Leveraging modern desktop computing power to enable full-fledged gravity terrain correction processing

Worden gravimeter

SAIMM 4th Digital Transformation in Mining Conference, 26 June 2025

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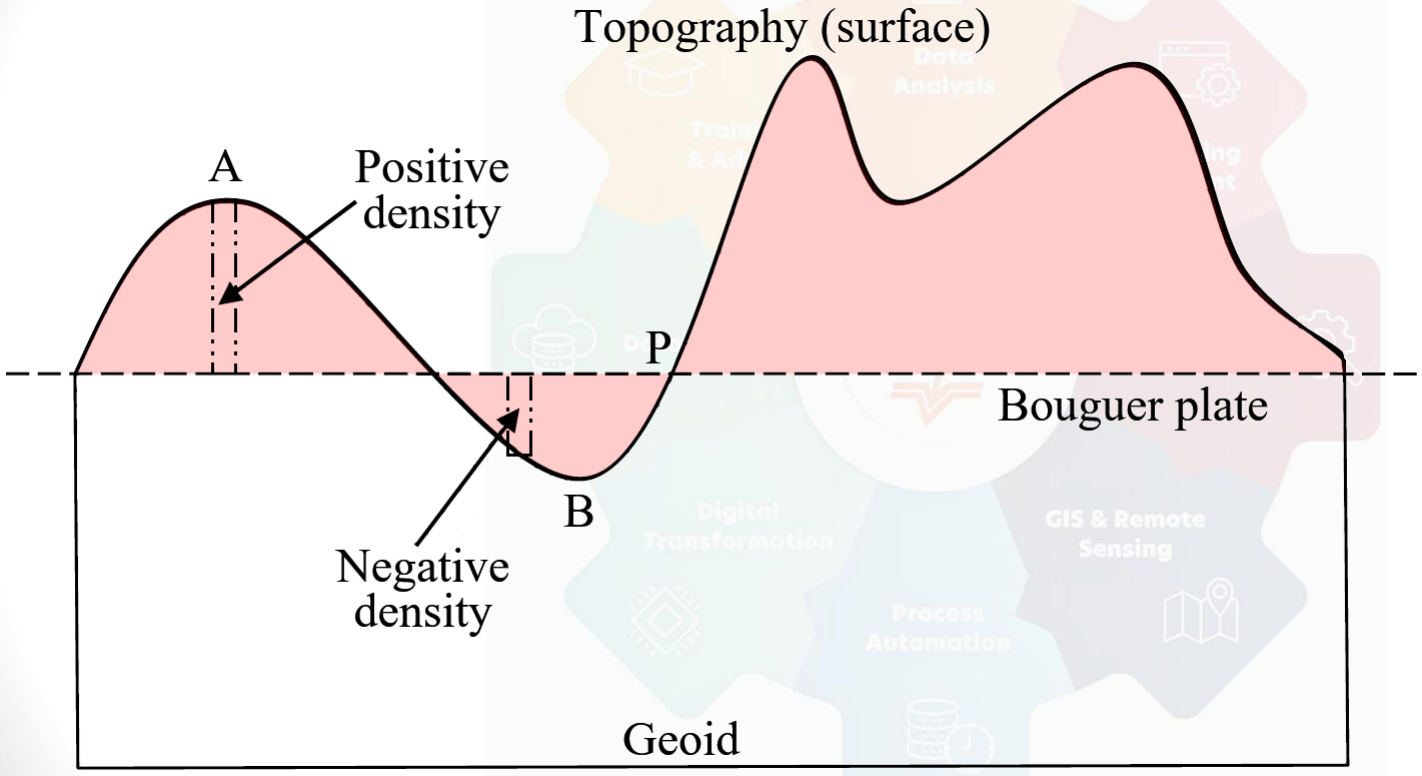
Background: What is a *gravity survey*?

- **A geophysical method using a ground-based or airborne *gravimeter* to measure the strength of gravity at selected points in an area, usually on a predefined grid, to identify subsurface density anomalies**
- **Various corrections are applied to the measurements to remove known effects that influence gravity measurements**
- **Corrections include:–**
  - **Drift** (temperature, gravimeter characteristic changes slowly during use)
  - **Latitude** (Earth is not perfectly spherical & is spinning)
  - **Elevation / Free-air** (Newton's ULG: $g \propto 1/r^2$)
  - **Bouguer** (mass between reference & measurement elevations)
  - **Earth tides** (Moon's effect)
  - **Regional** (deep & extensive large-scale variations that aren't of interest)
  - **Eötvös** (Earth's rotation, E-W motion, gravimeter on a moving platform)
  - **Terrain** (uneven topography, esp. nearfield)

Scintrex CG-5 Autograv gravimeter

Background: What is a *gravity terrain correction* (GTC)?



