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Georgios Bampasidis, Apostolia Galani, Issaac Parcharidis, Nikos Lambrinos, Constantine Skordoulis

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Georgios Bampasidis[1], Apostolia Galani[1], Issaac Parcharidis[2], Nikos Lambrinos[3], Constantine Skordoulis[1]
gbabasid@phys.uoa.gr, ligalani@primedu.uoa.gr, parchar@hua.gr, labrinos@eled.auth.gr, kskordul@primedu.uoa.gr
[1] National and Kapodistrian University of Athens, Department of Primary Education, Greece
[2] Harokopio University of Athens, Department of Geography, Greece
[3] Aristotle University, Department of Primary Education, Thessaloniki, Greece

Abstract

Remote Sensing applications are at the core of our modern technologies and its data is valuable in most human activities. Due to its vast impact in everyday life, several projects consider importing Remote Sensing in compulsory education. By its nature, Remote Sensing is strongly depended on software and Information Technology in general. Since the commercial software is too complicated for teachers and students and too expensive for the average school budget, serious projects have been published so far referring to specially designed software solutions for upper primary and secondary education students. The main goal of this work is to evaluate educational software packages presented in published papers in peer-reviewed journals, book chapters and conference proceedings that aim to help teachers integrate Remote Sensing in their lessons. These packages have certainly enriched teacher's inventory but, despite the high quality of the offered solutions, more effort is needed towards the Remote Sensing integration in schools. This framework may provide teachers and educational decision-makers with a guide for selecting the Remote Sensing educational software that meets their requirements and needs.

Keywords: Remote Sensing in education, upper primary education, secondary education, educational software

Introduction

More than 2,700 operational satellites orbiting the Earth provide a wealth of data for the environment and almost all human activities. The global satellite network facilitates communications, broadcasting, navigation, weather forecasting, Science and Technology experimentation and agriculture (Guo et al., 2019). A considerable amount of Earth Observation data is available to anyone (Harris & Baumann, 2015). Remote Sensing (RS) data mining and exploitation require the end-user to be RS literate. For this reason, from the early 1980s RS was suggested to be imported in schools (Jensen & Dahlberg, 1983; Voute, 1992).

However, the successful integration of RS in school lessons is a long and challenging pathway. RS data processing requires a combination of specific software and a proper hardware platform and teachers experienced on RS usage. The problem that arises is how a software RS package for school purposes will manage to overcome the technical barriers and facilitate the teacher community to adopt it.

The available commercial RS software solutions are often excluded due to their cost and their complexity for the inexperienced teacher (Matusch et al., 2018). In fact, as recent studies have unveiled (Dannwolf et al., 2020; Hodam et al., 2020), most schools suffer from below-average infrastructure, lack Internet connectivity or have low bandwidth web connectivity and speed. Thus, they cannot support RS projects or similar educational activities.

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Regarding the teachers experience, back in 1995 Lambrinos (1995) mentioned about the Greek primary school teachers who have neither experience nor training of any kind on this subject, although they are asked to give answers to their pupils about satellite images they watch on TV weather forecast. The situation in our days still remains almost the same. Ditter et al. (2015) and Dziob et al. (2020) emphasize the lack of modern teachers' experience in RS, while according to Hodam et al. (2020) teachers are not qualified in RS applications. This is easily explained by the fact that Higher Education Institutes (HEI) give no priority in training teachers in RS (Dannwolf et al., 2020; Hodam et al., 2020).

Additionally, teachers cannot find curriculum-related activities in RS repositories (Lindner et al., 2019), or in most of the available RS educational material (Hodam et al., 2020). They also stay without any support by field experts when applying RS in their lessons (Galani, 2015; Dziob et al., 2020).

Another important debatable factor is the upper primary and secondary education student ability to get involved in such projects. Indeed, students, being familiar with RS applications (e.g. Google Earth), are strongly motivated by satellite imagery when used in the classroom (Ditter et al., 2015). They enjoy working with RS images of the area in which they live (Dziob et al., 2020; Schüttler et al., 2019). However, the forced distant learning, caused by the COVID-19 pandemic, has unveiled the students' lack of basic IT skills (Williamson et al., 2020).

