Logitech Marble™ Optical Technology White Paper

Historical backgrounder:

The first computer mouse, developed in 1963, was completely mechanical. The ball moved small pivots, which were attached to rheostats. In addition to the separate power supply needed by the mouse, the innumerable small components and the low resolution, this type of mouse technology had several more drawbacks, including the wearing and grinding down of parts and sluggish mechanical reactions.

In 1983, Logitech revolutionized the computer mouse market with the use of optomechanical technology. From then on, mouse movements were no longer measured by means of mechanical resistance but were registered with the help of an optomechanical system. In an optomechanical system, the ball sets two small pivots in motion, which record vertical and horizontal movements. Each of the pivots is linked to a perforated disk, which turns in accordance with the movement of the mouse. The disks have narrow slits. Two photoelectric barrier units follow the motions and determine the exact changes in the position of the mouse. This technology permits a higher degree of precision, is cheaper and is less prone to attrition than the former purely mechanical design.

Unfortunately even optomechanical technology could not totally eliminate such drawbacks as wear and tear, and sensitivity to dirt and dust particles. Although the optomechanical mouse is the most common mouse technology in general use, attrition and dirt still frequently cause the computer mouse to move imprecisely. This may result in slow and "jumpy" cursor movements.

The only way to avoid the effects of wear and tear and the concomitant bad tracking lay in a design, in which - with the exception of the mouse ball itself - no further cogs were turned and the ball did not touch any other components. Users were demanding a design without mechanical components as early as 1988 when the first trackballs came onto the market. A project team, consisting of members from the Polytechnical University of Lausanne (EPFL), the CSEM (Centre Suisse d'Electronique et de

Microtechnique) in Neuchatel, the Commission for the Promotion of Scientific Research (KWF) and Logitech researched the possibilities of a purely optoelectronic solution, whereby a sensor would register the movements of the mouse without coming into contact with the ball and without employing mechanical components.

Marble Optical Technology History

1990-1991	First ideas of an image displacement detection device, experiments with a camera viewing a printed pattern as a student project at EPFL.
November 1992	Integration of 3 first chips to test various technologies
April 1993	Marble 4 chip, implementing the best of the 3 previous
October 1993	Marble 5.0 Introduction of differential light measurement
January 1994	Marble 5.1 Bug corrections
July 1994	Marble 5.2 Final production version

The outcome of more than four years` research resulted in a revolutionary technology modeled after a phenomena occurring in nature, known as Marble Optical Technology. In practice, this has meant the development of intelligent microsystems, which function in a similar way to the way our eye functions. Marble Optical Technology was "biologically inspired". The principle of Marble Optical Technology is based on the optical measurement of movement, whereby a camera measures the shift of a picture and evaluates it. The entire evaluation takes place in the sensor, which is essentially the heart of the system.

With the help of Marble Optical Technology, input devices can function completely optically and therefore without wear and tear. Dust or dirt no longer impairs current generations of Logitech trackball products.

By mid 1999, the first notebooks using the new Marble Optical Technology were made available from Dell, Compaq and Matsushita. In the retail channel Logitech provides a range of optical trackball products. They are the Logitech Marble Mouse, TrackMan Marble Wheel, TrackMan Marble FX and Cordless TrackMan Wheel.

Optimechanical versus Marble Optical Technology: A comparison

The mouse is like the hand of the computer

Point-and-click devices, such as mice and trackballs are well known personal computer and workstation peripherals. Such pointing devices allow rapid location of the cursor on the screen and are, with the keyboard and the monitor, one of the main channels of communication between the human and the computer. The mouse is the most

commonly found form factor, but trackballs are a derivative, particularly appreciated when specific factors such as limited space, additional precision or improved comfort, from an alternative hand position are needed. Trackballs are a specific breed of mice that are most appreciated by the advanced user who requires more from a pointing device.

The conventional mouse is a very complex optomechanical device

With a mouse the user controls the cursor by moving the device over a reference surface; the cursor is displaced proportionally to this distance. Today, almost all mice are built around an optomechanical technology where a ball, which is on the underside of the mouse, picks up movement by rolling over the reference surface when the mouse is moved. The ball is in contact with a pair of shaft encoders which each include an encoding wheel. As the ball moves, the shaft encoders and their wheels rotate accordingly. Two Light Emitting Diodes (LED) are positioned on one side of each wheel while two phototransistors are positioned at the opposite side. When the encoding wheels are rotated, the light is pulsed by the slit of the wheel and the phototransistors on the opposite side convert these light pulses into electrical signals. These two subsystems shaft/wheel, LEDs and phototransistors are required to detect movement on both the X and Y axis. The optomechanical operation of a trackball is similar, with certain structural differences. The device remains stationary while the user rotates the ball with the thumb, fingers or palm of the hand.

Mechanical systems are sensitive to all kind of dust and dirt

The mechanical elements- rollers, shafts, wheels - put a limit on the useful life of the device. In particular trackballs because the ball faces up and collects dust and dirt. If the ball and rollers are not cleaned regularly, heavy users will soon find that dust, grease and contamination have substantially degraded the performances of their device:

- Dust particles can get stuck to the ball and block the shafts. The ball can be moved for inches without any cursor movement.

