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EXPERIMENTAL VERIFICATION OF THE POSSIBILITY OF USING LIDAR DATA FROM A FORESTED AREA IN ARCHEOLOGY

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Experimental verification of the possibility of using LIDAR data from a forested area in archeology

Abstract: One of the most progressive method for spatial data acquisition is Airborne Laser Scanning (ALS), widely called LIDAR (an acronym of LIght Detection And Ranging). Its biggest advantage is that the laser beam can pass through vegetation so we can create a Digital Terrain Model (DTM) also in forrested areas where e.g. photogrammetry fails due to dense canopy cover. One of the most significant INSPIRE principles says "spatial data should be collected only once and kept where it can be maintained most effectively". That is reason we decided to test whether or not LIDAR data gathered for forestry can be used in archeology.

Keywords: spatial data, LIDAR, archeology, forested area, digital terrain model

Introduction

LIDAR is an active mapping sensor most often located on aerial platform. Principle of LIDAR is very simple – a pulse of light is emitted and after the reflection the precise time of detection of that reflected pulse is recorded. Then spatial distance between scanner and the measured point is calculated via this time delay. Position and orientation of the scanner is observed by Global Navigation Satellite System (GNSS) and Inertial measure unit located on the plane, so the XYZ coordinate of the measured surface can be computed.

LIDAR is a very effective tool for large areas mapping. Many developed countries use spatial data obtained by LIDAR in a great variety of applications, beginning in agriculture, through geology, aviation, ending in military. One of these application is archeology, where objects of interest are used to be hidden under dense vegetation, which can be discovered thanks to scanning the landscape with an airborne laser and receiver.

In Slovakia, archeologists don't have an opportunity to use this method for their research, due to unavailability and price of the LIDAR data. Better situation is in the Czech Republic, where the Project of Creating a New Altimetry of the Czech Republic is implemented since 2008. Main products of the project are Digital Terrain Model of 4th generation (DMR 4G) in form of the regular grid, Digital Terrain Model of 5th generation (DMR 5G) in form of irregular triangular network and Digital Surface Model of 1st generation (DSM 1G), but there can be also available raw (non-filtered and non-interpolated) LIDAR data in form of point clouds, which can be used for the purpose of archeological research. In our case, we had an access to data from National Forest Center and decided to verify whether this kind of data can be useful in archeological purposes in forested areas.

1. Study site

From the list of localities, which have been measured with LIDAR last year, we have chosen Turie Castle – a small hill in Rajec valley in Central Slovakia (Fig. 1).

The oldest finds of shards in this location can be dated back to the Iron Age, when there was apparently built the first fortification. Another imported period, when the castle was used to protect the surrounding area, was the 1st century BC. Unfortunately, none of the fortification resisted

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to the raid of Germans who arrived sometime in early 1st century. Most of the findings comes from the 14th – 15th century, mostly ceramics and iron items. Last known settlement of the Castle was at the breakthrough of 16th and 17th century. Appearance of the castle in the 19th century is shown in Fig. 2 (Slovanské hradiská, 2014).

Fig. 1 Turie – castle (Source: Google Earth v. 7.1.2.2041 (10/7/2013) Turie, Slovakia. N 49°08´50.35´´ E 18°44´01.01´´. Google, 2014, US Dept of State Geographer, http://www.earth.google.com [April 29, 2014].)

Fig. 2 Turie – Castle in 19th century (Slovanské hradiská, 2014)

A quarry for mining limestone existed here few decades ago, so today there is so called Turie – rock in its place (Fig. 3a). Nowadays a sunken courtyard (Fig. 3b) is situated on top of the hill alongside with some rock formations acting like the remains of ancient fortifications (Fig. 3c, d). These were supposed to be identified after LIDAR data filtration and classification.

Fig. 3 Turie – Castle nowadays (Photo by Jozef Kováč)

2. Data processing

Our aim was to remove (filter) all vegetation from LIDAR dataset and try to find mentioned archeological formations on the ground. We obtained LIDAR data in LAS 1.2 format file, which is common LIDAR data exchange format, together with trajectory file. The data were obtained on September 8, 2013. We performed LIDAR data processing using an evaluation license of product by TerraSolid software running on Bentley MicroStation called TerraScan. It was not necessary to work with the entire data file, so we cut out an area of 300 x 500 m and we got a point cloud of 30 000 points covering our study site (Fig. 4).

