Highlights

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Interactive interpretation of 3D surfaces in field-based geosciences using mobile devices - concepts, challenges and applications

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Abstract

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1. Introduction

- computing equipment continuously elevates the analytical capabilities for solving geoscientific problems
- large drawback on computing equipment: the more powerful it is, the more stationary it is
- geoscience disciplines such as hydrology, geology or glaciology are driven by outdoor experiments that prohibit bulky equipment
- the advent of mobile computing equipment, such as smartphones and tablets, provides a possible solution to the equipment problem

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- form factor of mobile devices is small enough to allow every field-related geoscientist to carry one in the field
- as seen is popular articles, the range of available devices increases, which allows to find a devices fit-for-purpose to each situation
- range of devices also comes with a range of capabilities that influence their usability for specific field tasks
- availability of small form factor devices is only on part contribution to making digital geosciences more "mobile“
- availability and easy access to geoscience data (e.g. domain-specific maps, digital elevation models (DEMs), surface models in 3D) is equally important to perform combined digital- and field analysis
- while basemap access on mobile devices is trivial, surface-scanned data in form of point clouds and (textured) triangulated meshes is becoming increasingly available with novice-operable structure from motion (SfM) software and drones
- crowdsourced data and Volunteered Geographic Information (VGI) provides numerous data for domain-specific analysis, which is facilitated by easier data capture from amateur scientists using mobile devices
- In order to connect data and devices in the field, domain-specific mobile software is required
- the difficulties in mobile software development stem from the specific demands and challenges for mobile software, such as energy efficiency, multi-manufacturer support, smart sensor utilisation [add and expand]
- with the emergence of new application cases, which are demonstrated and discussed in this article, and an increasing interest from geoscience- and computer technology industry, a significant rise in the mobile software

availability for geoscience problem solving is expected for the near-term future

- Challenges

2. Target case studies

3. Representation basis – Geometry and Radiometry

4. Algorithms

4.1. Structure-from-Motion model generation

4.2. Image-to-geometry

4.3. Data representation and rendering

4.4. Interpretation and annotation

5. Technology

5.1. Sensors

5.1.1. Localization

5.1.2. Orientation

- stability IMU (see 3D-NO)
- precision IMU

5.1.3. Parameter sensitivity

5.2. Graphics

- software- vs hardware renderer
- web-rendering
- rendering-on-device
- hardware differences: speed, capability, CUDA

5.3. *Power consumption*

6. Applications and Requirements

Due to the increasing usability of mobile devices for in the field annotations, several use cases concerning geosciences has become apparent. In the following, two essential

6.1. *Derivation of hydrological parameters: Water level gauging*

The last decade is characterized by a continued increase of globally devastating flash floods after heavy rainfalls. Even smallest creeks turned into hazardous streams causing flooding and landslides. Conventional gauging stations provide precise information about water levels measured over a short time period. State of the art techniques for administrative observation comprise water pressure sensors, floating gauges and conventional tide gauges. They are characterised by long-term stability and outdoor robustness providing accuries of several millimeters up to one centimeter [1]. Averaged over defined time intervals, it is advisable to remain caution regarding these accuracies may be too optimistic [2] .

Because of high costs in purchase and maintenance, gauging stations with complex sensing devices must be sparsely installed. A prime example here is the hydrological network in Saxony, Germany. Here, 184 gauging stations are installed for permanent observation on 154 of 259 rivers rising from small, medium and large catchments [3, 4]. Thus, around a third is not monitored neither during flood events when the most protection is required. Recently, commercial smartphone applications arose to enable crowd-sourcing based water level estimation for, among other things, such cases [5, 6]. But all of them have one thing in common: the water level is entered manually by engaged citizen scientists finding and photographing tide gauges close to rivers that makes - on the one hand a potential danger to themselves (f.e. by sudden landslides), and still limits on the other the approaches to open and visible gauges.

