3D Mouse Cursor Control for Smart TV Applications

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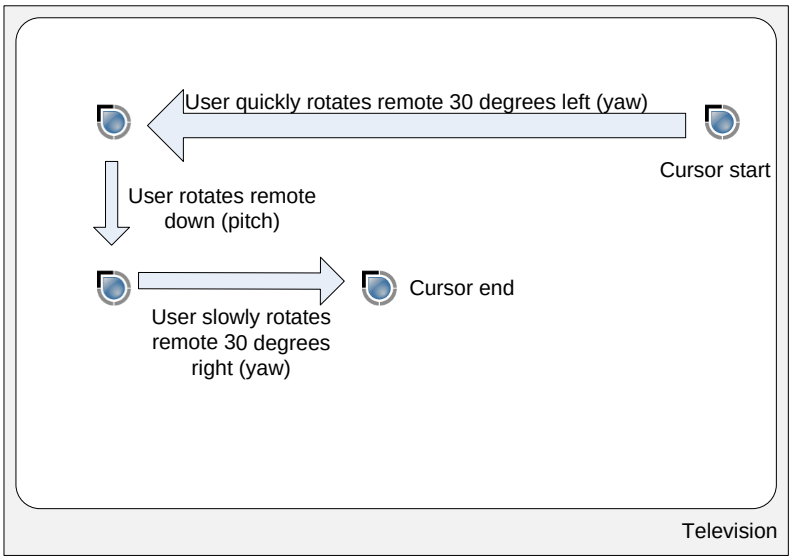
This document explains the foundations of 3D mouse cursor control for Smart TV applications. More specifically, it describes the 4 most important considerations for cursor control.

1. **The mouse as an input device for point and click control is based on decades of research and testing by human factors engineers. It is very well understood and accepted by consumers.**

The mouse was first created in the 1960s, adopted for commercial use in the 1980s, and is still in wide use today because it solves a fundamental problem for point and click control of a graphical user interface (GUI) on a display. The two most important and distinguishing characteristics of *all* computer mice are bounded pointing and non-linear ballistics cursor movement.

Bounded pointing, also known as relative pointing, is a feature whereby the mouse cursor stays bounded on the screen at all times. If the user moves the mouse past the point where the cursor would go off the edge, it won't. Bounded pointing was an explicit choice by human factors engineers who determined that it was better to decouple the movement of the mouse from the cursor on the screen. The advantage is that the cursor is always visible. This gives the user a feeling that they are in control and haven't "lost the cursor". Users quickly figure out that they may need to pick up the mouse to re-center the cursor on the screen. Over time, the adjustments become smaller and less frequent as the user subconsciously trains how to efficiently re-center or perhaps not re-center at all.

Non-linear ballistics cursor movement means that cursor movement is *not* a 1:1 mapping with mouse movement. When the user moves the mouse fast, the cursor accelerates and moves with a larger velocity towards targets. When the user moves the mouse slower, the cursor slows down and moves with a smaller velocity. This helps in two ways. The acceleration means less effort is required to move the cursor across the screen. The deceleration enables the user to more effectively hit smaller targets on the screen. The effect of this behavior is that the cursor will not always appear in the same position as the mouse moves around. If the mouse moves quickly in one direction and slowly back in the other direction, the location of the cursor relative to the mouse changes. This is shown in Figure 1.



Non-linear Ballistics Means Symmetric Motion of the Remote Does Not Result in Symmetric Motion of the Cursor

Figure 1 - Effects of Non-linear Ballistics on Cursor Movement

The explicit choice of bounded pointing with non-linear ballistics means that *re-centering is a feature* for point-and-click control. It is also the preferred approach since it is less fatiguing than other options. But non-linear ballistics and relative pointing require a small amount of training for users to become completely proficient.

2. Mouse dynamics as described above formed the foundation of air mouse cursor control. However, these dynamics were necessary but not sufficient for usable in-air operation in the living room.

Hillcrest Labs did not invent the mouse, but rather created the most user friendly 3D mouse for the TV. The default cursor control algorithm for Freespace motion is based on bounded pointing using non-linear ballistics cursor movement *just like the PC mouse.* This choice was made because the problem domains are the same: deliver easy to learn point and click user input control for a GUI on a display. Although the TV is different than the PC, Hillcrest user experience (UX) engineers found that the similarities outweighed the differences.

There are other important, non-obvious and non-trivial algorithms required to make an air mouse usable. An air mouse does not have the benefit of a flat surface with friction. So Hillcrest added algorithms to remove human tremor and make the cursor more stable on the screen during in-air operation.