Fig. 5 visually expresses elevation ratios of the locality.

The Terrascan software uses a slope-based filter, which uses the slope of the line between any two points in a point set as the criteria for classifying ground points. The technique relies on the premise that the gradient of the natural slope of the terrain is distinctly different from the slopes of non-terrain objects (trees, buildings, etc.). Any feature in the laser data that has slopes with gradients larger than a certain predefined threshold therefore does not belong to the natural terrain surface (Sithole, 2001).

The basic mechanics of the slope-based filter is illustrated in Fig. 6. The vertex of an inverted cone sweeps under each point in the point-set to be filtered. Wherever the cone cuts the point set, then the point at the vertex of the cone is filtered off. In Fig. 6 the point at the vertex of the cone (p_i) is not filtered off because the cone does not cut the surface. In the implementation of the filter, an inverted bowl whose shape is defined by a probabilistic function designed to minimize classification error replaces the cone. For simplicity, a cone is considered here (Sithole, 2001).

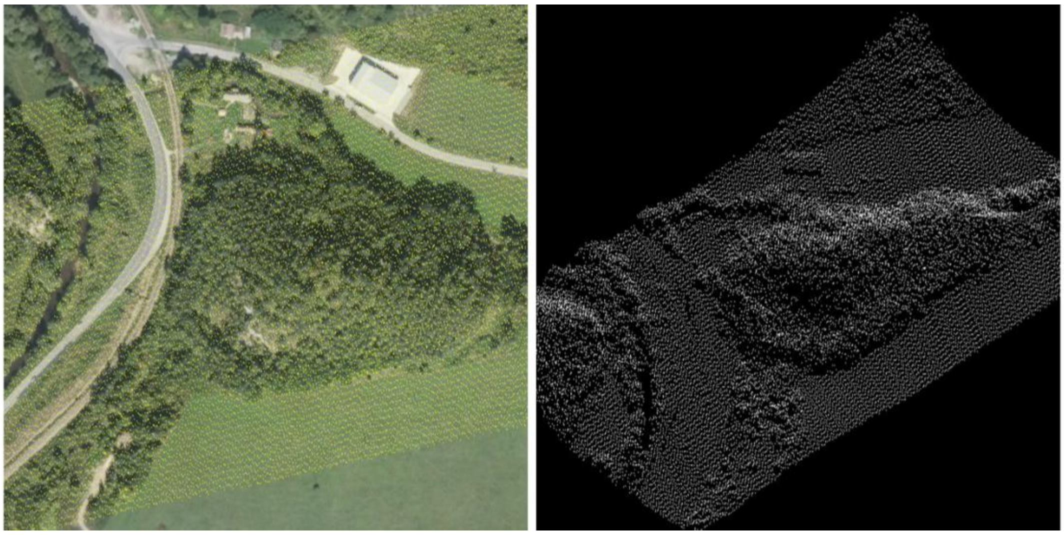

Fig. 4 Point cloud of Turie – Castle. Left – top view, right – isometric view

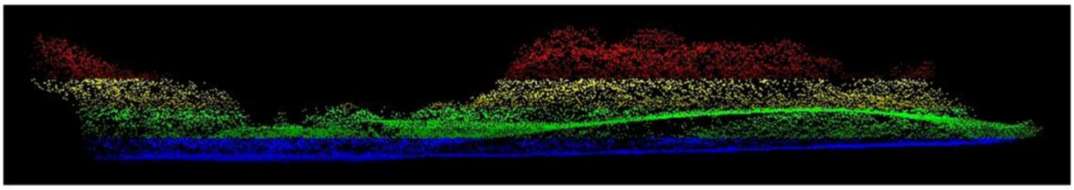

Fig. 5 Elevation ratios of point cloud – front view

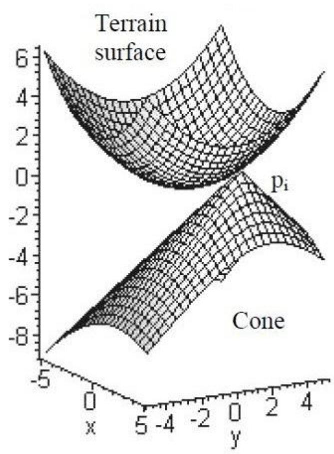

Fig. 6 Mechanics of the filter (Sithole, 2001)

The TerraScan software uses macros that are set-up to measure the angles and distances between points to determine what classification a point should be: ground, vegetation, building, other. The angle and distance values in the macros can be changed to be more or less aggressive with the classification of points (from ground to vegetation to building) by varying the incidence angles and estimated distances among neighboring points. Anything not classified as ground or error is eventually placed into a non-ground class (TERRAPOINT, 2004).

