Low Cost Six-Degree-of-Freedom Input Device Using Wii Remotes

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The Wii Remote

The Wii Remote contains an amazing set of sensing, interaction, and communication systems. Before its release, acquiring an equivalent system in a ready-to-use form would have cost thousands of dollars. Here's what's in it, beyond the buttons:

Camera & Point Tracker

Behind the dark window on the front of the Wii Remote lies its most innovative sensor. This camera can be used to track up to 4 infrared light sources.

Bluetooth Connection

Unlike most game controllers, the Wii Remote can connect wirelessly to most computers without special hardware.

3-Axis Accelerometer

This sensor detects gravity's pull on the Wii Remote, as well as motion imparted by the user.

Force Feedback

A small vibration motor, similar to that used in cellular phones, can provide feedback to users.

Speaker

A small monaural speaker could be used as another way to provide feedback to users. Its protocol is not yet understood.

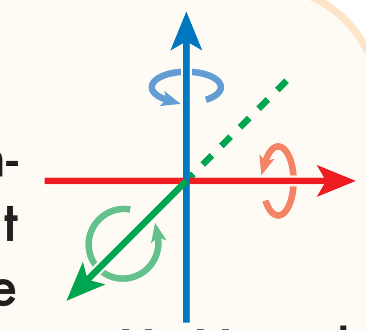
Player LEDs

The four LEDs, normally used to indicate which player a Wii Remote is used by, can each be individually controlled.

Extension Port

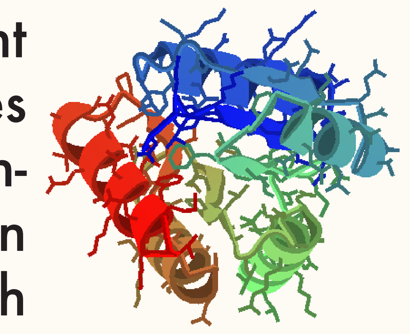
Extension controllers are accessed using the standard I²C bus protocol. Through this port, the Wii Remote can be used to wirelessly connect almost any device to a computer.

Problem:



To provide full control in 3D, an input system needs to have six degrees of freedom: X, Y and Z translation, as well as roll, pitch, and yaw. Existing systems are either unintuitive, have limited range of rotation, or cost many thousands of dollars. The goal of this project is to provide a system that tracks the full position and orientation of a handheld object as it freely moves and rotates through a reasonably-sized capture area, with a parts cost below $200.

Application - BME:



One of the current research challenges in biomolecular engineering is protein folding. While much work has been done using computers to solve these problems, humans can still predict protein folds faster and more accurately. Visualizing and manipulating the protein chains is an inherently 6DOF problem, requiring simultaneous manipulation of position and rotation.

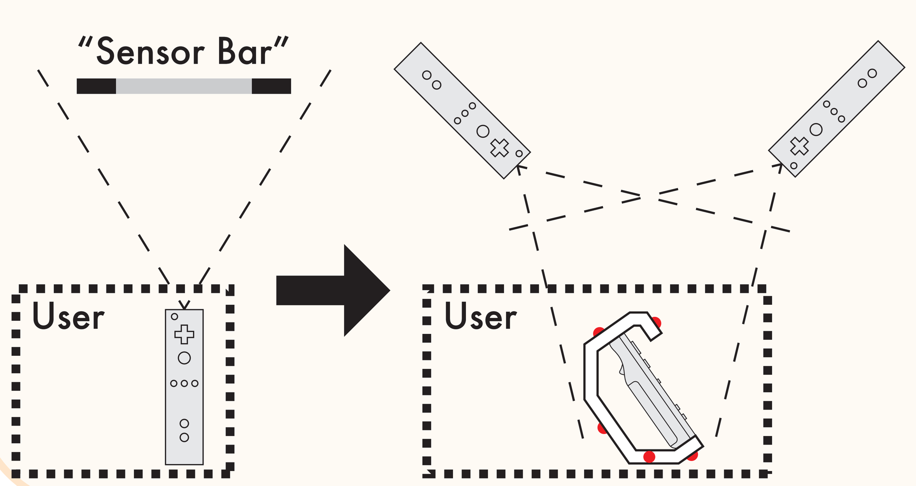
Application - CAD:

Computer aided design software often has to solve the problem of manipulating 3D data using only a 2D input device (a mouse). As a second application, a plug-in for Google SketchUp is being created to allow intuitive camera movement and manipulation of components of a model.