As a result, RS's presence in compulsory education is quite limited to only satellite surface snapshots, mostly printed, as complementary educational material (Kholoshyn et al., 2019) to an already designed lesson.

This work attempts to evaluate the most common software solutions presented in published papers in peer-reviewed journals, book chapters and conferences proceedings, that a non-experienced teacher in RS can use to import RS in school lessons. We focus on the technical part of this implementation and test these products in various devices with which students are familiar such as tablets, smartphones and home PCs. The research questions of this study are the following:

- Which RS educational software is the most suitable for the average school hardware equipment?
- Which RS educational software is the most user-friendly for a teacher inexperienced in RS?

This paper presents the first part of a significant ongoing project, which focuses on delivering educational material and techniques to import RS in upper primary and secondary education. The project is conducted by the Pedagogical Department of National & Kapodistrian University of Athens, Greece. In the following section, we describe our evaluation procedure's rationale and the criteria we have used. Next, we give an insight of the evaluation results, followed by their interpretation in the discussion section. The final section of the paper contains the conclusions of this study and summarizes its results.

Methodology

Software selection criteria

The criteria we have applied to conduct our research and selected software packages are: (a) Especially designed for upper primary and secondary education students; (b) Developed or proposed by space agencies and HEI; (c) Based on modern student-centered educational approaches; (d) Free of charge and (e) Offer interactive RS analysis tools for the user.

Our search strategy was focused on finding published papers in peer-reviewed journals, book chapters and conferences proceedings relevant to our topic. The research databases were the SpringerLink, the Elsevier's ScienceDirect and Scopus, the SAO/NASA Astrophysics Data System and the IEEE Xplore. The search items were "Remote sensing and primary education", "Remote sensing and secondary education", "Remote sensing in schools", "Remote sensing educational software packages", "satellite images in education", "Teaching Remote sensing" and "Satellite images in education". Through this database research, only four software packages have met our selection criteria:

1) BLIF (Blickpunkt Fernerkundung - Focus on Remote Sensing) by the University of Heidelberg (Germany), https://server2.blif.de/overview (Naumann et al., 2009). Started in 2009, BLIF is an online RS software for school students that includes RS systems' most common utilities (Ditter & Siegmund, 2009). It is connected with Geo:spektiv, a learning platform with RS modules based on German school curricula (Dannwolf et al., 2020) and has also been used to train teachers in RS (Schulman et al., 2021). BLIF is available in five languages (English, German, Spanish, Italian and French).
2) FIS (Fernerkundung in Schulen - Remote Sensing in Schools) by the University of Bonn (Germany), https://fis.uni-bonn.de (Hodam et al., 2020). It is an integrated learning environment, which began in 2006 (Voss et al., 2007). FIS is an online RS software developed for schools, and it also provides free teaching material (activities, worksheets, evaluation sheets) for the teacher on topics from Geography, Science, Mathematics (Voss et al., 2011). It is available in two languages, German and English.
3) LEOWorks, (Learning Earth Observation), by ESA/EDUSPACE http://leoworks.terrasigna.com (Ghaye et al., 2007). LEOWorks is an open-source software package for satellite imagery analysis released by Terrasigna and can be downloaded and installed in major operating systems. ESA provides quite enough worksheets in the form of exercises through its website. Part of the material is available in the languages of European Union.
4) Sentinel Playground, http://apps.sentinel-hub.com/sentinel-playground (Milcinski et al., 2017). The Sentinel Playground is a cloud Application Program Interface, developed by Sinergise Ltd. It provides satellite data and embeds many useful features for the teacher and the student. It is available only in English.

Smartphone applications that can be used for capturing RS data were excluded, since the produced images suffer from low spectral analysis (Anderson et al., 2016) and can be hardly used in image processing. Instead, they can be used for teaching data capture techniques. However, some projects present interesting results when using a digital camera as a sensor aboard a drone for high schools educational purposes (Schüttler et al., 2019).