At first we classified errors (Fig. 7). Error points are determined to be either high (spikes) or low (pits) outlier points, often beyond 3-sigma from the rest of the data set. Clouds, birds, pollution, or noise in the data can cause error points, for example.

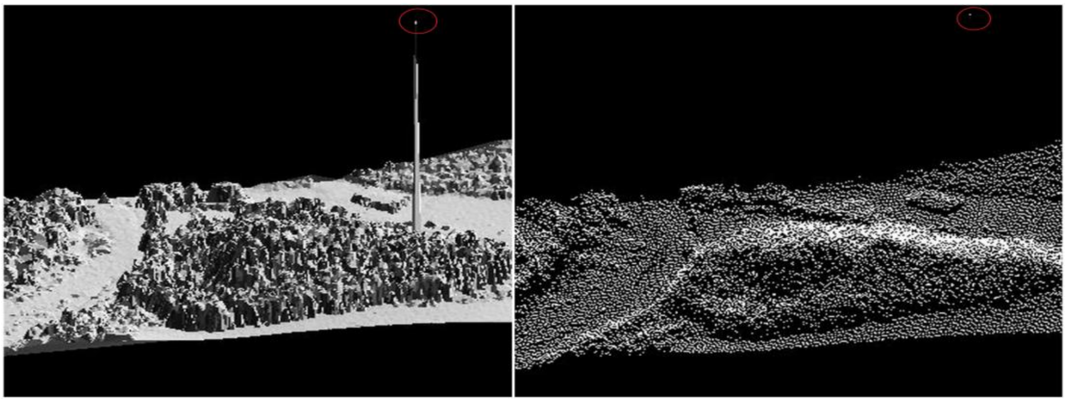

Fig. 7 Errors. Left – visualization by shading, right – visualization by class

The next step was automated classification into Ground points. A lower iteration angle and varying distances allow that only the lowest Z values points will remain classified as ground. Not every minimum Z value is classified as ground. The distance and angle among points are still key factors in determining whether a point actually penetrated to the ground surface or remains higher up in vegetation or other structure. No distinction is made between ground points that hit roads or other paved surfaces versus true ground shots (TERRAPOINT, 2004). This step required several attempts before we set the best settings, e.g. maximum terrain angle or iteration angle. But right after the briefly preview of classified points it was clear, that significant manual classification is needed, because not all points classified as ground points really are ground points (Fig. 8).

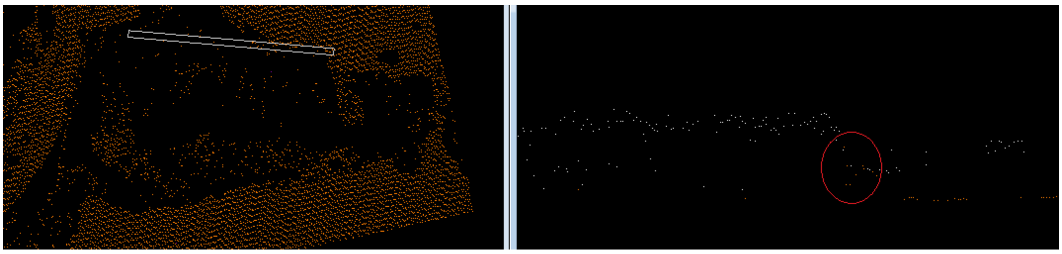

Fig.8 Wrong classification, vertical cut

In the Fig. 8 we can also see, that density of ground points on the hill is very low (average 0.02 points/m^2) compared to total density of points. 0.2 points/m^2) and digital terrain model of the area would be very rough and inaccurate, yielding no chance to find any archeological objects. One of the LIDAR’s advantages is multiple pulse return (Fig. 9).

