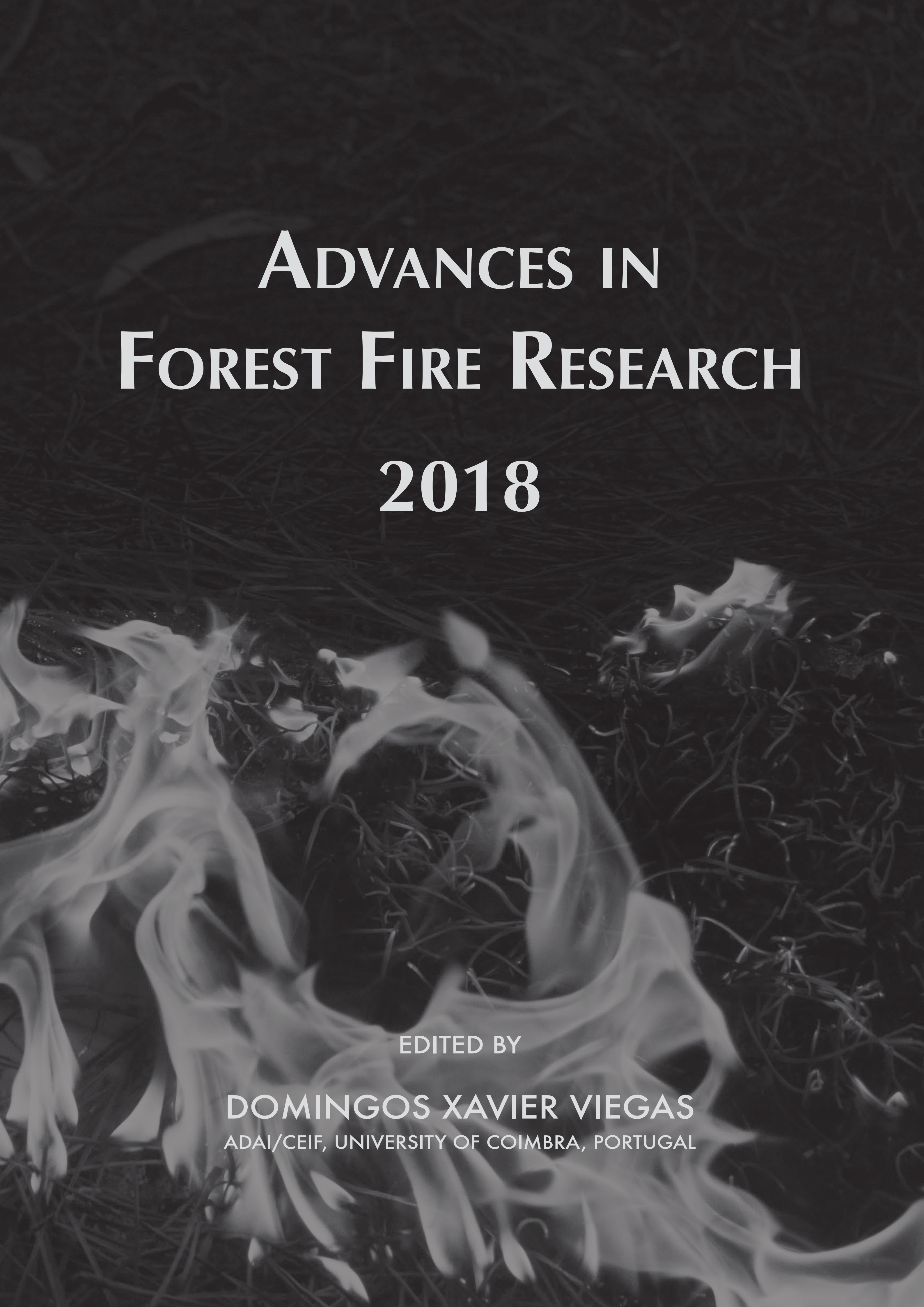


ADVANCES IN FOREST FIRE RESEARCH 2018

EDITED BY

DOMINGOS XAVIER VIEGAS

ADAI/CEIF, UNIVERSITY OF COIMBRA, PORTUGAL

https://doi.org/10.14195/978-989-26-16-506_124

Wildfires – web application concept and prototype

Sandra Nieves[1]*; Olga Mordvinova[2];

[1]*Data and You. Mathy Straße 31, 76133 Karlsruhe, {sandra@data-and-you.eu*}*

[2]*incontext.technology GmbH, Friedrich-Ebert-Anlage 27, 69117 Heidelberg, {olga@inctec.de}*

Abstract

In 2016 there were 50,653 wildfires in Europe, which destroyed 352,729 hectares of land – about the size of 490,000 soccer fields. 46% of all land destroyed was in Portugal (European Commission, 2016). That amounts to 161,522ha (Figure 1).

