GaussStarter:
Prototyping Analog Hall-Sensor Grids with Breadboards

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ABSTRACT

This work presents *GaussStarter*, a pluggable and tileable analog Hall-sensor grid module for easy and scalable breadboard prototyping. In terms of ease-of-use, the graspable units allow users to easily plug them on or remove them from a breadboard. In terms of scalability, tiling the units on the breadboard can easily expand the sensing area. A software development kit is also provided for designing applications based on this hardware module.

Author Keywords

Analog Hall-Sensor Grid, Breadboard, GaussSense

ACM Classification Keywords

H.5.2. Information Interfaces and Presentation (e.g. HCI): User Interfaces

INTRODUCTION

Camera-based object tracking techniques have been applied for years, but the thin-film magnetic field camera, GaussSense [4], is indeed an unusual one. With a dense grid of Hall-sensors deployed, GaussSense functions as a short-depth camera that tracks the 3D position and orientation [3], shape [2], and ID [5] of multiple magnetic objects nearby it by seeing their magnetic field distribution; GaussSense also functions as an X-ray camera that sees the magnetic objects coated in non-ferrous materials and/or expressive forms, through users' hands. Therefore, GaussSense can be attached to the back of prevalent portable displays for TUI design, or attached to human body for on-body input [1]. Though the design and application spaces have been well-explored, there is still one fundamental challenge remains: *How to build an analog Hall-sensor grid from scratch?*

The challenge motivates us to consider the breadboard, a common construction base for prototyping of electronics. Because prototyping electronics with a breadboard does not require soldering, it is easy to use for creating temporary prototypes and experimenting circuit designs with electronic components; the structure of the breadboard also supports making tidy circuits, which is essential for an effective sensor grid.
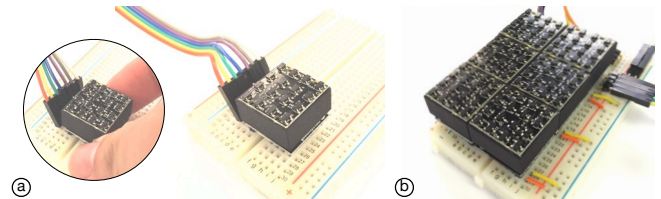
Figure 1. (a) *GaussStarter* is an analog Hall-sensor grid module that is compatible with the breadboard. (b) Tiling the modules can easily extend the sensing area.
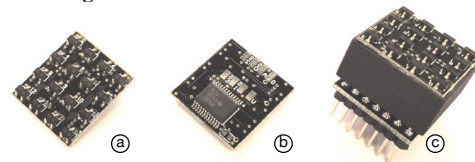

Figure 2. Hardware design of *GaussStarter*. (a) Top view and (b) bottom view of the Hall-sensor grid. (c) Overview of the assembled module.

However, the major limitation of the breadboard is its capacity, since makers can only build a relatively sparse sensor grid because they can only plug one sensor to each 5-hole row. A sparse sensor grid only supports tracking relatively large magnets with relatively low resolution, and thus limits the applications.

GAUSSSTARTER: GAUSSSENSE FOR BREADBOARD

This work introduces *GaussStarter* (Figure 1), a breadboard-compatible, tileable analog Hall-sensor grid module for breadboard prototyping. In terms of *breadboard-compatible*, each 2cm-width×2cm-height×1cm-thick module consists of a grid of 4×4=16 Winson WSH136 analog Hall-sensors[1] and an 1-to-16 multiplexer (Figure 2), which reduces each module's I/O pin to 7: *VCC*, *ground*, 4 *selection inputs* and *1 analog output*. With the cuboid form and the 7 standard 1" pitch Dupont male connector at the bottom, users can easily grasp and plug the module to a breadboard. In terms of *tileable*, the 4×4 sensor grid that is located in the center of each module allows users to easily expand the sensing area by tiling them on the breadboard, which also aligns them physically. Although a 0.8mm gap may occurs between each unit, the effect on signal processing is negligible. This novel hardware module, therefore, allows novice users to prototype interactive devices with an analog Hall-sensor grid easily.