Laser beam splits as it hits object and it can reflect back up to four returns. This can be very useful when measuring height of the objects. Terrascan software allows to classify the points by echo (order of returns) in four different ways: the only echo, first of many, intermediate and the last of many. Logically, we used the last option, but there is a need to say, that the last return doesn't always reach the ground, especially in forestry areas. That means, we had to manually control every single point classified as last return and decide, whether or not belongs it to ground. Sometimes it was truly a very tough choice (Fig. 10).

Finally, after several-hours of manual classification of hundreds of points, we made DTM, where the Turie – rock mentioned above is very clearly visible (Fig. 11).

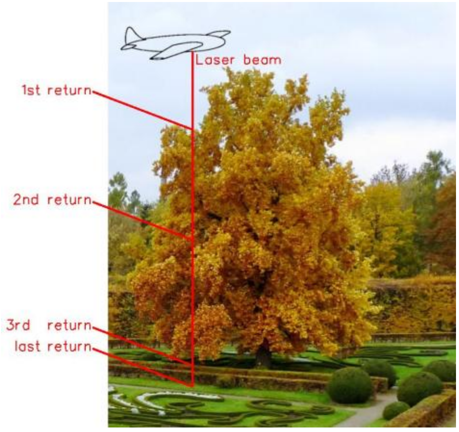

Fig. 9 Principle of multiple puls return

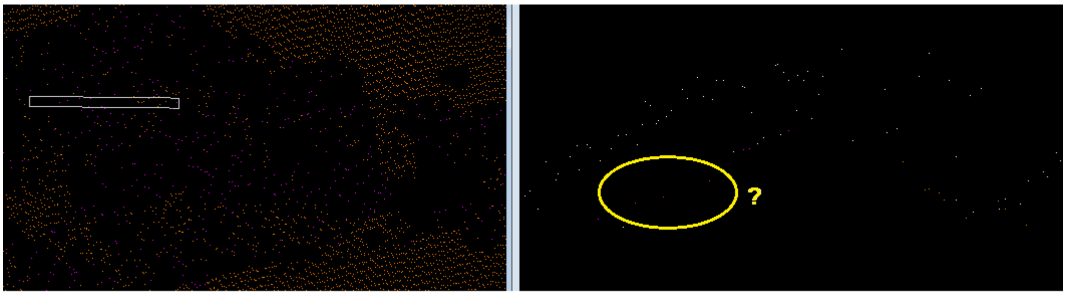

Fig. 10 Decision making process

Fig. 11 Turie – rock

Unfortunately we weren't able to find any others expected objects. For better orientation we classified low, medium and high vegetation as well. For visual evaluation of classification we can compere our results with Google Earth (Fig. 12).

After classification of vegetation we could compare our model with ortophoto and we were able to find the sunken courtyard on the top of the hill (Fig. 13). This was only because of missing vegetation on that particular place. Nevertheless, despite addition of significant amounts of points from Last echo class to ground class, point density on the hill was still very small - 0.02 points/m^2 average. Only few pulses of laser beam achieved the bare ground. The main variables are the type and density of vegetation, the height and speed of flight, thus on purpose of spatial data acquisition in general.