- When moving a non-optical trackball ball, the fingers leave a greasy layer all around the ball that contains all kind of chemicals including acids. Metallic parts of the mechanism get contaminated and then rust.

- As with all mechanical systems, non-optical mice and trackballs wear fast and their precision is reduced substantially with time.

- Given that the movement is detected via two rollers, one roller is always slipping when the ball is moved. This creates friction and a driving effect that makes it more difficult to move the ball.

Marble Optical Technology brings unmatched reliability, performance and accuracy

The Marble Optical Technology replaces all mechanical moving parts with an electronic detection of the ball movement. As a result, Marble based devices retain their high standard of reliability, performance and accuracy during all their life.

The ball of Marble-based devices has a random pattern of black dots printed on a red background and covered by a protective layer which is transparent to infrared light. The dots can be randomly sized (within a suitable range) and randomly shaped. The color of the dots and background are selected to show an optimum contrast under infrared light. They don't necessarily need to be black on red.

One or more light sources, typically LED's, illuminate a portion of the ball with diffuse light. A portion of that light reflects onto a sensor array comprising a multitude of individual sensor elements that recreate an electronic image of a small area of the ball. A lens focuses on the image of the ball on the array. The overall electronic system acts very much like a camera observing the position of the dots on the surface of the ball.

When the ball is moved, the image of the moving dots is observed by the sensor array. The signals generated are then processed by various analog and digital electronic circuits to track the X and Y dimensions of the movement of the ball.

Marble is to pointing devices what Compact Disk was to audio: *a technological revolution*

With Marble based devices, mechanical parts are no longer required to detect the movement of the ball thus eliminating all problems, limitations and inconveniences linked with the use of mechanical components at source. In the same way that the compact disk has replaced the traditional vinyl record, Marble will obsolete the current optomechanical technology.

Marble devices have been tested with a wide range of contaminants. They are immune to liquid, dust, dirt and grease. They will work even if coffee is spilled on them, or if dust and crumbs penetrate the workings. With Marble, a input device will remain as good as new - precise and reliable for years to come.

III. Marble technology functional description:

Traditional trackballs are very sensitive to dust, due to their mechanical contact between the ball and the displacement encoding devices (rollers). The idea with Marble is to

suppress these and avoid direct contact by observing a patterned ball. When the ball is moved the displacements are extracted from the moving image and passed on to the computer which can in term move the cursor.

Marble system:
When the user rotates the ball of a Marble trackball, the sensor will see a moving image of dots. This image is analyzed and a displacement is computed. The microcontroller in the trackball then transmits this information to the host computer through the cable or by radio transmissions on cordless mouse products. The mouse driver program then draws the cursor on the screen, and passes all information on to the various applications.

Operating principle:
The principle is quite straightforward: The image of a ball is illuminated with two LEDs (Light Emitting Diodes). The image then goes through a lens and is focused on the Marble sensor:

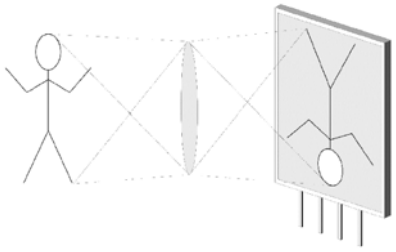

Fig. 1: Principle of image projection

In order to reduce the space required, the optical path can be deviated through a mirror placed onto a custom designed lens:

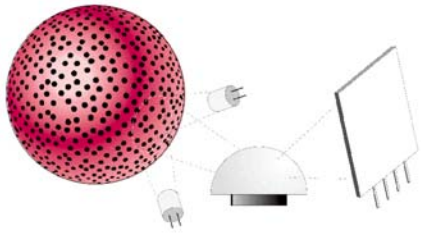

Fig. 2: TrackMan Marble Wheel optical configuration

This image is then regularly sampled 1000 times per second, and between each two successive samples the Marble sensor calculates the shift and returns the new displacement to the microcontroller in the device.

The sensor is composed of 93 small cells working independently as a neural network. Each of them can detect a unitary motion by sharing information with its direct neighbors, quite similarly to how a human eye would operate.

The sensor then computes the average of the displacement returned by all these individual cells and passes this information on to the microprocessor. This collective computation creates a highly reliable system. If any part of the sensor is obstructed because of dirt on the window, a scratch, or any other reason, the result of the collective calculation will be affected by only a very small percentage, without the user noticing anything. This system is very independent of light quantity or uniformity reaching the sensor ball, further increasing the robustness.

Testing:

At the production stage all tracking tests are conducted under conditions that are more severe than what would occurs in real life. Typically the LED light is reduced by half and the supply voltage is lowered to ensure a correct operation and a security margin once shipped.

Marble Optical Technology products:

Today this innovative optical technology is available in all of Logitech's trackball devices. In addition, Logitech has continued to invest in furthering optical technology for mouse products.

These state of the art devices are being made available through retailers, catalogs and distribution. For more information on the Logitech trackball family, visit our web site at www.logitech.com