At “A” (hill), there is excess mass above the elevation-corrected measurement point “P” which reduces the gravity measurement because it has an upward vertical gravitational force component.

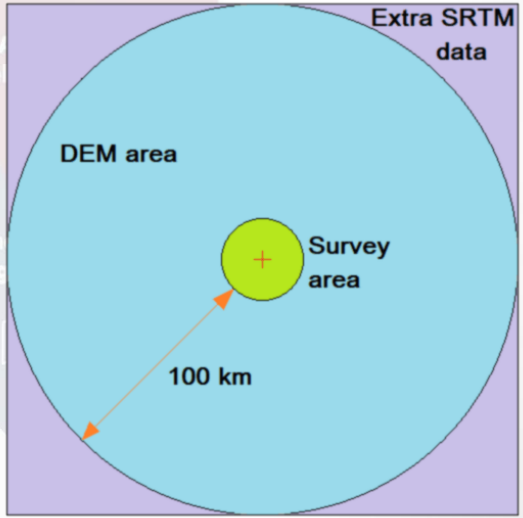
At “B” (valley), there is missing mass below “P” which also reduces the net vertical gravitational force component.

GTC code input data requirements:

1. A survey specification giving the positions and elevations of the observation points.
2. Digital terrain model (DTM) data* giving a grid of points with known elevations out to 100 km or more beyond the survey area and including it.
3. DTM point average rock column densities, if available.
4. Any local DTM data obtainable from the mine operator and/or in the public domain.

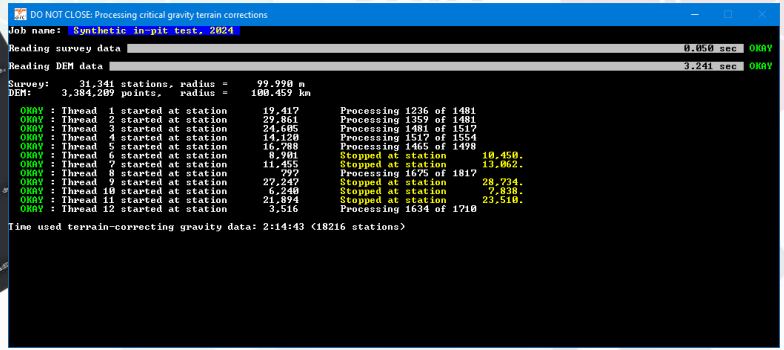
* The bulk of the DTM data is usually taken from a public-domain Shuttle Radar Topography Mission (SRTM) source.

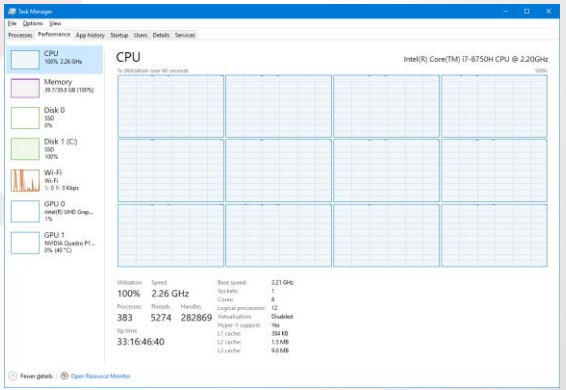
Areal concept:



GTC code features

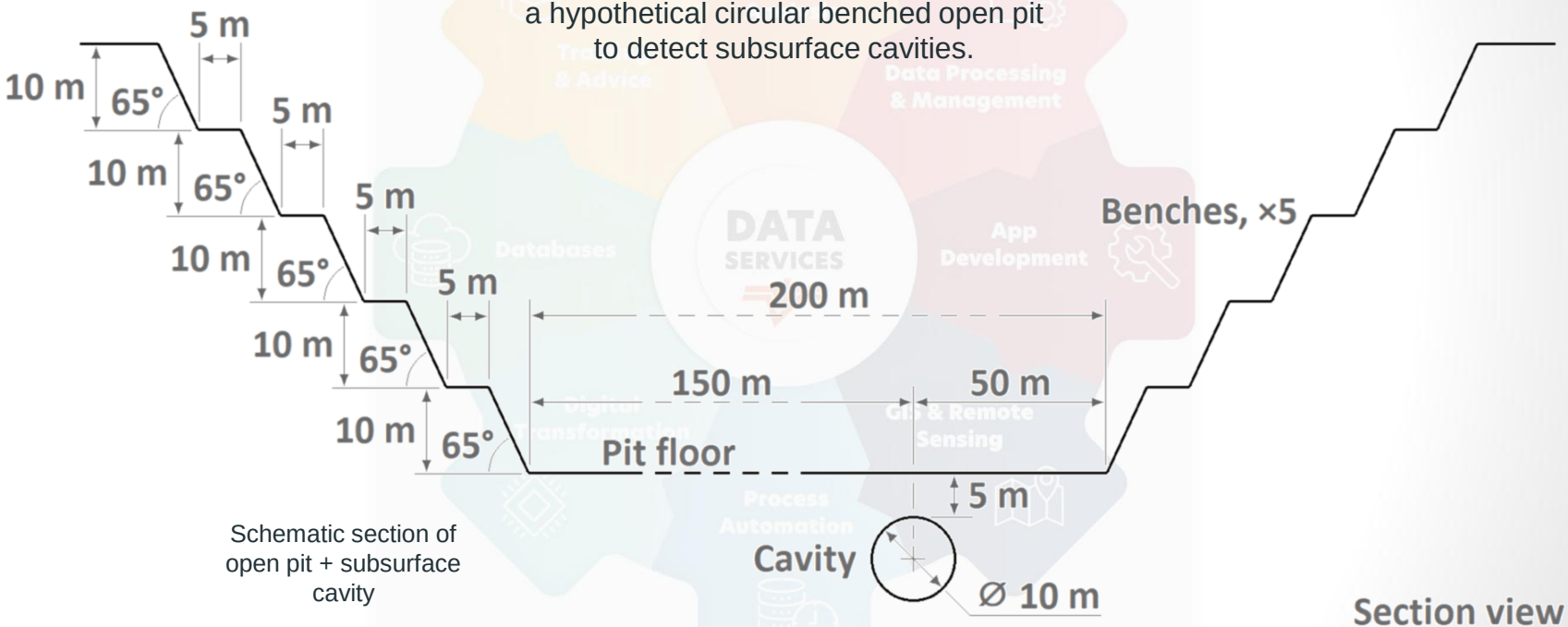
- 64-bit compiled (i.e., native x64 code) standalone MS Windows console program.
- Algorithms optimised for speed (minimal library code, trigonometry eliminated wherever possible, and more).
- Multithreaded, uses all available vCPUs/cores with each thread assigned to a specific vCPU/core.
- Some core routines coded in Assembler to eliminate overhead and use modern instruction set extensions (SSE, AVX).
- Automatically divides a new job into as many equal portions as there are vCPUs/cores.
- Job can be parcelled out to multiple PCs simultaneously to process different parts of it.
- Job specification is done via a simple text-based INI file.
- Job can be interrupted at any time by the user and resumed later where it left off.





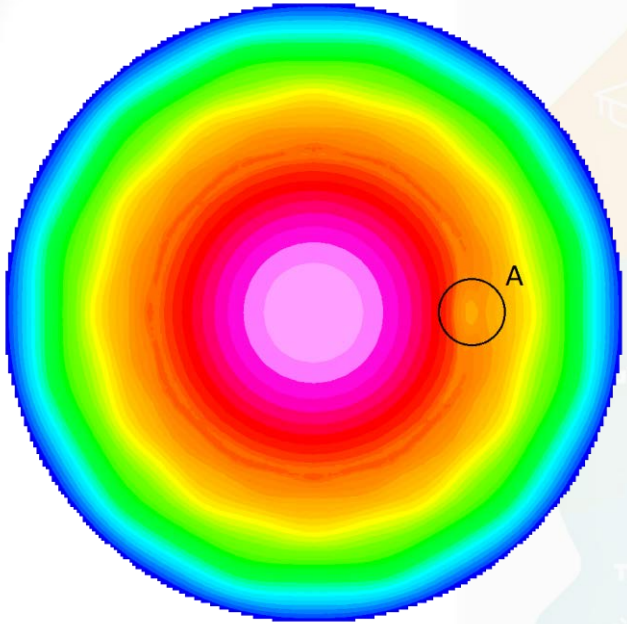
GTC processing in a synthetic example – part 1

Synthetic example of a gravity survey in a hypothetical circular benched open pit to detect subsurface cavities.