According to the news, the fire around Pedrógão Grande, Portugal in June 2017 caused losses that are estimated to be €497 mil., plus €300 mil. for future prevention. In this one fire, 481 houses burnt, 374 people lost their jobs, 45ha of land were destroyed and 64 people died (ECO News, 2017). By October 2017 fires in Portugal have already burnt 520,000ha (abc Net, 2017).

Fires have had a tremendous impact on people, especially in Southern Europe. People living in rural areas, are often on their own to protect themselves. Unfortunately, following one's gut feeling might not be the best choice. Last year in Portugal, most people died on the roads, when trying to escape the flames.

We conducted qualitative research which revealed, that there is a lack of reliable, current and contextual information available to people, that can support good decisions during fire emergencies.

There is an abundance of quantitative research coming out of the fire science and geo science community, that has explored the topic, and scientists have discussed and evaluated data driven- and artificial intelligence approaches to predict fire behavior and fire danger.

However, we did not find a solution that applies insights from qualitative research and knowledge from quantitative studies in form of a practical web application, that can be intuitively used by people in affected areas.

In this paper, we illustrate how *design thinking* – a process for creative problem solving, can bring together technology and science with needs of people, and to create a solution that enables them to make better decisions related to forest fires.

Keywords: forest fires, fire science, geo science, *design thinking*, data visualization, user experience design, artificial intelligence, data science, geo informatics, software engineering

1. Introduction

On October 15, 2017 there were 344 active recorded fires that were "on-going" or "in resolution" based on data from a Portuguese website (fogos.pt) that provides information regarding forest fires.

Figure 2 shows that fires, between September 19 and October 30th, were concentrated mostly in the Central and Northern regions – which is where we conducted our user research.

Figure 3 shows the exceptionally high number of active fires on October 15, 2017, which put the Portuguese firefighting capacity beyond their limit – judged by the local observations, where no firefighting means were available to protect people. Civilians had no choice, but to take it upon themselves to fight the flames and to figure out how to stay safe.

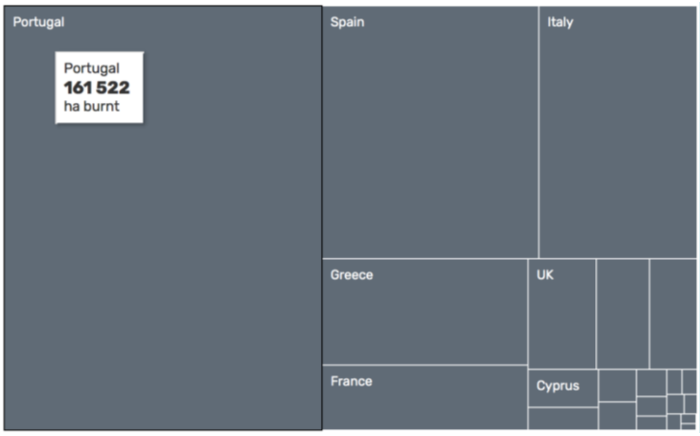


Figure 1 - (left): 2016 burnt area in ha (based on the European Commission, JRC science for policy report, 2016)
Figure 2 - (right): Fires with status "on-going" or "in resolution", in Portugal between September 19 and December 28, 2017. It shows that Central and North Portugal were most affected. The size of the bubbles represents the number of fire fighters on site. (The data was derived from fogos.pt.)

Figure 3 - Number of unique fire IDs with status "on-going" or "in resolution", in Portugal between September 19 and December 28, 2017. (The data was derived from fogos.pt.)

Our user research revealed that available information offerings do not consolidate enough context information – in form of an intuitive user experience, to paint a coherent picture, so that people can quickly gain a 360° view of the situation, prior to making decisions. We observed people using multiple information services concurrently to try to understand what is going on – which is cumbersome and time consuming.

On other hand, we found quite a lot of research, that approaches the topic from a scientific angle.