The living room environment is also very different from a PC. PC users generally sit 1/2 meter from their monitor looking straight on. Living room users "sit" in many different orientations, at different distances, and at various angles with respect to the TV. The use of the remote control must be comfortable and usable in all these different positions. For this reason Hillcrest also needed to compensate for the

orientation of the device in the user's hand. This means that the user is not required to hold the remote control exactly parallel to the floor and point the remote directly at the TV in order to use it. A person can lie on the sofa at a 30 degree viewing angle to the TV, and make small wrist motions and control the cursor in a more relaxed manner.

3. Absolute pointing systems may be appropriate for certain use cases but are not appropriate for the TV's primary use case which is to browse, select, and enjoy multimedia entertainment (including videos, audio and photos).

For many years, consumer electronics companies have explored the use of absolute pointing to control the cursor movement on the screen. An absolute pointing system is embodied by a laser pointer where the user moves his or her arm to control a beam of light on a screen. Imagine if the user had an apparatus similar to a tripod to hold the laser pointer. Pretend that the user puts it in the apparatus and focuses the laser on an LCD screen. If the user subsequently takes the laser pointer out of the apparatus, walks around the room, places it back in the apparatus, it would form a beam of light on the LCD screen *in approximately the same location.* This is the essence of absolute pointing.

There are substantial user experience problems with absolute pointing systems. First an absolute pointing system by definition does not support bounded pointing and does not provide non-linear cursor ballistics. Since the cursor is not bounded on the screen, the user must first "find where the cursor is hiding" which is frustrating and the user is then forced to physically point at the screen which requires line of sight and is fatiguing with extended use. The lack of non-linear ballistics means the user must make large wrist and arm movements to move the cursor across the screen, which requires more stamina and makes the selection of small targets difficult.

There are practical implementation and business challenges as well. Common absolute pointing systems rely on a camera sensor that has field of view constraints, which make it hard to move the cursor unless a user is directly in front of the TV. Cameras are also challenged with lighting variations and 3D cameras are expensive.

The primary use case for the TV is to browse, select and enjoy multimedia entertainment. This should be a relaxing and efficient experience which is best served with traditional mouse dynamics not absolute pointing. The cursor should always be visible on the screen and should move efficiently for the user.

Other use cases *may* be improved with absolute pointing. Certain fast paced, point-and-shoot games may work better with absolute pointing as the effects of re-centering (due to bounded pointer and non-linear ballistics) could degrade the game experience. The word "may" is used because there is evidence that with training those effects are offset by the benefits of a relative system. It is notable that Nintendo chose a purely inertial solution for their latest gaming console, the Wii U's GamePad, which uses mouse dynamics that require re-centering. When asked about this, Nintendo's Chief game designer said "It's true that with some of the sensors that are used there are limits to the precision they are able to measure. It becomes our role to look at how can we manage that or how can we make it so

that the recalibration becomes part of the gameplay. That's what we're going to be working on going forward."

Hillcrest strongly believes that for general purpose point-and-click control standard mouse dynamics with bounded cursor and non-linear ballistics work best. Usability tests should be conducted to test other approaches for niche gaming applications.

4. Hillcrest's state-of-the-art Motion Engine product powers the best TV air-mouse solutions in the industry and is flexible enough to meet all Smart TV demands.

Hillcrest's flagship MotionEngine product powers industry leading TV air-mouse solutions such as LGE's Magic Motion remote control. Magic Motion has received excellent reviews from many from journalists and analysts praising the performance, usability and benefits of a motion controlled Smart TV UI.

MotionEngine enables best-in-class user experiences for our customer's products and is flexible enough to support all Smart TV needs. Hillcrest offers both 6 and 9 axis versions of Motion Engine software. The 6-axis implementation provides unparalleled pointing and gesture control with orientation compensation. The 9-axis implementation provides better yaw stability which corresponds to left-right movements of the cursor. And with the additional magnetometer data, fine-grained (slow) movements of the cursor are better supported as the sensor fusion algorithm can distinguish real movement from gyroscopic bias that must be filtered out. The 9-axis implementation also allows additional movements and better natural motion tracking. This means that games that require precision tracking of the remote control such as Frisbee, tennis, and golf can attain a higher degree of accuracy and more realistic game play.

With 9-axis technology, Hillcrest can additionally enable an "absolute mode" for niche game applications. With "absolute mode" processing, the cursor is unbounded and uses linear ballistics. Hillcrest enables this mode for customers that wish to use absolute pointing dynamics without the need for additional sensors such as a camera. And unlike other technologies, there are not field of view constraints or lighting issues to consider.