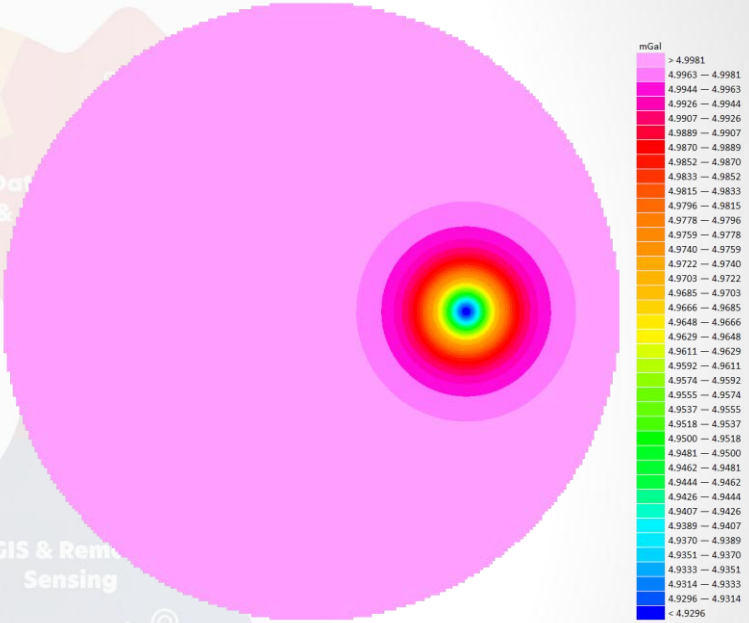


Schematic section of open pit + subsurface cavity

GTC processing in a synthetic example – part 2



Gravity residuals at the pit floor



All corrections applied, except *GTC*.

Anomaly at “A” could easily be missed or disregarded as insignificant.

Thus, the terrain can mask faint signals!

All corrections applied, including *GTC*.

Anomaly is now much clearer and more well-defined.

Thus, *GTC* processing can unmask faint signals!

GTC code — recent developments & improvements

Code enhancements:

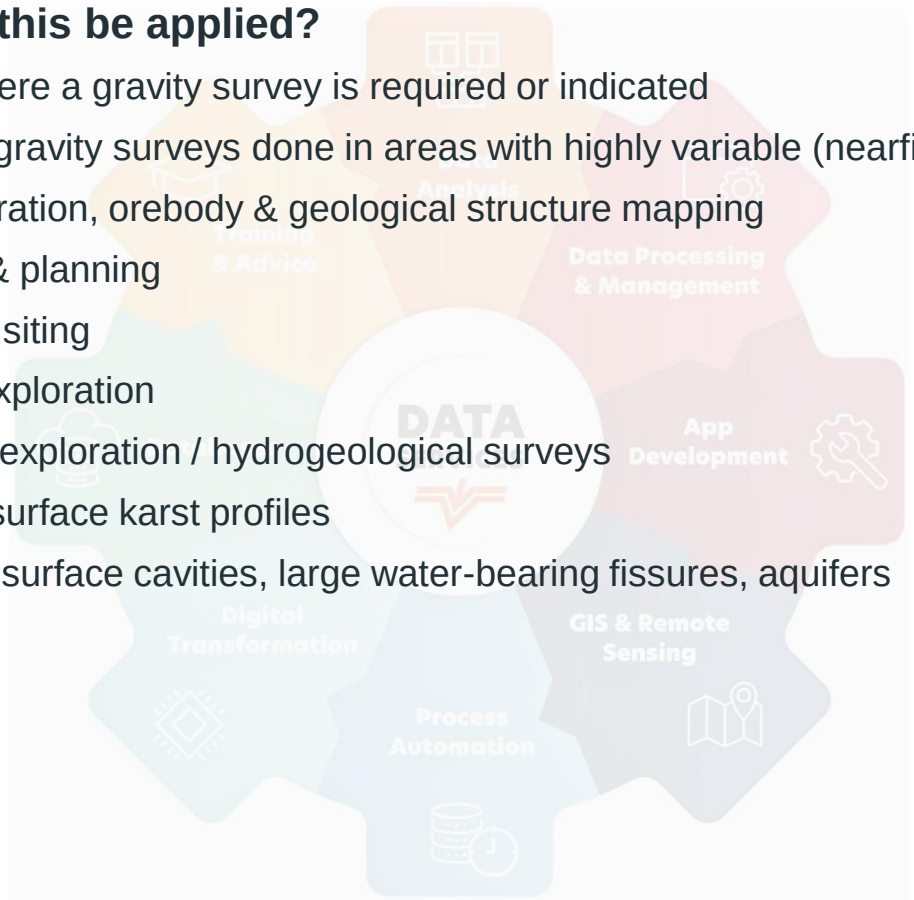
1. Automatic thread reassignment (threads process at different rates on the same PC for various reasons; slow threads are reassigned to faster vCPUs/cores, and vice versa).
2. Fourfold speed increase reading input data files (replacing library code with direct Windows API calls).
3. Additional library code replacements of trigonometric functions for faster processing.

