Approaches to low-cost gait analysis

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Gait Analysis

- Analysing movement of animals (including but not limited to people)
- Variety of uses from the serious (health and rehabilitation, controlling robots) to the whimsical (motion capture for movies and video games)
- Two main approaches: markers and image processing (without markers)

Purpose and Aims

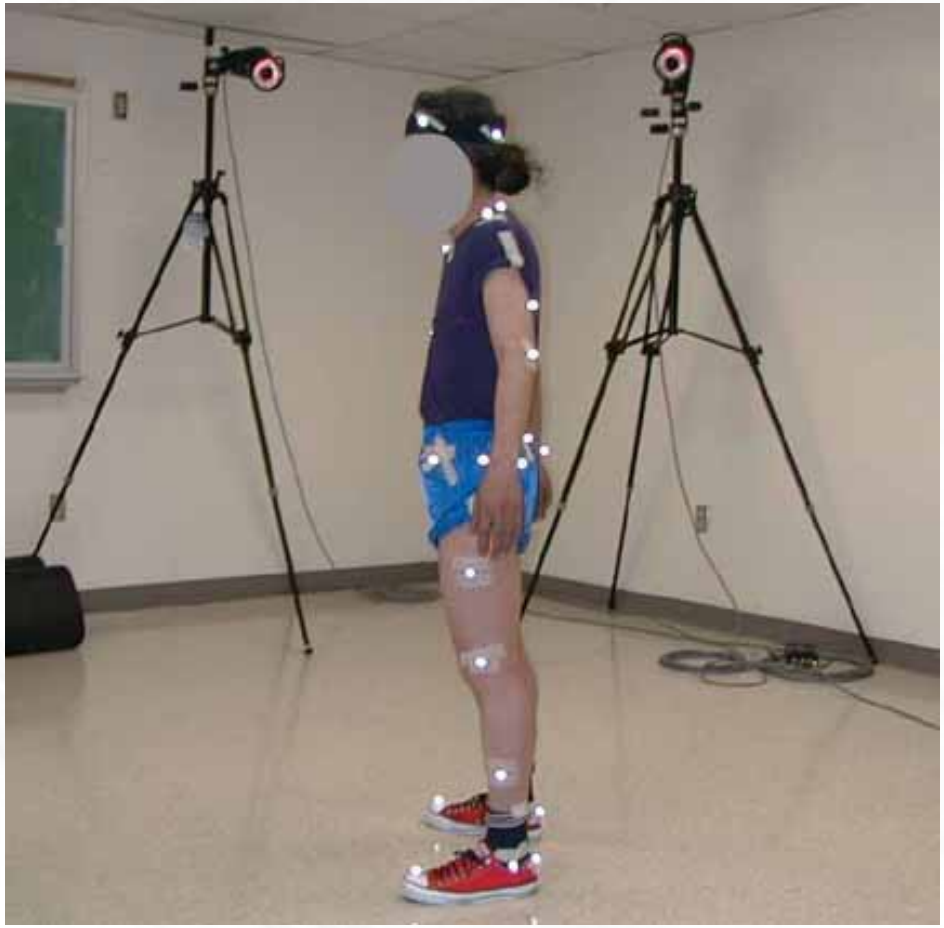
- Compare low-cost systems to high-cost systems for gait analysis by comparing to a model within a medical context
- Techniques should be easily transportable for transport to patients houses, around hospitals
- Allow comparisons between data collected from a high-end system and various low-cost systems (especially the Microsoft Kinect)
- I can only cover what we did up until I left about a month ago

Team

- Sarthak Sarangi
- Akhand Tripathy
- Will Smith
- Dave Collins
- KP
- Me

Marker Equipment

- Multiple cameras + markers at key positions
- Uses triangulation to determine positioning
  - ($\rightarrow$ complicated)
- *Very* expensive but also accurate (at best sub-mm)
- Requires installation of multiple IR sources + sensors $\rightarrow$ not portable, destructive of environment
- Used as control for analysis



New York University Rehabilitation Engineering Research Centre

Markerless Techniques

- Relies primarily on computer vision/image analysis techniques, rather than triangulation
- Recent resurgence due to high(er) performance processors being commonly available
  - Microsoft Kinect uses ~10% of one Xenon core but this is improving with newer releases