Described below are just a few examples of scientific research which addresses fuel moisture determination, how to work with data captured by satellites, and fire behavior predictions, that are relevant to the solution we propose. New papers around the topic are surfacing every day, which demonstrates that science already holds answers to difficult questions in this context.

The NDVI is a remote sensing technique to identify a vegetation's vitality. It is based on the spectral signatures of plant species and is a comparatively simple method to estimate the moisture content of plants. It is based on red and near infrared reflectance (Joyce, 2016).

Our solution proposes to use the NDVI, to discriminate plant species and to visualize land cover types that play a significant role in determining how fire spreads.

A worldwide compilation of the available fire behavior data was collected in the BONFIRE project (Fernandes at al. 2018). The data variables used in this research are similar to the ones proposed in *Wildfires*.

The challenges BONFIRE faces, relating to data quality, are pretty much universal, when it comes to big data applications: 1) availability, 2) completeness and 3) reliability of the data. How *Wildfires* handles these issues is addressed later in this paper (see chapter *2.2. Data Technology*).

Different models to predict the rate of fire spread for different fuel types have been evaluated (Cruz et al., 2018). While the results showed a consistent improvement in prediction accuracy of newer models in comparison to older ones, Cruz estimates that fire behavior predictions could be improved, e.g. by improving classifications of plant species and better mapping of fuel moisture.

It is suggested, that quantifying the uncertainty of predictions for fire spread in an operational setting, should be favored over deterministic approaches (Pinto et al. 2016)

From our experience in developing predictive applications, uncertainty distributions require data science skills to draw sensible conclusions and to trust the outcome. People living in rural areas most likely do not possess these skills, therefore we propose to visualize the prediction model's input data, so that they can draw their own conclusions. Probabilistic fire behavior predictions, in our view, should only be exposed to trained fire management professionals – if qualitative research with these potential users can positively validate its usefulness.

The following chapter describes, how *design thinking*, a process where interdisciplinary teams work together to solve complex problems in an iterative way, can bring together available research with data technology, and to create an intuitive user experience that delivers value for people.

2. Design thinking, data technology and user experience to improve decision making

2.1. Design Thinking

Design thinking is a human-centered approach to innovation that draws from the designer's toolkit to balance the needs of people, the possibilities of technology and business requirements, in order to come up with successful solutions (Brown, 2018). It is a generic method and therefore can be applied to design anything, from a simple toothbrush to complex software.

In software development, *design thinking* has a proven track record of success. For example, Hasso Plattner, who is one of the founders of SAP – a German-based European multinational software corporation, infused the company with *design thinking*, to put users in the center to design business software, in order to not overwhelm them, and instead help them to reach their goal.

Other examples show how *design thinking* was applied to social innovation, e.g. to find ways to provide low-cost healthcare throughout the world (Brown and Wyatt, 2010).

Recently, IDEO, one of the most successful design consultancies, acquired Datascope, a data science company, to help merge machine learning and human-centered design (Budds, 2017), much like *Wildfires* is proposing.

In summary, *design thinking* will help to achieve a balance of goals of the different stakeholders of our web application *Wildfires*.

Figure 4 shows the *design thinking* process applied to user experiences involving data technology.

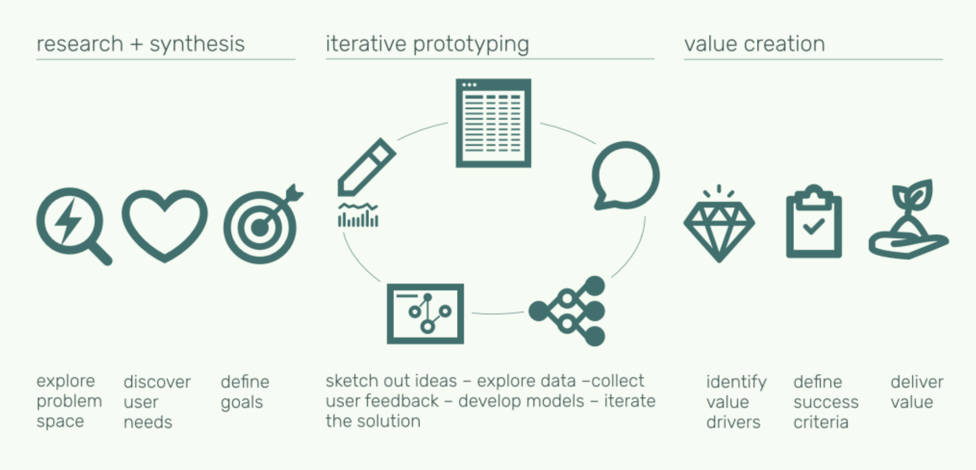


Figure 4 - Overview of a process: 1) understand problem space and synthesize the results 2) iterative prototyping between user needs and data technology and 3) validate the solution with users and prioritize the development to deliver incremental value.