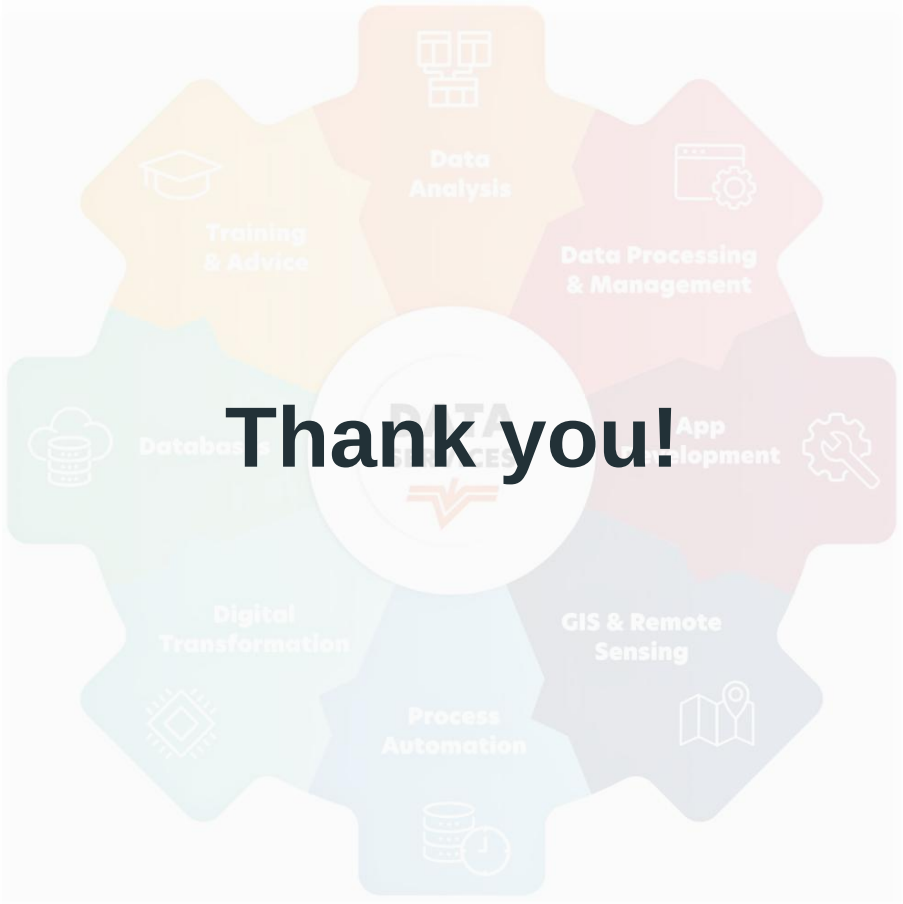
Four support codes:

1. Best-fit reconciling of survey area & DTM point elevations (a common problem due to different datums, measurement methods & dates).
2. Geometrical statistics for each gravity station of the group of DTM points that lie within a certain distance – say, 100 m – of each station (useful for identifying stations for which GTC calculations could be problematic – e.g., DTM points that are too close and have a large elevation difference).
3. Crash recovery program – occasional sudden shutdown of high-spec PCs due to CPU overheating after running for hours at near-100% (recovery program trims trailing partial writes from the output files and corrects / updates the job config INI file accordingly).
4. Assistant app for deploying GTC processing across multiple PCs (code will take a list of target PCs with their respective computational capabilities and assign processing such that expected completion times are all equal).

Where can/should this be applied?

- Anywhere where a gravity survey is required or indicated
- Especially to gravity surveys done in areas with highly variable (nearfield) topography
- Mineral exploration, orebody & geological structure mapping
- Mine design & planning
- Infrastructure siting
- Oil and gas exploration
- Groundwater exploration / hydrogeological surveys
- Mapping subsurface karst profiles
- Detecting subsurface cavities, large water-bearing fissures, aquifers





Thank you!