**Advanced Surveying Techniques for Measuring the Marathon Course**

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**Marathon Course**
- Unlike track races that follow a standardised construction, road races vary greatly.
- Marathon times are referred to as "world best" times not "world records".
- The IAAF (International Association of Athletics Federation) emphasises the requirement of producing "accurate" courses that are at least the stated distance.

**Current IAAF Regulations**
- IAAF rule 165: "the course shall be measured along the shortest possible route (SPR) that a competitor could follow within the section of the road".

**Measurement Procedures**
- The "lay-out" procedure uses the SCPF - short course prevention factor - equal to 1:1000, which guarantees that the actual length is not less than the advertised course length.
- The "validation" process determines and certifies the true length of the course.
- The uncertainty to determine the true length should not exceed 0.1% of the distance of the course (IAAF rule 240.3).

**Measurement Techniques**
- IAAF does not enforce any specific technique; however, the preferred method is the "calibrated bicycle".
- The wheel revolution counter is called the Jones-Oerth (JO) counter (1990).
- The number of revolutions of the bicycle wheel needed to cover the course are compared to the number of revolutions needed to cover a standard calibration course.

**Steps in Measuring the Course**
- A calibration course of 300-500m is laid out. The measurement may be performed using steel tape, EDM or GPS.
- The calibration of the bicycle over the course defines the "working constant" = number of counts/km x 1.001.
- The full racecourse is measured following the SPR (tentative start and finish marks).
**Steps in Measuring the Course (cont’d)**

- A recalibration of the bicycle is performed and a “constant of the day” is calculated
- The measured distance of the race course is calculated using the “constant of the day” (< 0.8% difference)
- When differences between the measured course and desired length exist, additions are added to the course

**Course Measurement Experiment**

- Test site of a typical non-linear course of length ~0.5km
- Course was selected on ring road of the university campus

**Conventional Surveying**

- The SPR was laid out using 39 HILTI nails
- The course was measured independently using a 50m steel tape and a Leica TC1800 total station (±2mm ±2ppm)
- Difference of 29mm between the two computations (not significant at 95%)

**Bicycle Method**

- A calibration baseline of 300m was measured using GPS receivers and a steel tape
- The cyclist performed two laps of the road course (difference <0.8%)
- Mean of laps differs from distance measured by total station (1.99m) and tape (2.02m)
- The use of SCPF factor of 0.1% was incorporated

**Terrestrial Laser Scanning**

- The Riegl LMS-Z360 scanner was used (FOV 90º x 360º)
- 3 scans were taken at angular resolution of 120/mdeg (~ 15 million points)
- Retroreflector targets positioned over the HILTI nails

**Point Clouds**

- Processing of laser scanner data with propriety software
- Decimation of data at 10cm
- Georeferencing of the registered data to the local system (RMS ~ 3-8cm)
Surface Model

- Textured Surface
- Registered point cloud

Short Possible Route
- Digitisation of the SPR on the surface model
- Total distance of SPR is measured in 3D (i.e. slope) and not onto the plane

Moving Platform for Rapid Documentation
- Imaging Sensor Z210
- Automatic extraction of features (e.g. curbs)
- Mississippi DOT, USA

Summary
- The bicycle method provides a single value of the distance and no permanent record of the traversed path
- Disadvantage of method is lack of repeatability
- GPS attached to a bicycle is not practical because of obstructed line-of-sight
- Standard surveying is extremely cumbersome for non-linear routes

Summary (cont’d)
- Terrestrial laser scanning provides a permanent 3D record of the road course and easily defined SPR
- Disadvantage of method is the slow set-up of instrument
- Use of mobile survey platform allows for fast data acquisition