2.1.1. Design Thinking process used for the Wildfires solution concept

Design thinking begins with qualitative research – also called *design research*, which aims at discovering user needs, pain points, process steps and usage context. Design research data is not evaluated using statistical methods. It serves as a means to develop empathy for the target users, by unmasking underlying motivations.

The results are qualitative statements, that enable the team to make design choices. When doing qualitative research, you start to discover patterns in users' statements after 5-7 interviews.

For *Wildfires*, we conducted 10 interviews, in October 2017 – prior to, and after the fire on October 15th has affected the region around Benfeita in central Portugal. The participants were English-speaking residents. We recorded and transcribed the interviews, and then captured individual data points on post-it notes. During the so-called *synthesis phase*, the following themes emerged:

1. There is a lack of clear and reliable information available related to forest fires, so it is difficult for people to gage what is going on.
2. Some people panic, they spread misinformation, or sometimes they are not capable of providing accurate location information.
3. People feel, that they are left to themselves, to defend their lives and livelihoods.
4. Trying to escape is dangerous, because the location of the fire changes quickly and information whether or not the roads were safe, was not available.

People organize civilian firefighting that relies on a functioning communication infrastructure, without which, everything breaks down.

2.2. Data technology

2.2.1. Data that supports the solution

To support the needs discovered during research and to enable better prevention planning and decision making during forest fires, data from different sources can be collected. The source spectrum begins with a) data from official authorities, who provide information about fire locations, firefighting activities, and publicly available mission reports; b) basic environmental data, such as satellite data – that can be used to derive land cover and fuel moisture information c) weather data from service providers d) end user data provided by people in the affected areas, such as current fire locations, road blocks, shelter locations or messages. Users' input might, on the one hand, offer more recent updates than authorities, but at the same time might be biased by subjective perception (in chapter 2.3 The underlying platform, we show how we apply data technology to mitigate risks of mis-information); e) data collected from users' mobile devices, i.e. location information and user IDs. Figure 5 provides an overview of expected data sources.

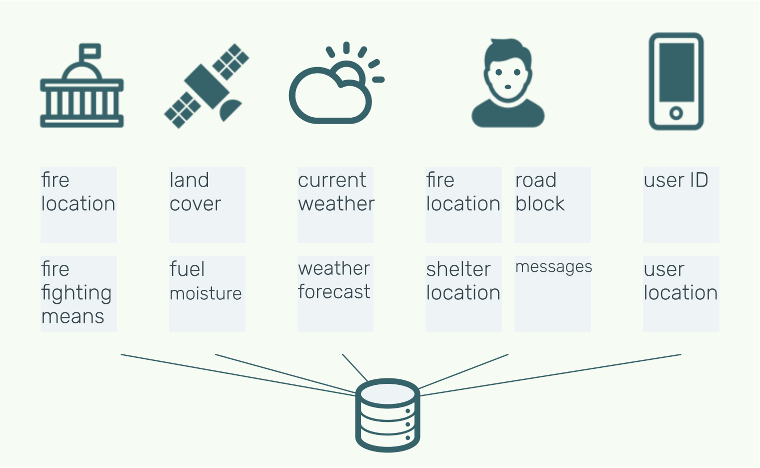


Figure 5 - Overview of possible data sources and data types.

According to its nature, processed data is classified into 3 categories a) structured data, i.e. geo or weather data; b) semi-structured, i.e. meta data about user input and c) non-structured data, i.e. end-user messages. In the next chapter, we talk about how these different data classifications impact the design of the underlying platform to store and process the data.

As for its size, we expect to handle large data volumes, in particular due to targeted long-term objective, to create fire spread predictions, which require sufficient data history.

2.2.2. The underlying platform

The main requirement for the underlying data platform architecture is its ability to efficiently collect, store, process and expose large amounts of heterogeneous data, needed to paint a coherent picture for end users. Besides this, the technological foundation should be openly accessible, so that it can be extended by a broad community which is, motivated to contribute and improve the platform. This imperative led to the selection of mature, open source components as the application foundation. As shown in figure 6, we split the platform into three layers: a) data collection and storage, b) data modeling and analytics, incl. methods of artificial intelligence and c) the data visualization and user experience.