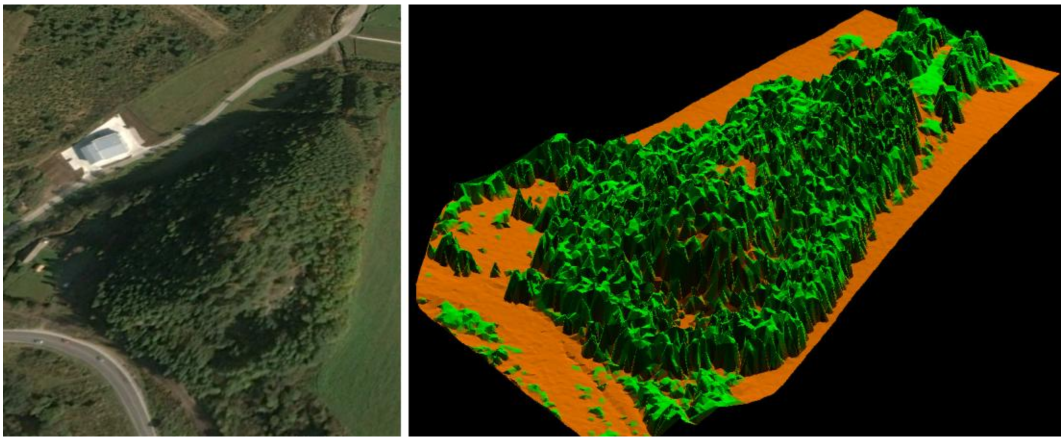

Fig. 12 Comparison classified LIDAR data with Google Earth (Source of the left Fig.: Google Earth v. 7.1.2.2041 (10/7/2013) Turie, Slovakia. N 49°08´50.35´´ E 18°44´01.01´´. Google, 2014, US Dept of State Geographer, http://www.earth.google.com [May 08, 2014].)

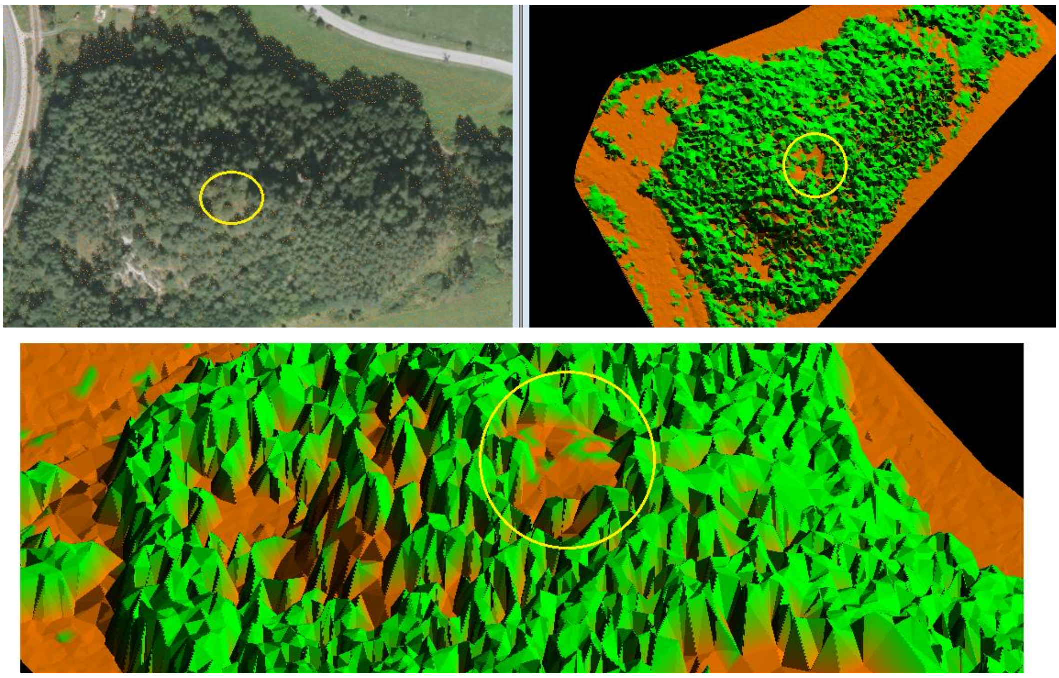

Fig. 13 Sunken courtyard on the top of the hill

Conclusion

Although the experiment of ours was no very successful, we don't want to claim that LIDAR is not an appropriate method to use in archeology. Quite the contrary, not only that LIDAR data have a huge potential in such kind of research, but there are also many foreign studies already proving it. For example, as mentioned above, in Czech republic is already implemented the Project of Creating a New Altimetry of the Czech Republic. This data was tested for the archeological purposes by Czech archaeologists in Pilsen, whose area of interest was the cairn burial in the woods (Holota and Plzák, 2013). They were much more successful, but their objects were much bigger than our rock formation, which did simply loose in medium and high vegetation.

Another study shows how a lost city in Honduras had been discovered by using LIDAR data (Fig. 14) (Daukantas, 2014).