WORKFLOW: USING THE GAUSSSTARTER

1. Wire the circuit with breadboard: Users power up the sensor grid by connecting the *VCC* and *ground* pins between a micro-controller and the GaussStarter module, and then

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[1]http://www.winson.com.tw/
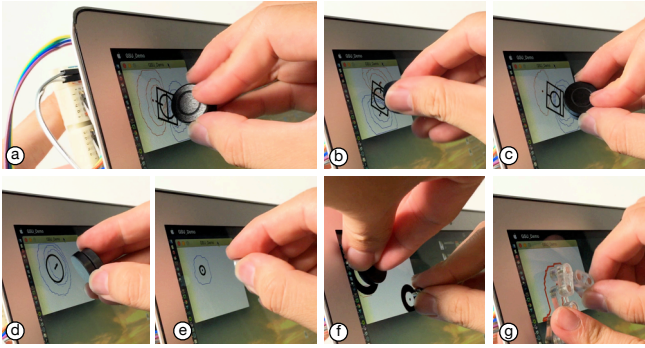
Figure 3. (a) The gridded GaussStarters attached to the back of a display track the (b) roll, (c) pitch, (d) pitch and yaw, (e) hover height of a magnetic token, (f) the ID of different magnetic tokens, and (g) the shape of a magnetic construction.

connect the digital output pins and the analog input pin of the micro-controller to the four *selection* pins and the *analog output* pin of each module, respectively. Additional multiplexers are useful if the amount of modules is more than the number of analog pins provided by the micro-controller. Figure 1(b) shows utilizing the structures of the breadboard effectively reduces the clutter of wiring.

2. Upload the firmware to the micro-controller: The signal processing firmware uploaded to the micro-controller designates the digital output pins and the analog input pin while initialization. Then, the firmware switches the selection pins to get all sensor data from the sensor grid, and then records the collected data as an integer array. Once requested, the firmware sends the data to the client software via serial connection.

3. Build software applications with GaussSense SDK: The *GaussSense SDK*[2] is available online for software application developers. In the software applications, users initialize the gridded GaussStarters with the height and width of the grid as well as the name of the serial port information provided. For example, a 3×2 GaussStarter grid to *COM*3 can be initialized by the following method:

```
GaussSense gs = new GaussSense(3,2,COM3);
```

To refresh the sensor data, users obtain the target magnetic field image in an array of sensor data with the height, width, and the up-sampling rate provided. For example, a $600 \times 400px$ magnetic field image that is up-sampled using the bicubic interpolation in a sample rate of 5 can be obtained by the following method:

```
float[][] Image = getUpsampledImage(600,400,5);
```

Figure 3 shows the gridded GaussStarters attached to the back of a display device can sense magnetic objects on and above the display surface. The obtained magnetic-field image is used for extracting the 3D position and orientation of multiple magnetic tokens by applying the feature extraction algorithms introduced in *GaussBits* [3], identifying multiple magnetic objects by extracting the area-intensity profiles as *GaussStones* [5], and extracting the geometry and skeleton of

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[2]http://developers.gausstoys.com/
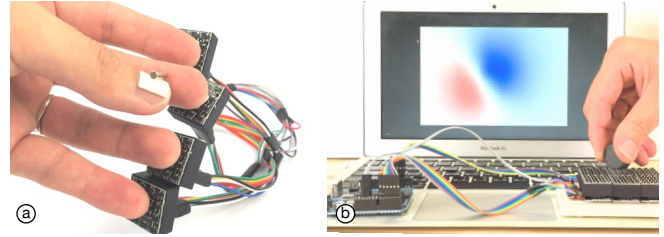
Figure 4. Use *GaussStarter* to prototype (a) wearable input devices, and (b) standalone devices for 3D interactions.

a magnetic construction as *GaussBricks* [2]. The APIs and examples are available online as well.

DISCUSSION AND FUTURE WORK

GaussStarter is an analog Hall-sensor grid module that is compatible with breadboards, thus is easy-to-use and reusable for iterative prototyping. Applying the concept presented in this work is also useful for fabricating the analog Hall-sensor grids in different sizes and resolutions, and the thickness can be further reduced to 2mm or less for more portability [4]. Figure 4 also shows developers can consider using this toolkit for prototyping wearable interactions or standalone devices for high-degree-of-freedom interactions with ease. The proposed hardware module and software toolkit have been tried in several design workshops and used by a few artists and programmers. Future work will gather the results and user feedback to inform researchers and practitioners the novel uses of this technology.

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