For the collection and consumption of the heterogeneous mass data, we use different types of data stores, that are tightly bound together: 1) Classical databases – for structured data. 2) Search engine technologies, that let you perform searches for structured, unstructured, geo, and metric data (Elastic Search). 3) Unstructured data and NoSQL for large, scalable data storage – using a framework that allows for distributed processing across clusters of computers using simple programming models (Hadoop).

We also integrate common application interfaces, for the consumption of constantly changing resources i.e. during peak times of fire reports and access to weather information, in JSON, CSV or other formats, as well as streaming – using a distributed streaming platform (Kafka).

The objective of the modeling layer is the combination and transformation of data into advanced analytical and decision-making capabilities.

The provided logical models work with distributed SQL, Python, and Scala programming languages and leverage the data processing capabilities of a leading open source data science and machine learning platform (H2O) with its set statistical algorithms like K-means clustering, naive bayes, principal component analysis and more.

By assigning data to particular models, the data can be checked for its plausibility, for example by comparing fire locations reported by civilians with data from official authorities, weather information, satellite data, as well as fire spread predictions.Finally, the user interaction layer supports an effective and scalable visualization technology by using latest web trends in progressive web applications (PWA) and mobile cross-platform development approaches (Apache Cordova).

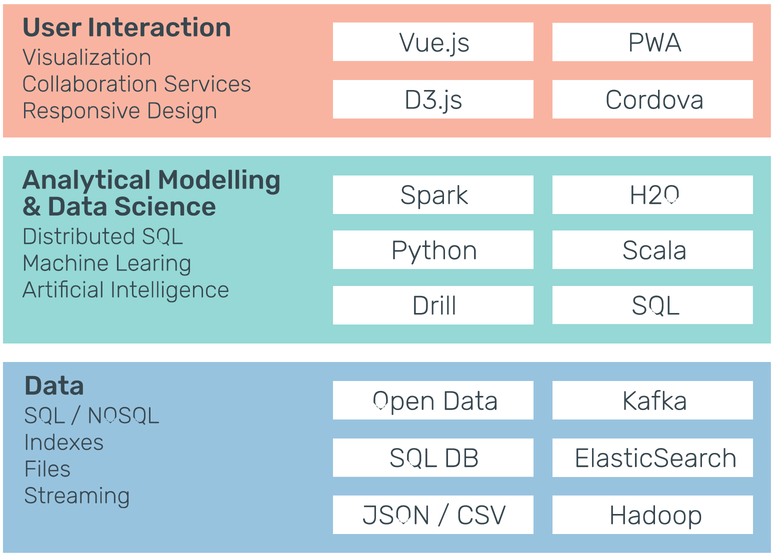


Figure 6 - Overview of proposed freely available technology components suitable for collection, processing and visualization of fire-related data.

2.3. User experience

2.3.1. Design principles

The *Wildfires* user experience is based on design principles that were developed during the synthesis phase of the design process.

There are two main factors that drive them. 1) *Wildfires* is intended for use during emergencies, where people are under immense pressure to make good decision. 2) *Wildfires* uses large amounts of divers data types and technology that only creates value, if it is adopted by users.

Design Principles:

1. simple, and intuitive visual information and interaction
2. information related to forest fires needs to be reliable, current and coherent
3. provide transparency, into data sources, system status and validity of the data
4. people are in control, visual information should support them
5. availability at all times, particularly during emergencies
6. minimal technical requirements for end user devices

2.3.2. Solution concept

The following section describes how our solution concept addresses the needs we heard during user research.

2.3.2.1. "We want to be prepared, or prevent fires in the first place"

Visualizing geographic information, such as current land cover types, fuel moisture or topography, in the context of a fire map, which includes the person's current location, enables people to quickly assess, how relevant on-going fires are to her.

Wildfires translates information from multiple sources into visualizations, so that users are not overwhelmed by data and instead are able to consider the most critical factors influencing fire spread in their personal decision-making process. Having data that includes e.g., 12-hour weather forecasts supports people in being proactive. Land cover and fuel moisture visualizations can unmask high risk areas, that require action and fire prevention measures.

