OMMO - 3D Tracking Technologies Comparison

1. Introduction

Ommo's patented 3D tracking technology is the world's first permanent magnet approach that combines submillimeter precision with unrivaled convenience and versatility.

From medical navigation to robotic automation to human-machine interfaces, Ommo takes 3D tracking to the next level, to be the foundation of digital transformation it is meant to be.

2. Overview Chart

TRACKING SYSTEM	System Composition	Advantages	Disadvantages
Permanent Magnet ommo	· Permanent magnet based signal generator and tracking sensors (active)	· Precision <1mm · No line of sight required · No calibration required · The smallest wireless capable system · Flexible sensor arrangement · Resistant to conductive metal	· Susceptible to ferromagnetic metals (can be compensated) · Limited range
Optical (passive marker)	· Cameras and reflective markers	· Precision <1mm · Wireless capable · Passive marker does not require power	· Generally requires multiple markers · Limited tracking space · Requires line of sight · Sensitive to lighting condition · Rigid tool tracking only · Marker mounting/embedding can be difficult · Can only track limited number of sensors
Optical (active marker)	· Cameras and infrared emitting diodes	· Precision <1mm · Wireless capable · Higher range than passive marker	· Generally requires multiple markers · Limited tracking space · Requires line of sight · Sensitive to lighting condition · Rigid tool tracking only · Marker mounting/embedding can be difficult · Can only track limited number of sensors
Optical (markerless)	· Cameras based on image segmentation	· Wireless capable · No sensor/marker required · Contextual information · Versatile	· High noise · Limited tracking space · Requires line of sight · Sensitive to lighting condition · Must pre-define tracked object · High post-processing cost
Electromagnetic	· Electromagnetic emitter antenna (AC coil) and tracking sensors (active)	· Precision <1mm · No line of sight required · Flexible sensor arrangement	· Limited range · Limited wireless capability · Susceptible to conductive and/or ferromagnetic metals · High power consumption · Requires specialized processing · Can only track limited number of sensors
Mechanical	· Relative orientation and distance of mechanical elements	· Precision <0.5mm · Robust and reliable	· Cumbersome and restricted movement · Larger tracking range requires larger mechanical fixtures · Requires frequent recalibration · Relative orientation only · Very expensive for high end use
Inertial	· IMU (inertial measurement unit) made of accelerometers and gyroscopes	· Portable · Wireless capable · Fast calibration	· Low precision · Only tracks relative movement · Sensor drift over time · Must avoid physical impact

3. Optical Tracking

Optical tracking systems are the most commonly available options when it comes to 3D tracking. While they are precise in ideal conditions, their precision is subject to environmental factors such as lighting conditions and tracking angles of the cameras.

The most fundamental limitation, however, is that it requires a clear line of sight. This means the object being tracked must be rigid and straight tools that are artificially extended in order to stay within the camera's field of view. Such modifications can get in the way, seriously hampering the dexterity of the surgeons.

4. Electromagnet (EM) Based Tracking

As an alternative, an electromagnet-based approach using an AC coil was developed in the 1970s. By modulating the current at a high frequency, the coil actively generates a variable magnetic field that can be used for 3D tracking. It does not require a line of sight, except for conductive/ferromagnetic materials, due to the penetrative property of the magnetic field, which is its most prominent advantage.

The current modulation process, however, requires a complex signal processing device that makes the setup/operation complex and drives up the cost. It is also very power-hungry, requiring a high-power electricity source. But the most significant limitation is its susceptibility to electromagnetic interference (EMI) caused by nearby conductive/ferromagnetic materials. Because the EMI affects the coils at its core, the generated magnetic field can become significantly distorted.

The only remedies to this critical weakness have been to either remove all conductive/ferromagnetic objects from the operating environment or to perform fusion tracking with another system (such as optical) that is unaffected by the EMI. But neither of these is very effective or convenient, which has prevented the EM approach from becoming more mainstream.

5. Mechanical

Mechanical systems were among the first tracking systems ever used. They are based on the direct measurement of the object's dimension and orientation. These systems are effective because external factors such as lighting or EMI cannot affect the measurement. In addition, it is robust and reliable when properly calibrated, allowing speedy operation.