Software evaluation criteria

In order to deal with the research questions of this study, we have applied the generic evaluation criteria of software packages proposed by Jadhav & Sonar (2009). We have chosen only the criteria that meet the requirements of the main issues related to the integration of RS in education, teachers' experience and technical obstacles. Our evaluation framework consists of 13 criteria, listed in Table 1.

Table 1: The criteria we adopted to evaluate the education software for importing Remote Sensing in upper primary and secondary education (Jadhav & Sonar, 2009) and the meaning of each criterion.

Criteria	Criteria meaning
Platform variety	Software execution process in different platforms
Robustness	Functions correctly without failure
Time behavior	Deliver the outcome timely
Hardware platform	Which hardware platform is appropriate to run the software properly
Field customization	Personalize the software layout
Outcome customization	Personalize the software outcome
User types	User levels depending on their experience in RS
Data visualization	Data presentation using visual elements
Error reporting	Deliver error messages
Ease of use	Easy graphical user interface for the user
User manual	Existence of easily accessible user manual
Tutorial	Provide online learning module
Troubleshooting guide	Frequently asked questions, problem-solving lists

For the purpose of this study, we have performed only a qualitative evaluation. Our evaluation is a simplified black-box testing (Behavioral Testing) from the end-user perspective (Limaye, 2009). Black-box testing is a software testing method entirely based on input and output of software applications. We mainly focus on software applications' functionalities without knowing the internal code structure, the implementation details and the internal paths. Indeed, teachers and students who might use these software toolkits seek only for the results, without considering the way they are produced. For the "Time Behavior" criterion we have used the terms quick and rapid, considering the adequate time of producing the output. The term "User Types" refers to the fact that some applications offer different user modes from the beginner to professional.

The case study

Since the purpose of all the selected software is to provide an introduction in RS we have designed and applied only one case study, the false color image creation. We used each package to produce an image where the near-infrared emission (NIR) is shown. This activity is very popular within educational RS applications. The healthy vegetation appears bright in the NIR as it has high sunlight reflectivity in NIR wavelengths, while it looks dark in the optical (Mangold et al., 2013).

We compare the number of operations needed by the user in each package to produce such a NIR image as well as the time needed. We use only satellite image files already included as samples in each package.

Results

The intent of the study is to present an evaluation of the most common RS software packages that are designed or can be used in upper primary and secondary education. We focus our research on the use of these packages from a teacher without experience in RS. We also evaluate the performance of these platforms in common students' devices, which are smartphones, tablets or home PCs.

Table 2 depicts the results of this analysis according to the evaluation criteria. Each software's performance is described in the second column of Table 2 and beyond. The results of the case study evaluation are listed in Table 3.

Table 2. The evaluation results of RS educational software packages.

Criteria	BLIF	FIS	LEOWorks 4	Sentinel Playground
Platform variety	Web-based	Web-based Major issues as Flash-based	Installation needed. Not working in Android	Web-based
Robustness	Yes in PCs Problems in Android 8 and newer version	Major issues as Flash-based	Yes in PCs	Yes in PCs Operates well in Android 8 and newer but it depends on the device's screen size. The user should rotate the device twice or more for execution
Time behavior	Quick (More than 1.5s to respond)	Major issues as Flash-based	Quick	Rapid (Less than 1.5s to respond)
Hardware platform	PC	Major issues as Flash-based	PC	All
Field customization	No	Major issues as Flash-based	No	No
Outcome customization	No	Major issues as Flash-based	No Problems in exporting GeoTiff files	Yes The user can filter easily the image e.g. cloud coverage removal
User types	Yes	Major issues as Flash-based	No	No
Data visualization	Yes	Major issues as Flash-based	Yes	Yes
Error reporting	No	Major issues as Flash-based	Yes	No
Ease of use	Very (no prior knowledge in RS)	Major issues as Flash-based	Moderate	Very
User manual	Yes	Yes	Yes	Yes
Tutorial	Yes	Yes	Yes	Yes
Troubleshooting guide	No	No	Yes	No

BLIF is a complete platform that operates everywhere. The combination of BLIF with the educational portal Geo:spektiv is very flexible and it has been successfully used for performing separate educational projects (Matusch et al., 2018). BLIF has been designed for desktop PCs (Matusch et al., 2018), and it works properly on them. However, there are some crucial malfunctions when BLIF is used on Android 8 or 10 devices, where the menu bars do not appear and the user cannot perform activities such as creating false color images.