Improvements in this sense can be achieved through *image-2-geometry intersection* and 3D annotation for automatic water level determination without reference gauges for almost every situation regarding running waters. for this, the smartphone application *Open Water Level* that bases on the freely available open source camera framework *Open Camera* [7]. Open Water Level allows for free stationing water line detection using short hand held time-lapse image sequences (for details please refer to [8]). To interpret these, image measurements must be transformed into object space. Thus, exterior information needs to be provided by smartphone sensors for orientation and positioning.

6.1.1. Requirements applying to the sensors

To solve the task of autonomous water level determination on running rivers f.e. emergency cases using *image-2-geometry intersection*, citizen scientists position and orientation must be know. As figured out in 5, smartphone sensors accuracies for orientation and location are highly dependent on user's environment. Especially the strong correlation of heading and disturbing magnetic sources may be a issue must be solved specifically related to running rivers where metal railings usually exists. Similar effects can also be noted using high-end IMU systems for instance autonomous car navigation. But the magnetic influences inside cars are almost stable and can be calibrated during the drive (advanced navigation manual). For smartphone orientation, the magnetic strengths attaching the phone may change substantially in short time. A typical scenario would be: a citizen scientist walks along street, taking his phone inside the baggage close to metallic keys. While walking he passes several street lamps, signs, etc. Finally, he arrives at a bridge over a urban river, takes out the phone, looks down to the river and records the time lapse image sequence a few centimetres above a metallic railing. Meanwhile, several cars passing the same bridge. In this simple use case, the magnetic field around the smartphone changes countless times due to several unpredictable disturbances (table˙mag˙disturb) [9].
The heading angle has the highest influence compared to pitch and roll regarding 2D image and 3D object data registration. For this, a so-called synthetic image is rendered from colored 3D reference point clouds using scientist's location and orientation to define a situation-dependent bounding box of points

to be projected onto image plane with respect to depth and indentations (see [10]). Thereby the heading defines the rotation of the depth direction, as a false angle gives a false viewing direction resulting in a synthetic image that has no similarity or only a little with the time lapse sequence. However, in case of no similarity and thus no possible solution for *image-2-geometry intersection*, simply no water level can be calculated. But in case of slight overlapping, there might be image matches but with very bad distribution that impedes a correct positioning (fig˙heading˙test) and may lead to even worse results of false water levels.

It is obvious that a second source for destructive results exists: the absolute geo-positioning using smartphones currently installed GNSS receivers. In urban scenes with several shadow effects due to high-rise buildings, errors of several meters in latitude and up to more than 30 meters in height are highly possible where even the weather has impact [11, 9, 12]. It is likely that, in the near future, smartphone's GNSS modules will be improved solving lateral accuracies of 50 centimetres [13].

For now, possible relief might come including other sources for positioning like digital elevation models for simple height correction or invoke map services that allows the user for position refinement. For this, some APIs are already provided by Google (quellen) but they are rather cost-expensive by extensive accessing. Another upcoming option is including barometers in sensor fusion, altitude can be measured within three meters [14] but for now, they are not a standard.

- (table, observation heading during water line detection outside → check magnetic strengthens and there changes over short times)
- (figure/table, sensitivity analysis → heading changed in terms of 10 degrees, what does it make for)

6.1.2. Requirements applying to the scenario

- *online processing and position refinement: need online connection*

- *image quality for water line detection: influence of image resolution, lightning, ...)*

- available approach to address the task

6.2. Field Geology

- recap: task to be solved

- main requirements for (location- and orientation) sensor accuracy and geometric accuracy

- specific requirements to this use case: data availability; illumination; network inavailability

- available approach to address the task

6.3. Virtual Field Trips

- recap: task to be solved

- main requirements for (location- and orientation) sensor accuracy and geometric accuracy

- specific requirements to this use case: data availability; illumination; network inavailability

- available approach to address the task

6.4. The digital fieldbook

- recap: task to be solved

- main requirements for (location- and orientation) sensor accuracy and geometric accuracy

- specific requirements to this use case: device range to cover; data integration; no network

- available approach to address the task

7. Conclusions

which problems are sufficiently solved ? which challenges remain that have already been discussed

8. Discussion

- porting existing desktop algorithms on mobile devices [quick and fast]
- vegetation in scans
- pre-processing of geodata for mobile use

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