Our System:

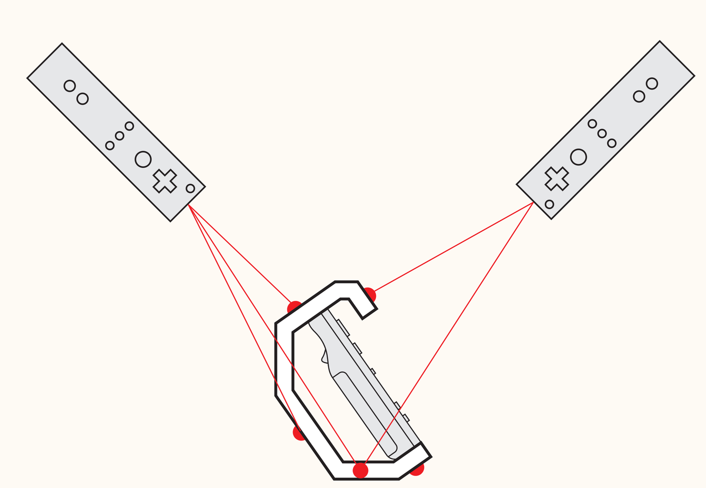
1. Turn it Around

Use fixed Wii Remotes, and place IR sources on a handheld object. This is the opposite of what the Wii does.



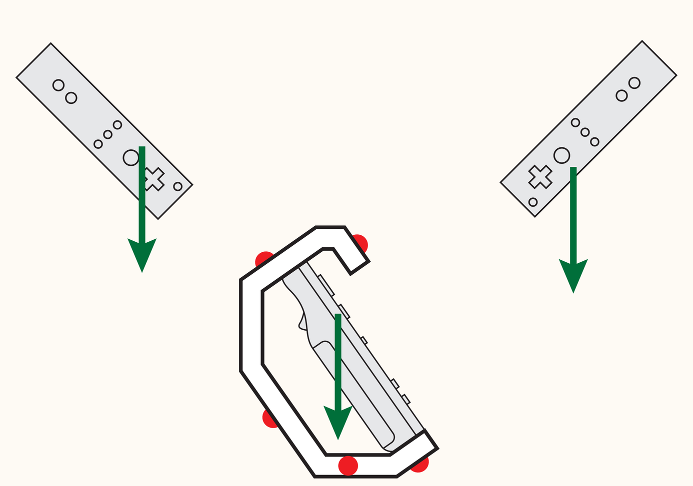
2. Do Some Math

Each remote's camera will report the position of up to four IR sources it sees. The data from the cameras is combined (details below) producing a set of possible poses for the handheld.



3. Gravity Doesn't Suck

The handheld includes a third Wii Remote. At rest accelerometers detect gravity. The correct solution is identified by checking that gravity is in the same direction.



Solving for Pose:

The handheld object has 6 infrared emitters on it. Each of the camera Wii Remotes will only see at most 4 of these at a time, and often only 3.

Using pure parallax to determine the pose of the handheld wouldn't work as you would need both cameras to see the same three points to determine orientation. Instead, a two-phase approach is used.

In cases where the object's pose is unknown, a brute-force pose-from-perspective solve is performed for each camera separately. The results are then searched for similar solutions that agree with each other and gravity.

In cases where the previous state is known, a simple gradient-descent solve is performed. The Wii Remote returns data at 100Hz, so the change between two adjacent frames is small enough that local minima are rarely found. If GD does get stuck in a local minima, the first approach is used.