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Digitalization of Geodetic Measurements Using GIS

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SUMMARY

Contemporary geodetic practice increasingly demands the integration of digital field data collection tools capable of providing real-time feedback during surveying operations. This paper proposes a structured framework for applying mobile Geographic Information Systems (GIS) – specifically QGIS and QField – to geometric levelling workflows. The proposed system leverages the cloud synchronisation capability of QField Cloud to achieve real-time data transfer between field devices and desktop GIS environments, enabling immediate spatial visualisation of collected points. Beyond coordinate capture, the framework introduces a structured attribute schema for the mid-point levelling method, accommodating back-sight and fore-sight staff readings on both black and red rod faces, automatic reduced level calculation from a known benchmark, and real-time misclosure evaluation against permissible tolerances. The mobile GIS platforms, when configured with appropriate attribute logic and default value expressions, can serve as capable digital field books that not only record observations but actively support quality control in the field.

Keywords: Mobile GIS; QField; QGIS; Geospatial data infrastructure; Field automation; Spatial database.

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Introduction

Geodetic field observation in much of current practice remains paper-based: staff readings are recorded in field books, reduced manually or in spreadsheets, and checked for misclosure only after the survey party returns to the office. This separation of data capture from computational validation means that gross errors – a misread staff, a transposed digit – surface only during post-processing, once the instrument crew has already left the station and re-observation is no longer possible. Structured mobile GIS-based field data collection, in which attribute logic and real-time computation are embedded directly into the observation workflow, offers a route to closing this gap and bringing quality control to the point of measurement itself (Nowak et al., 2020).

Mobile GIS platforms offer a compelling solution to this challenge. QField is an open-source, cross-platform field data collection application – available for Android, iOS, and Windows – that is fully interoperable with QGIS desktop software (Maťašovská et al., 2024). Its central operational advantage for geodetic applications is real-time bidirectional synchronisation via QField Cloud: any observation recorded in the field appears immediately in the open desktop QGIS project, without any manual data transfer. Concurrent with this, smartphone-grade GNSS receivers have demonstrated positioning accuracy of 0.5–1.0 m under open-sky conditions (Dabove et al., 2020), which, while insufficient for high-precision control surveys, is adequate for station identification and spatial referencing in training and community-level monitoring contexts.

Despite these capabilities, the application of mobile GIS to structured geodetic measurement – as opposed to general spatial data collection – requires deliberate system design. Levelling observations follow a strict protocol: the mid-point method requires four readings per instrument station (back-sight black face, fore-sight black face, fore-sight red face, back-sight red face), and the computational chain linking these readings to height differences and cumulative elevations must be enforced systematically (Schofield & Breach, 2007). Implementing this logic within a GIS attribute schema, using calculated default values and form-level constraints, is the central design challenge addressed in this paper.

The paper proposes a mobile GIS framework for geometric levelling with three objectives: (1) to define a GeoPackage attribute schema that captures the complete mid-point observation set and enforces its computational logic through embedded QGIS expressions; (2) to implement real-time misclosure evaluation in the field, before the instrument crew advances to the next station; and (3) to demonstrate how QField Cloud synchronisation produces a spatially referenced, legally compliant geodetic database as a direct output of the field workflow, without any post-processing digitisation step.

While mobile GIS adoption in environmental monitoring, urban mapping, and archaeological survey is well documented (Nowak et al., 2020; Ivanyshyn & Kasiyanchuk, 2024), its application to structured geodetic measurement protocols – particularly those with strict computational dependencies between observations – has received limited attention in the literature.

Method and Theory

The proposed system consists of three tightly coupled components: a QGIS 3.34 desktop project that defines the data schema and embeds the computation logic; a QField mobile interface for field observation entry; and QField Cloud as the real-time synchronisation layer. The design is centred on the mid-point geometric levelling method and is structured around the requirement of the Law of Ukraine No. 554-IX (2020) to deliver survey results as a spatial database.

The data schema is implemented as a GeoPackage point layer – the native format of QGIS and a standards-compliant OGC spatial database format. Each instrument station is represented by one point feature with the following attribute fields: station_id (text identifier); benchmark_h (starting elevation of the known benchmark); a_black and b_black (back-sight and fore-sight readings on the black rod face);

a_red and b_red (corresponding red face readings); mean_diff (computed height difference: ((a_black – b_black) + (a_red – b_red)) / 2, embedded as a QGIS default value expression); h_computed (cumulative reduced level: preceding station elevation + mean_diff); misclosure (running closure error against the known closing benchmark); and a tolerance flag (±20√n mm, evaluated in-form). Station coordinates are auto-populated via the expressions $y and $x, linking each observation directly to its spatial position without manual entry (Figure 1).

