

# AR Tennis

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## 1. Introduction

Modern mobile phones combine a display and processing power with a camera, and so are ideal platforms for augmented reality (AR), the overlay of computer graphics on the real world. Henrysson [2] has ported the popular ARToolKit [1] computer vision library to the Symbian operating system which allows developers to build AR applications that run on a mobile phone.

Mobile phones are already designed to support local and remote communication, so one interesting area for research is supporting collaborative AR applications. AR Tennis is the first example of a face to face collaborative AR application based on mobile phones.

## 2. AR Tennis

In the AR Tennis application two players sit across a table from each other with a piece of paper between them with a set of ARToolKit markers drawn on it. When the player points the phone camera at the markers they see a virtual tennis court over the real world. As long as one or more of these markers are in the field of view then the virtual tennis court will appear. This marker set is used to establish a global coordinate frame and both of the phones are tracked in this coordinate frame.



Viewing the AR Content

The two phones are connected to each other using Bluetooth client-server wireless networking. There is a single ball that initially starts on the phone that is set up as the blue-tooth server. To serve the ball the player points their phone at the court and hits the '2' key on the keypad. A simple physics engine is used to bounce the ball off the court. Players hit the virtual ball by simply moving their phone in front of it. Once the ball is in play there is no need to use the keypad any more.

The direction and position vectors of the ball are sent over to the other phone using Bluetooth, synchronizing the simulation each

round. When receiving data the device switches state from outgoing to incoming states and starts to check for collision with the racket. Both devices also check for collision with the net and if the ball is bounced outside the court. If an incoming ball is missed the player gets to serve. Each time the ball is hit there is a small sound played and the phone of the person that hits the ball vibrates, providing multi-sensory cues to help the players.



Playing AR tennis

The game has been tested on both the Nokia 6600 and 6630 phones, which have a screen resolution of 176x208 pixels and camera resolution of 160x120 pixels. The 6600 has a 104 Mhz ARM processor and ran at 3-4 frames per second, while the 6630 has a 210 Mhz ARM processor and achieved 7 frames per second.

In a user study with the system [3] players felt it was much easier to collaborate with their partner in an AR condition than in the non AR case, and that audio and haptic feedback made it much easier to work together than in conditions with less feedback.

## 3. References

- [1] ARToolKit website: [www.hitl.washington.edu/artoolkit/](http://www.hitl.washington.edu/artoolkit/)
- [2] Henrysson A. and Ollila M. *UMAR - Ubiquitous Mobile Augmented Reality* In Proc. Third International Conference on Mobile and Ubiquitous Multimedia (MUM2004) October 27 - 29, 2004, College Park, Maryland, U.S.A.
- [3] Henrysson A., Billinghamurst M., and Ollila M. *Face to Face Collaborative AR on Mobile Phones*. In Proceedings of the International Symposium on Mixed and Augmented Reality (ISMAR 2005), October 5th – 8th, 2005, Vienna, Austria..