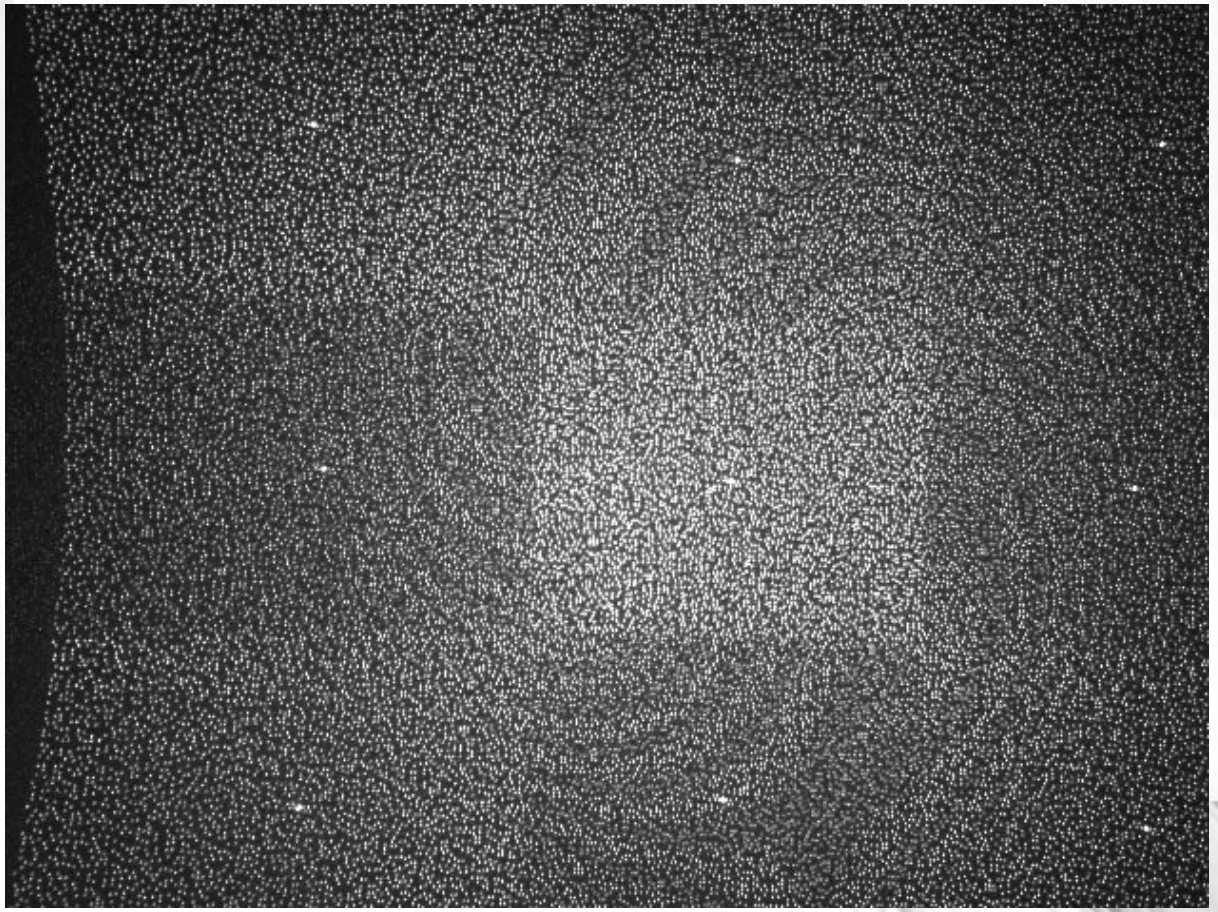
Microsoft Kinect

- Sensors:
  - Colour camera (15fps @ 720p)
  - Depth sensor (30fps @ 480p)
- Detect 6 people, track skeletons of 2 in software
- No dedicated processing hardware
  - But should work with fairly modern hardware
  - Any arch better than *NetBurst* should be fine
  - Decent chunk of memory
    - >=4GB for development, less for production

Microsoft Kinect

- Uses triangulation against a known pattern

Specific algorithm is proprietary and a trade secret, academic perspective at http://mediabox.grasp.upenn.edu/roswiki/kinect_calibration(2f)technical.html