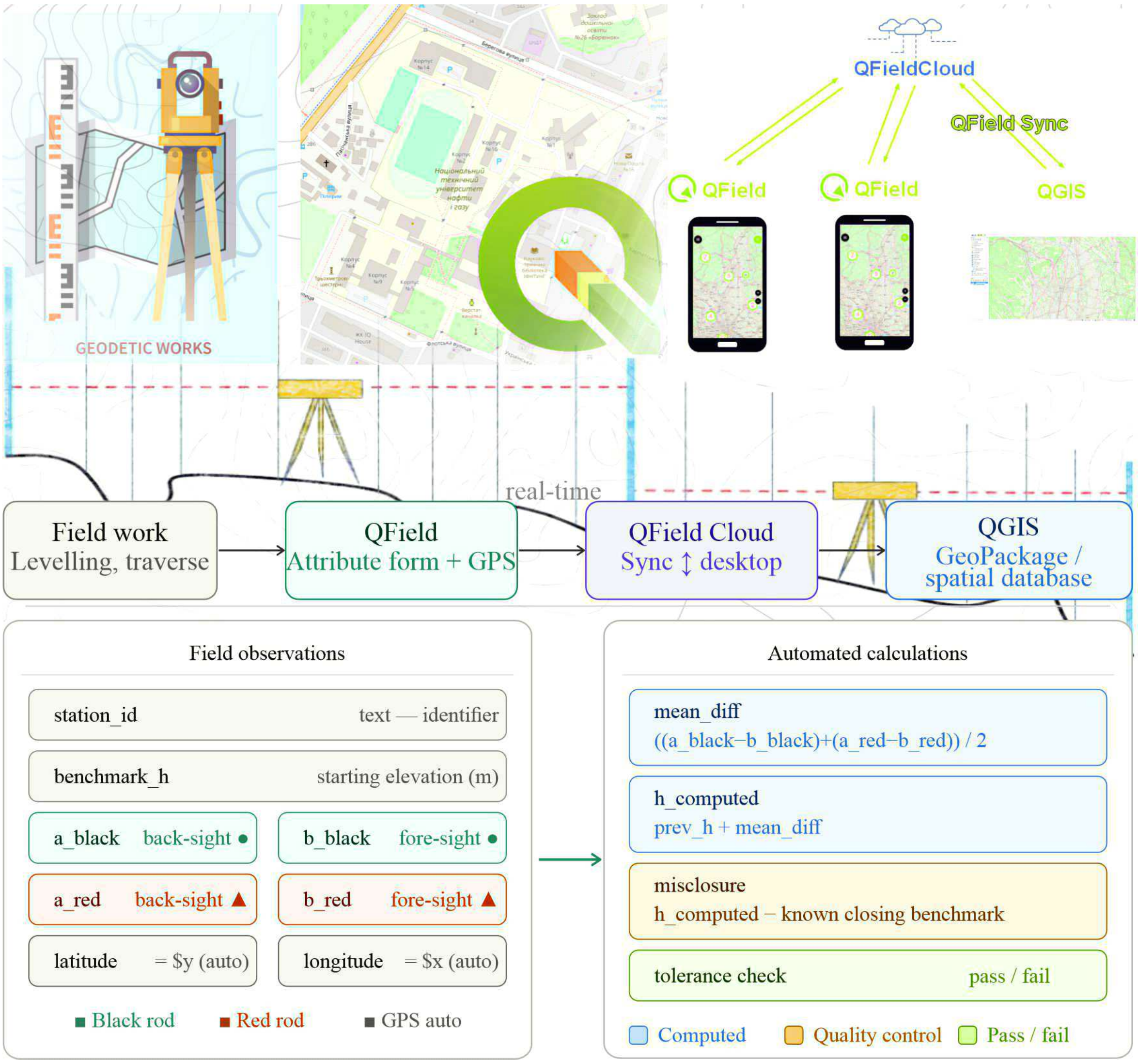

Figure 1. *Mobile GIS framework for geometric levelling*

In the field, the operator creates a new point feature at each instrument station. The attribute form presents observation fields in the sequence prescribed by the mid-point method. Upon saving, the form automatically evaluates mean_diff, h_computed, and the misclosure flag – providing immediate feedback on whether the station meets the tolerance requirement before the instrument is relocated. This in-field quality control is the primary operational advantage of the proposed system over paper-based practice: blunders are detected and corrected at the point of origin, not discovered during office processing.