Since it is rigid, mechanical systems are only suitable for very specific movements and use cases. It is naturally heavy and cumbersome, making it difficult and expensive to manufacture, especially for high-precision applications. Because all of the components need to be properly aligned, the system requires frequent calibration/maintenance, which is costly and time-consuming.

6. Inertial

Inertial tracking devices are based on accelerometers and gyroscopes. The sensor is placed on the object to measure its acceleration and orientation. Inertial systems are considered portable and nimble enough to be used in practically any environment.

But because it is estimating the position based on movement and not actually measuring in absolute coordinates, the calculations introduce a cumulative error that results in sensor drift over time. The sensor will interpret any physical impact as a sudden acceleration in the opposite direction, resulting in unintended spikes in measurements.

Due to its limitations, the inertial system is not considered a high-precision tracking system and is usually used as part of sensor fusion models to improve other systems' performances.

7. Permanent Magnet-Based Tracking

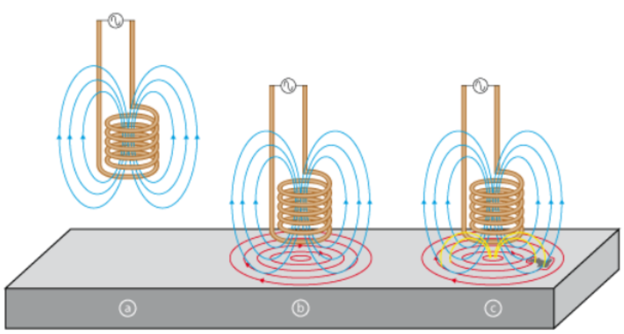
With the previously shown advantages and disadvantages of various 3D tracking technologies in mind, we decided to develop a novel solution. After trying both the available and theoretically possible solutions, we chose to pursue the permanent magnet approach.

Here were the benefits and challenges of the permanent magnet approach we considered:

- **Benefits**
  - Retains the benefit of an EM system that does not require line of sight
  - The magnetic field does not need to be actively generated, making it power efficient
  - Can be compact and affordable since it does not require a separate signal processing device
  - The source of the magnetic field is unaffected by EMI, so it is naturally resistant and also allows algorithmic distortion compensation (pictured below)
- **Challenges**
  - Creating a variable magnetic signal for 3D tracking using a permanent magnet is difficult and was not fully explored in the past due to mechanical complexity
  - Difficulty in processing the low frequency signal generated while achieving high precision
  - Ensuring mass producibility and cost-effectiveness using mostly off-the-shelf parts with low tolerances
  - The symmetrical nature of the magnetic field ensures consistent/uniform 3D tracking, but it also leads to ambiguities in sensor output when using a single sensor, which must be resolved in order to minimize the sensor form factor

Many attempts were made in the past by researchers to use permanent magnets for 3D tracking, but they failed to overcome the challenges, so it was never successfully commercialized.

TRADITIONAL EM



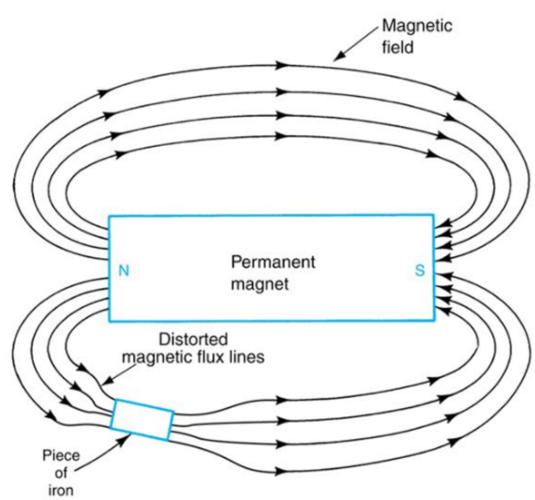
a) Alternating current generates a primary magnetic field

b) Eddy current is induced in the nearby conductive material

c) The eddy current causes a secondary magnetic field that opposes the primary magnetic field

The source is affected and generates a distorted magnetic field.