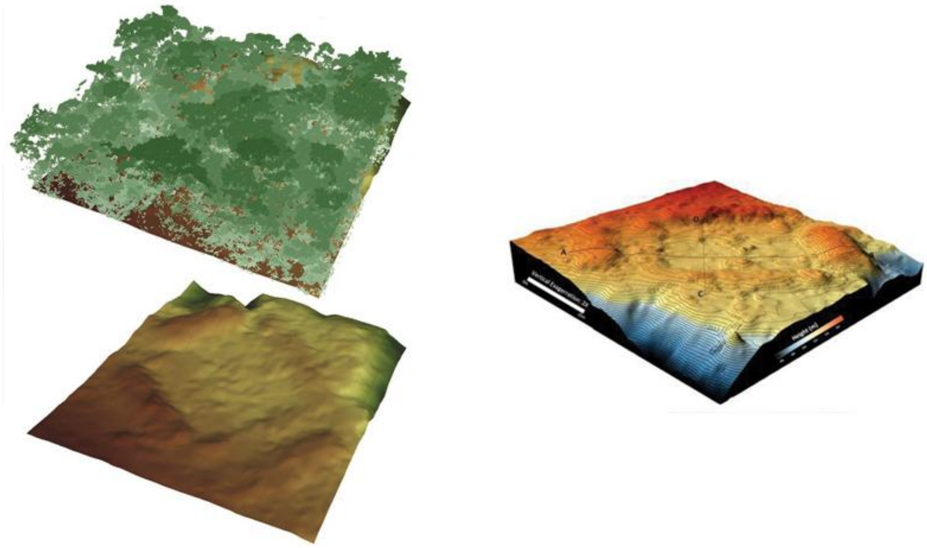

Fig. 14 Lost city in Honduras. Light green (left top) shows vegetation that can be removed by filtering the LIDAR point cloud data (left bottom). Right – a rectangular plaza surrounded by mound structures from one of the possible lost cities. (Daukantas, 2014)

As we have already mentioned, the most significant factor of the success of using LIDAR data is the purpose of their acquisition itself. So we believe, despite our initial failure, that Slovak archeologists will make a significant discoveries due to LIDAR data in the future. Because, as an American documentary filmmaker Steve Elkins said: "When you're in the jungle and you're wandering around, you could stumble upon a giant structure and you can't even see it from 50 feet away because it's completely covered by dirt and plants. LIDAR is like super-X-ray vision. You can 'fly over' and see these shapes and see if there's anything worth walking to." (Daukantas, 2014).

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S u m m a r y

Experimentálne overenie možnosti použitia lidarových dát zo zalesnených oblastí v archeológii

Jednou z najprogresívnejších metód na zber priestorových údajov je letecké laserové skenovanie, známe pod pojmom LIDAR. Najväčšou výhodou tejto metódy je to, že laserový lúč dokáže prejsť cez vegetáciu až na reliéf zemského povrchu a môžeme tak vytvárať digitálne modely reliéfu aj z oblastí, kde iné metódy zberu zlyhávajú kvôli hustej vegetačnej pokrývke. Mnoho rozvinutých krajín používa dáta získané pomocou LLS v mnohých odvetviach, počnúc poľnohospodárstvom, cez letectvo, geológiu až po vojenské účely. Jednou z takýchto aplikácií je archeológia, kde sa objekty záujmu skrývajú pod hustou pokrývkou vegetácie. Kvôli finančným nákladom potrebným na mapovanie pomocou LIDAR-u nemajú slovenskí archeológovia možnosť používať túto metódu pri svojom výskume Keďže však v súčasnosti je snaha o využitie raz získaných údajov v čo najväčšom množstve aplikácií, testovali sme možnosť využitia lidarových dát získaných primárne pre potreby Národného lesníckeho centra vo Zvolene pre účely archeológie. Našou testovanou lokalitou bol vrch Turie – Hrádek v Rajeckej kotline, na ktorom sa nachádza niekoľko archeologických objektov. V článku vysvetľujeme podrobný postup hľadania týchto objektov pomocou filtrovania a klasifikovania surového množstva bodov v špecializovanom softvéri. Na prvý pohľad sa náš pokus nezdal byť veľmi úspešným, čo bolo spôsobené nie moc vhodným typom lokality, lenže v danej dobe bola jediná možná. Vhodnosť tejto metódy v archeológii však následne dokumentujeme úspešnými prípadovými štúdiami v zahraničí.

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