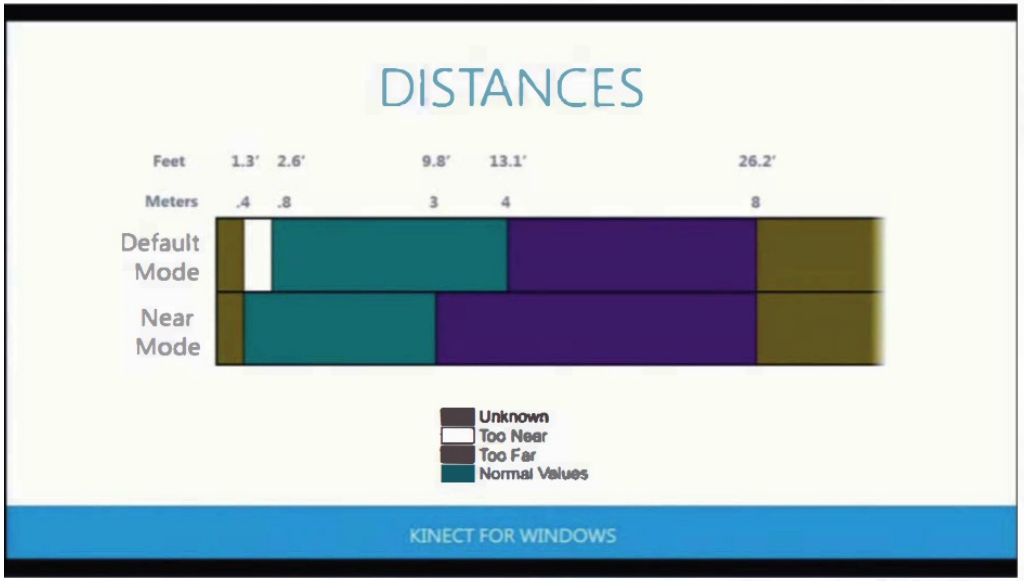
Above: University of Arkansas
Left: University of Pennsylvania

Kinect Development

- Plenty of libraries:
  - Official SDK (KSDK)
  - OpenNI (+ bindings)
  - FreeKinect (+ bindings)
- Provide access to at least depth and colour streams (and hardware control such as LEDs)
- KSDK & OpenNI also provides skeleton tracking
- Skeleton tracking through software alone

How accurate is the Kinect?

- Officially, to within $\pm$10mm (optimal range can vary with configuration and environment)
- Our experiments and others (El-laithy *et al*) back this up



UPenn

How accurate is the Kinect?

- Accuracy of the Kinect is limited by hardware – we compared OpenNI and KSDK with no difference between them
- Every study we found agrees with this
- Sadly, not as accurate as we needed/wanted

Improving accuracy with multiple Kinects

- Hackers have tried this with varying degrees of success (2 seems to be the practical limit)
- Both Kinects operate on same IR frequency leading to interference
- Hardware issues with multiple Kinects on same USB bus
- Leads to silly solutions like rotating disks for a hybrid “Kinect stereoscopy” approach
  - A bit silly!

Stereoscopy

- Use 2 (identical) cameras with a known distance between them to calculate a *disparity map*
- Easy to convert this map into a depth map
- Most accurate techniques (e.g. block matching) are incredibly resource intensive
  - ~40 minutes/frame in our very unoptimised experiments but not usually this expensive

Stereoscopy

- Possible to use stereoscopy and image processing for gait analysis in real time
- *However,* practicality means this is infeasible, especially for our needs
  - Extremely accurate measurement between the cameras is vital, this cannot be guaranteed
  - Long processing times

Practicalities

- How are we going to analyse people whilst walking?
- What is the best way to allow for natural walking motion?

Treadmills!

- Perhaps the most logical solution...
- Look good on the outset but there are three major issues
- Experimented with Physiotherapy and the Sport Centre's equipment

Non-removable console obstructs sensor!

More issues

- Uses a predefined speed – not ideal for natural walking motion
- Microvibrations from motor appeared to cause issues with sensor
- Our treadmill was too “thin” to allow for arm swinging
- Get around the console by moving the sensor behind the operator?
    - Software no longer works!

Manual treadmills!

Too good to be true...

- Friction *much* too high, makes it almost impossible to walk on (nevermind naturally)
  - Need to use the handrail

Possible solutions

- There are treadmills designed for gait analysis that facilitate natural motion
  - Sadly, they are very expensive and not portable
- Others have used multiple sensors to capture people walking in a circle
  - We didn't have time to try this
  - Seems complicated
- Some kind of rig like Steadicams
  - Expensive (tens of thousands of $)

Final software

- The final product is a Windows application (.NET 4.0/WPF) used to track and record data for analysis
- Plugin architecture supports many devices (Kinect, stereoscopy etc)
- Records data in a standardized format
- Read from log files
- *I would demo but I don't have a Kinect or a PC!*

Conclusions

- The Kinect is very good but not quite good enough for gait analysis
  - Rumours surrounding Kinect 2 suggest this will not be an issue in the next version
- Other techniques are either too complicated, too expensive or too slow to be worthwhile
- Practicalities are annoyingly difficult and *still not solved* (as of ~1 month ago)

Conclusions (software)

- Kinect SDK is mature, stable, well documented and supported by a major corporation
- OpenNI: nice idea but not stable (yet)
  - *Could* replace KSDK eventually
- FreeKinect: appears project has died, very low-level

- Conclusion: use Kinect SDK for now, but look at OpenNI