Hillcrest Labs

Modern User Experiences Enabled by Motion Technology

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HMDs – A History of Specialized Applications

Military Aviation

1984
The Integrated Helmet and Display Sight System (IHADSS), 1984 Version

2000
The Integrated Helmet and Display Sight System (IHADSS), 2000 Version

Today
Helmet-Mounted Display System for the F-35 Lightning II Joint Strike Fighter

Engineering / Industrial

1989
The Virtual Interactive Environment Workstation (VIEW)

1994
The “Flight Helmet”

today
SENSICS zSight SXGA
Emerging Mass Markets

Consumer, Public Safety, and Medical

Google Glass
Avegant Glyph
Sony HMZ-T3W
Recon-Zeal Transcend
Kopin / Verizon Golden-i
Epson Moverio BT-100
Oculus Rift
Consumer, Public Safety, and Medical HMDs

For Entertainment
Gaming – Portable Display

For Real-Time Sports

For Smart Devices

For Hands-Free Information Access
Leading to Healthy Growth?

Figure: Transition and Forecast on Size of Global HMD Market, Yano Research Institute (Japan), August 2013

As with any emerging market, shipment volumes are hard to predict.
Head tracking is the foundational use of motion in HMDs. It can be used for navigating menus and documents in AR applications.

Latency is a critical user experience performance factor for HMDs.

Heading, position and velocity are particularly important for AR applications to identify exactly where a user is or what they are looking at.

Understanding the context of the user is key to facilitating interactions.
Latency: The Enemy of Immersive VR

- Latency is the delay between a user’s actions and the user’s perception of a corresponding action initiated by the system.
- In HMDs, the user’s action is usually a head movement, and the corresponding action is the image updating on the screen.
- Since real world ‘latency’ is effectively zero, our goal must be to have latency which is perceived as zero.

Latency in HMD systems can severely impact the immersive experience, damage enjoyment and contribute to motion sickness.
What Does the Perception of Zero Latency Mean?

HMD’s for VR based applications must create the perception of reality. Therefore, the real latency in these systems must get as close to the 20ms instantaneous threshold as possible.
Motion Sickness in Virtual Reality HMDs

- A major contributor to this is jumpy or jittery movements of the immersive world viewed inside the HMD
- Motion discontinuities result from the difference between the ‘truth’, the actual HMD movement, and the ‘estimate’, the motion derived from inertial sensors
- Motion discontinuities can result when these differences are resolved

HMD solutions need to make the proper trade off between ‘smoothness’ of movement and accuracy of movement for the specific application
Introducing the BNO070

- Application Specific Sensor Node optimized for the HMD market

- Result of a collaboration between Bosch Sensortec and Hillcrest Laboratories
  - Uses Bosch BNO ‘absolute orientation’ system in package (SIP), integrating sensors and MCU
  - Uses Hillcrest SH-1 sensor hub software

- Suitable for AR and VR applications
Hillcrest SH-1 Sensor Hub Software Architecture

**Host / AP**
- Sensor HAL (libsensors)
- \(^2\text{C} \) Kernel Driver
- Freespace MotionElements*

**HID / \(^2\text{C}\)**

**BNO-070**
- **MotionEngine™ Fusion and Calibration**
  - Report Mgmt.
  - Sensor Control
  - Power Mgmt.
  - Messaging
  - Thresholding
- **‘Always-On’ Functions**
- **Sensor Drivers**

**MCU: 32-bit ARM Cortex M0+**

**Sensors**
- 12-Bit Accel
- 16-Bit Gyro
- 3-Axis Mag

*MotionElements are optional add-on features.*
# BNO 070 Technical data

<table>
<thead>
<tr>
<th>Features</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>9-axis sensor fusion</td>
<td>Size</td>
</tr>
<tr>
<td>Android 4.4 compliant</td>
<td>5.2 x 3.8 x 1.1 mm³</td>
</tr>
<tr>
<td>Automatic calibration</td>
<td>MCU</td>
</tr>
<tr>
<td>Immune to magnetic distortion</td>
<td>32-bit ARM Cortex M0+</td>
</tr>
<tr>
<td>Intelligent power management modes</td>
<td>9-axis Fusion Rate &lt;=250Hz</td>
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<tr>
<td>Step Counter</td>
<td>Static</td>
</tr>
<tr>
<td>Stability Detection</td>
<td>Accuracy: 1.5°</td>
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<tr>
<td>Tap Detection</td>
<td>Heading: 1.0°</td>
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<tr>
<td>Shake Detection</td>
<td>Non-Heading: 1.0°</td>
</tr>
<tr>
<td>Activity Monitoring</td>
<td>Dynamic</td>
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<tr>
<td></td>
<td>Accuracy: 1.5°</td>
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Thank You!

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