Building Your Magnetic Field Mapper with LEGO®

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Magnetics 2018
Hall field mappers: (from Magnetics 2007 presentation)

- **Need:**
  - 3-Axis Hall sensor or array
  - Positioning jig
  - Temperature control
  - Calibration

- **Get:**
  - 3 components of \( B \)
  - Point-sampled
  - Low to medium precision
Hall field mappers today: Turn-key solutions

Senis MMS-1A-RS (www.senis.ch)  Magcam Combi Scanner (www.magcam.com)
Oldest turn-key field mapping system:
Metrolab NMR Magnetic Field Camera

1992

Today
Another example:
Metrolab Hall Magnetic Camera
(Magnetics 2017 presentation)

Sensor disc – Metrolab
Field mapper – FZ Jülich
Barriers to entry

- Cost (~ 50 - 100 k$)
- Up-front choices: (c.f. Magnetics 2007)
  - Use: R&D, production, field service?
  - Measurement: field components, total field, integral, gradient?
  - Field: strength, uniformity, AC/DC, stability?
- Precision: 10% or 10 ppm?
- Environment: vacuum, cryogenic?
- Positioning: access, range, precision, reproducibility?
- Speed: cost, external error sources, human error?
- …
Goal: reduce barriers to entry

- Iterative design:
  - Start small
  - Explore
  - Test
  - Validate
  - Demonstrate
  - Grow

- Low cost of entry
Concept: modular field mapper

- Magnetic field measurement: network of small, independent, flexible, low-cost sensor modules
- Mechanical positioning: easily reconfigurable, expandable, little mechanical expertise
Realization: MV2Lego™

Bricks
(standard 2x4 studs top/bottom, 3 lateral holes for Technics axles)

“Super-Hub”
(synchronization, non-magnetic connectors)
MV2Lego™: Demo
MV2Lego™ Software in Action
Why LEGO?

- Modularity
- Variety of elements (including Technic and Mindstorms)
- Availability
- Familiarity
- Cost
- Mechanical precision

https://www.cailliau.org/Alphabetical/L/Lego/Dimensions/General%20Considerations/
LEGO gallery

Technic

Mindstorms

A devotee and his project

https://www.youtube.com/watch?v=gsPTgKrJX8A
My personal favorite:
World-champion Rubik’s Cube Solver

https://www.youtube.com/watch?v=staapsj3eRQ
Why not wireless?

- Complexity, size, cost: antenna, comm. chip, battery, charging system, firmware, more powerful μ-processor, …
- RF interference (e.g. MRI scanners)
- Ferromagnetic material in components
MV2Lego™: key figures

- Magnetometry:
  - **Calibrated**
  - Measurement ranges: 0.1, 0.3, 1, 3, 10, 30 T
  - Resolution: 14, 15, 16, 16+ bits
  - Sample rate: ≤ 3 kHz
  - Active volume: 200x200x10 µm
  - Triggered acquisition

- Modularity:
  - Magnetometry:
    - Up to 12 modules
    - Synchronized trigger
  - Mechanical:
    - Equivalent to 3 2x4 bricks
    - 3 Technic axle holes

- Size:
  32 x 16 x 29 mm

- Cost:
  - ??? ~ 5 k$ per unit

- Schedule:
  - ??? End of 2018
Early results: mapping of remote magnetic navigation system

J. Pascal, F. Yeung – FHNW-HLS-IMA
Early results: mapping of remote magnetic navigation system

J. Pascal, F. Yeung – FHNW-HLS-IMA
Early results: Same sensors reconfigured to measure MRI gradients

Conclusions

- Flexible, expandable magnetic field mapping system
- DC as well as AC fields
- Not a universal solution: constraints of mechanics, magnetometers
- Can be used with non-LEGO positioning systems
- Low cost of entry
- Cost of maximal system similar to existing mapping systems