As an integrated learning environment, FIS offers a web-based platform with several teaching packages. The basic issue of this project is that it is based on Adobe Flash Player technology (Hodam et al., 2020), which is not now supported in any device. Therefore, teachers and students cannot use this RS software today. BLIF includes some parts of FIS educational modules (Ditter et al., 2011).

Table 3. Results of the case study: Production of a false color image in which infrared emission is depicted.

Software Package	Result
BLIF	The user can easily produce the image by just assigning the bands
FIS	Not tested due to major issues as Flash-based software
LEOWorks 4	The user needs to assign bands first and perform two more steps compared to BLIF
Sentinel Playground	No need for assigning the bands. It has ready-to-use RGB combinations.

LEOWorks 4 has to be installed in PCs and operates in multiple operating systems except for Android. The user has to upload a satellite image in order to interpret it.

The Sentinel Playground is a package that operates in all platforms and in Android devices too. This platform is user-friendly and there is no obligation to upload a satellite image, since it is connected with satellite databases. It offers multiple search criteria as the location of the area in planetary scale, the date of the image capture and the cloud removal. Its graphical user interface is very simple and easy for all users.

Discussion

This paper aims to contribute to the integration of the RS in upper primary and secondary education. We evaluate four software packages, which teachers can use in schools. These packages offer important features for helping students understand the concept of RS and its impact in our everyday lives. The evaluation of their effectiveness and easiness takes place according to the 13 criteria of the generic list of Jadhav & Sonar (2009). The main limitation of this study is the lack of student evaluation of the education RS software, by following the abovementioned criteria to present student's point of view, concerning the usability of these software platforms.

Currently, the FIS package cannot operate because it is based on the Adobe Flash Player, which is no longer supported (Hodam et al., 2020). Its learning modules are still available online as teaching material, but there is no interaction with this software. This is a major interoperability issue.

BLIF has several malfunctions on Android 8 or later devices. Some of its applications do not operate in mobile devices, which the students have to use when they work out of the school computer lab

LeoWorks has no version for Android devices. As mentioned above, this malfunction could be a serious problem, since many students possess only Android devices, tablets or smartphones instead of home PCs. Additionally, another drawback is that the user has to search and extract from external databases the raw satellite images

The Sentinel Playground platform is executable in all hardware equipment and operating systems and also in Android devices. It has useful features as the cloud coverage removal from the image. It has the advantage of selecting the region of interest, which is motivating for children, as we have discussed in the Introduction. There is no need for uploading an image, since it is connected with six different satellite datasets, the Sentinels 1, 2 L1C and 2 L2A, Landsat 8, MODIS and DEM. This platform lacks educational modules, but the teacher can use the ones offered from BLIF and FIS or the LEOWorks website.

Conclusions

Integrating RS in upper primary and secondary education is an ongoing process and several efforts are working towards this direction (Hadjimitsis et al., 2020). RS software developers should consider the low performance of the current school computer equipment and their low Internet connectivity in both bandwidth and speed. They may find our evaluation results useful when designing future versions.

In conclusion, Sentinel Playground seems to be the most appropriate educational RS software. It can be easily supported even by average school computer labs or in classrooms and by any operating system. Moreover, its software toolbox meets the requirement of user-friendliness according to the criteria of our evaluation.

However, all the evaluated software packages can be used for Remote Sensing integration to upper primary and secondary education. Teachers can select the RS software that fits their profile or combine them, according to the curriculum and their student needs.

Future work

It would be interesting to ask students, preservice teachers, IT specialists, inservice teachers and HEI students to evaluate these packages by using the same methodology and criteria. The case study should be tested with imagery from a satellite database and especially, the same file should be tested for all the mentioned RS educational software packages.

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