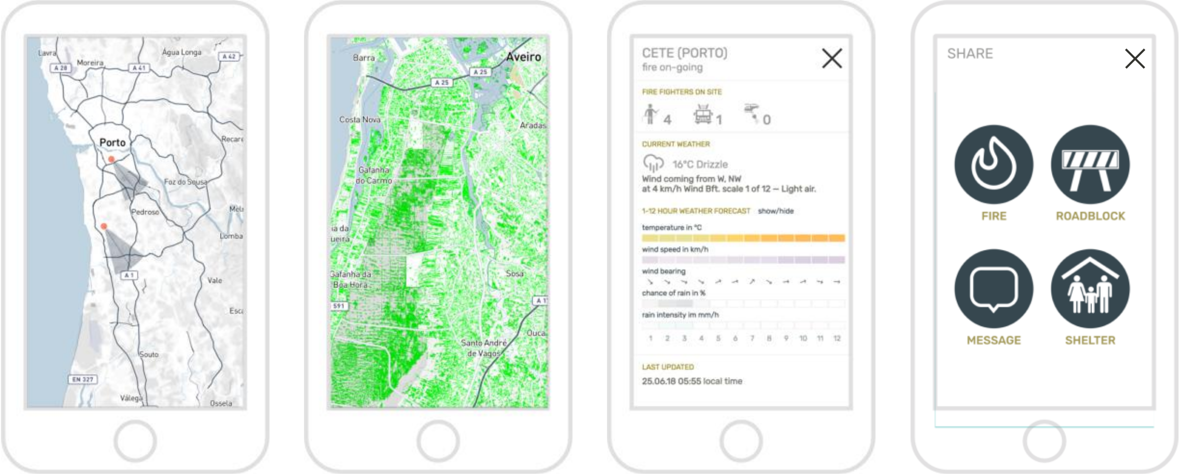
2.3.2.2. "We need reliable information"

During user research we heard, that people are posting fire locations on Facebook. However, there were situations, when people were not capable of providing accurate location information – which misguided fire fighters to the wrong location in one instance – which is a problem.

In the analytical modeling and data science layer of our data platform, relationships between data types are created and plausibility checks can be performed using machine learning algorithms. These data quality checks, along with a user's automatically captured location information, can significantly reduce the spread of misinformation

2.3.2.3. "Fire is not static – we need to see how the fire moves"

Not knowing where exactly a fire was at any given time, was the biggest pain point we heard. With *Wildfires,* people can easily report fires and provide an up to date picture of the situation – along with other helpful information, such as roadblocks or shelter locations.



CETE (PORTO)
fire on-going

FIRE FIGHTERS ON SITE
4 1 0

CURRENT WEATHER
16°C Drizzle
Wind coming from W, NW
at 4 km/h Wind Bft. scale 1 of 12 – Light air.

1-12 HOUR WEATHER FORECAST show/hide
temperature in °C
wind speed in km/h
wind bearing
chance of rain in %
rain intensity im mm/h
1 2 3 4 5 6 7 8 9 10 11 12

LAST UPDATED
25.06.18 05:55 local time

Figure 6 (left to right): Current, functional prototype of a minimal viable solution scope visualizes 1) active fires and wind speed and direction at the location. 2)"forest" areas, based on the NDVI. 3) further information, such as a 12-hour weather forecast and data sources. 4) a conceptual prototype to share fire locations and more

3. Summary and conclusion

Our data platform collects, stores, processes and makes available large amounts of divers data. Data that is accessible for the analytical modeling layer, where artificial intelligence can deliver answers to complicated questions, such as "Where will the fire go?" or "How reliable is the input data?".

Design thinking ensures that the solution focusses on those questions, that are most relevant for the target users, and that the great scientific achievements become available to create value for people.

Data visualization and user experience design ensure that people can see clearly and draw the right conclusions in times of emergencies. In addition, by seeing areas that pose high fire risks *Wildfires* can deliver evidence to support prevention measures.

