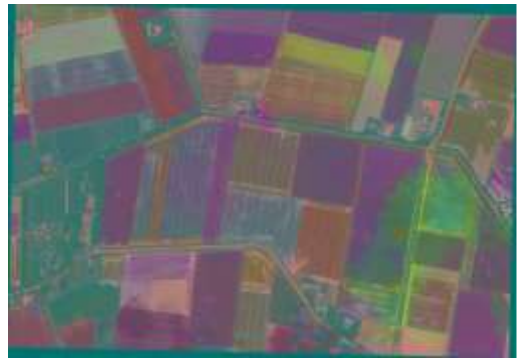
The next step is to discuss the above solution with the SME (Subject Matter Expert) in the field and after this the below approach is implemented. The images are merged of different dates into one image. We take the RGB bands of N different images and compute PCA on all the RGB bands from the N images. We can then extract the top 3 bands according to PCA. The result is showcased in Figure 14.

By this, BlankSpace will reduce the task of an archaeologist from looking for patterns in 2 images with 6 bands to 1 image with 3 bands. As anticipated in Section 3.3, many negative factors imposed the decision to abandon this project.

(a) Original RGB image



(b) PCA computation on multiple bands from single image multiple images



(c) PCA computation on all RGB bands from

Figure 14: Different visualisations of the same fields near Kortgene, Zeeland