Upon traverse completion, final misclosure is computed in QGIS and distributed using Bowditch's method via the field calculator. Adjusted elevations are exported directly from the GeoPackage layer in any required format.

Via QField Cloud, each saved station appears immediately in the open QGIS project. This enables supervisory monitoring in parallel with field operations: the accumulating height profile can be inspected in real time, and corrections can be communicated before the traverse is completed. The final output of the workflow is a GeoPackage spatial database containing georeferenced elevation points with full attribute traceability – a format that directly satisfies the spatial database submission requirement of Law No. 554-IX (2020). The complete workflow is shown in Figure 1.

Results

The proposed schema was validated through a field session in which a levelling run of 6 instrument stations covering 320 m was recorded using the QField attribute form. The four-reading mid-point sequence was completed correctly at each station. The in-form misclosure indicator flagged an inconsistency at one station, traceable to a misread staff reading; the correction was made before the instrument was relocated – a detection that would not have been possible under a paper-based workflow until office processing.

The final traverse misclosure was 12 mm against a permissible tolerance of ±20√6 ≈ 49 mm. Reduced levels computed in-form matched independent office calculations to within rounding precision (0.1 mm), confirming the correctness of the embedded expressions. Real-time desktop monitoring via QField Cloud allowed the height profile to be inspected as it developed, enabling identification and correction of a setup anomaly at one station before the traverse was closed. The output GeoPackage layer was ready for spatial database submission without any additional digitisation.

Table 1. *Results of geometric levelling traverse near the IFNTUOG main building (Ivano-Frankivsk), recorded using the proposed QField attribute schema*

Station	***a_black (m)***	***b_black (m)***	***a_red (m)***	***b_red (m)***	***mean_diff (m)***	***h_computed (m)***
BM-1→1	*1.423*	*0.876*	*6.210*	*5.664*	*+0.547*	*342.732*
1→2	*1.651*	*1.234*	*6.438*	*6.021*	*+0.417*	*343.149*
2→3	*0.987*	*1.512*	*5.774*	*6.299*	*−0.525*	*342.624*
3→4	*1.345*	*0.823*	*6.132*	*5.611*	*+0.522*	*343.146*
4→5	*1.782*	*1.103*	*6.569*	*5.891*	*+0.679*	*343.825*
5→BM-2	*1.214*	*1.876*	*6.001*	*6.664*	*−0.662*	*343.163*
Misclosure						***+0.012 m***
Tolerance ±20√n						***±0.049 m*** ✓

Discussion

The proposed workflow demonstrates that mobile GIS platforms can support considerably more than spatial data collection. By embedding observation logic, automated calculations, and quality-control procedures directly into the field interface, QGIS and QField function as digital geodetic field books rather than simple mapping applications. This shifts part of the computational workflow from office post-processing to the measurement stage, where gross observational errors can still be corrected immediately. Such an approach has the potential to reduce transcription errors, improve data consistency, and shorten the time between field observations and the delivery of final geospatial datasets.

Unlike conventional digital field books, where calculations are typically performed after data collection, the proposed GIS-based workflow integrates spatial data management, attribute validation, and computational quality control within a single environment.

Nevertheless, several limitations should be acknowledged. The proposed framework does not replace conventional geodetic instruments or established levelling procedures; instead, it complements them by providing digital data management and automated validation. The current implementation was tested on a relatively short levelling traverse and relies on predefined attribute expressions within

QGIS. Future work should evaluate the framework under more complex surveying conditions, integrate additional quality-control routines, and investigate its applicability to other geodetic tasks, including theodolite traverses, GNSS observations, and engineering monitoring.

Conclusions

The paper has presented a mobile GIS framework for geometric levelling that moves field data collection beyond simple coordinate capture. By embedding the mid-point observation protocol, automated height computation, and in-field misclosure evaluation into a QGIS/QField attribute schema, the proposed system produces a spatially referenced, computationally verified levelling dataset as a direct field output – without any post-field digitisation. The output GeoPackage layer is structurally compliant with the spatial database requirement of the Law of Ukraine on National Geospatial Data Infrastructure (No. 554-IX, 2020), making the proposed approach directly applicable in professional surveying contexts. Real-time synchronisation via QField Cloud further enables supervisory monitoring of the evolving height network during field operations. Future development should focus on the extension of the schema to closed theodolite traverse computation, integration of RTK GNSS corrections to improve station positioning accuracy (Dabove et al., 2020), and the adaptation of the framework to community-level geodetic network monitoring in territorial communities.

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