4. References

abc Net (2017). Portugal fires: Interior Minister resigns as death toll passes 100, PM under fire to stand down. (See www.abc.net.au/news/2017-10-19/portuguese-minister-resigns-as-wildfire-toll-passes-100/9065714, visited on October 19th, 2017)

Apache Cordova. Explanation: Apache Cordova is a mobile application development framework to build mobile apps with HTML, CSS & JS that lets you target multiple platforms with one code base. (See https://cordova.apache.org/ visited in June 2018)

Diana Budds (2017). Exclusive: Ideo's Plan To Stage An AI Revolution. Co-Design. (See https://www.fastcodesign.com/90147010/exclusive-ideos-plan-to-stage-an-ai-revolution, visited in May 2017)

ECO News (2017). Pedrógão fires: Government estimates losses of 497 million euros. (See https://econews.pt/FSRJV, visited on July 3rd, 2017)

Elastic search. Explanation: Elastic search is a distributed, RESTful search and analytics engine capable of solving a growing number of use cases. As the heart of the Elastic Stack, it centrally stores your data so you can discover the expected and uncover the unexpected. (See https://www.elastic.co/ visited inJune 2018)

European Commission. Joint Research Centre in collaboration with other Directorate Generals of the European Commission, including DG ENV, DG GROW and DG ECHO, and the national wildfire administrations of the countries in the Expert Group on Forest Fires (2016); JRC science for policy report. Forest Fires in Europe, Middle East and North Africa 2016. European Commission (Luxembourg) (See http://effis.jrc.ec.europa.eu/media/cms_page_media/40/Forest_fires_in_Europe_Middle_east_and_North_Africa_2016_final_pdf_JZU7HeL.pdf)

H2O. Explanation: H2O combines the power of highly advanced algorithms, the freedom of open source, and truly scalable in-memory processing for big data on one or many nodes. (see https://www.h2o.ai/h2o/ visited in June 2018)

Hadoop. Explanation: The Apache™ Hadoop® project develops open-source software for reliable, scalable, distributed computing. (See http://hadoop.apache.org/ visited in June 2018)

Kafka. Explanation: Kafka is used for building real-time data pipelines and streaming apps. (See https://kafka.apache.org/ visited in June 2018)

Karen Joyce (2013). Vitality of plants based on the NDVI – Normalized Difference Vegetation Index. (See https://youtu.be/rxOMhQwApMc Channel for remote sensing educational resources, visited in May 2017)

Miguel G Cruz, Martin Edward Alexander, Andrew Sullivan, James S. Gould and Musa Kilinc (2018). Assessing improvements in models used to operationally predict wildland fire rate of spread (page 1). Part of the project: Wildland fire behaviour and spread prediction systems (DOI: 10.1016/j.envsoft.2018.03.027) (See https://www.researchgate.net/publication/324845113_Assessing_improvements_in_models_used_to_operationally_predict_wildland_fire_rate_of_spread)

Paulo Fernandes, Davide Ascoli, Carlos G. Rossa, Mário G. Pereira, Miguel G Cruz, Martin Edward Alexander, Ângelo Sil and Malik Amraoui (2018). BONFIRE – gloBal-scale analysis and mOdelliNg of FIRE behaviour potential (PTDC/AAGMAA/2656/2014) (page 5, 6). Paulo Fernandes's Lab, Universidade de Trás-os-Montes e Alto Douro. (Vila Real, Portugal) (See https://www.researchgate.net/project/BONFIRE-gloBal-scale-analysis-and-mOdelliNg-of-FIRE-behaviour-potential-PTDC-AAG-MAA-2656-2014)

PWA. Explanation: Progressive Web App (PWA) is a term used to denote a new software development methodology. Unlike traditional applications, progressive web apps are a hybrid of regular web pages (or websites) and a mobile application. This new application model attempts to combine features offered by most modern browsers with the benefits of mobile experience. (See https://medium.com/@deepusnath/4-points-to-keep-in-mind-before-introducing-progressive-web-apps-pwa-to-your-team-8dc66bcf6011 visited inJune 2018)

Renata Pinto, Akli Benali, Ana C. L. Sá, Paulo Fernandes, P.M.M. Soares, Rita M Cardoso, Ricardo M Trigo and José M.C. Pereira (2016). Probabilistic fire spread forecast as a management tool in an operational setting (page 9, 10). SpringerPlus 5(1):1205. (DOI: 10.1186/s40064-016-2842-9). (See https://www.researchgate.net/publication/305401391_Probabilistic_fire_spread_forecast_as_a_management_tool_in_an_operational_setting)

Tim Brown (2018). CEO of IDEO. (See https://www.ideou.com/pages/design-thinking, visited in May 2017)

Tim Brown and Jocelyn Wyatt (2010). Design Thinking for Social Innovation. Stanford Social Innovation Review. (See https://ssir.org/articles/entry/design_thinking_for_social_innovation, visited in May 2017)