PERMANENT MAGNET



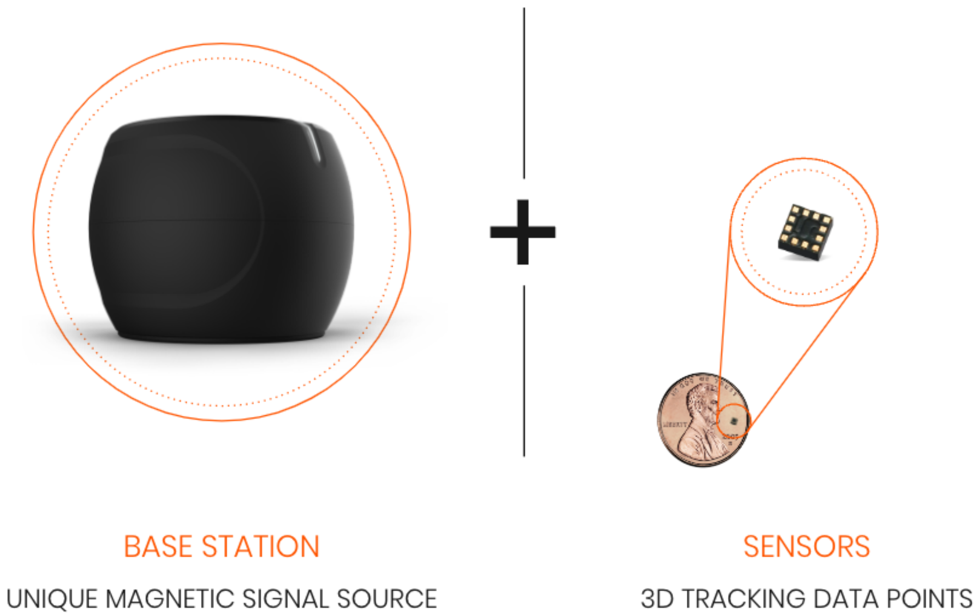
The source is unaffected even when the field is distorted around a conductive material. Because we characterize each magnet we always know what the undistorted magnetic field looks like, allowing us to algorithmically compensate for the distortion.

8. Ommo’s Solution

Through years of R&D, Ommo has developed a permanent magnet-based approach that overcomes the fundamental limitations of legacy solutions while addressing the challenges mentioned above.

Combining our proprietary algorithm and patented mechanical design, Ommo’s system produces a unique low-frequency magnetic signal that allows a single 3-axis magnetic sensor to resolve its individual position and orientation without any ambiguity.

Consisting of just a base station and sensors, the streamlined 2-part system is easy to deploy, does not require any user calibration, and offers nearly unlimited customizations. In the medical field, it can be deployed for as little as 10% of the cost compared to optical or EM solutions.



9. Unique Advantages of Ommo

- **Independent Tracking**
  - Each individual sensor’s 6DOF information is acquired independently
  - The system does not require multiple sensors for a single data point
- **Absolute Positioning**
  - 6DOF information is absolute and is not calculated based on movements
  - Even the static sensor provides the most accurate information without any sensor drift issue
- **No Line-of-sight Needed**
  - Permanent magnet’s magnetic field penetrates most materials
  - Sensors are able to resolve its 6DOF information even when with occlusions present
- **Power Efficient**
  - The magnetic field is always present and does not need to be actively generated
  - Both the base station and sensors are able to operate on a smallbattery
- **Scalable Architecture**
  - A single base station can track an unlimited number of sensors
  - Adding sensors only require a linear increment in data bandwidth
- **Submillimeter Precision**
  - Up to 0.1 mm in precision, which is less than the thickness of a human hair
  - Submillimeter precision within its operating range of 75 cm radius
- **No Calibration Required**
  - The system does not require additional calibration by users
  - Powering on and off the system does not hinder acquiring of sensors’ 6DOF info
- **Resists EM Interference**
  - A permanent magnet is inherently more robust against interference than EM systems
  - Static and dynamic distortion compensation can be done algorithmically
- **Wireless Ready**
  - Smallest wireless form factor of any 3D tracking system that is smaller than a penny
  - Proprietary wireless protocol is auto-provisioned and scales automatically
- **Embeddable Micro Sensors**
  - Magnetometers are as small as 0.8mm and even smallers ones are in development
  - The sensors can be embedded directly into the surgical tools for the most critical operations