# **Thought**Works®

bespoke AR for mobiles

# SEEING STARS

Using technology to deliver an engaging app to capture meteorite sightings, on Android and iOS





# HTTP://o BIT.LY/FIREBALLSDL

Or search App Store or Google Play for "Fireballs in the Sky"

## **HELLO**







Maths nerd
@davidcolls
AR MATHS

**BRAD WARD**Developer

IOS

NATHAN JONES

Developer

@the\_nathanjones

ANDROID



## 1. WHY NATIVE?

## To describe a fireball

Words & numbers fall short, so animated recreations were MVP.

# With particle systems

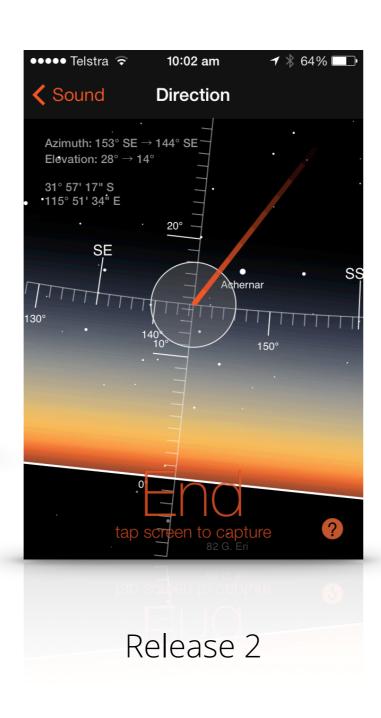
Demanded performance beyond the reach of mobile web for the majority of devices.

## Meant 2 native apps

Developed in parallel.

#### 2. WHY AUGMENTED REALITY?





## AR not MVP, but *delightful*

And improved reporting

Option for Release 1

Implemented in Release 2

#### 3. WHY BESPOKE AR?







## A unique context

No desire to license technology

Based on sensors not camera image

Camera view just black at night

Very simple interaction

Google Sky only Android

Google Sky won't subordinate

And we had a Processing prototype

#### 4. WHY PROTOTYPE IN PROCESSING?











## Fastest way to start

Dave knew Processing (visualisation IDE)

Rapidly iterate and demonstrate we could do star maps (highest risk)

No dependencies

## And finish

Porting together would be low risk

# **Thought**Works®



\* Guaranteed to contain NO equations

# APPROACH

Where are the stars?



How do we draw this (in a virtual window)?



## APPROACH

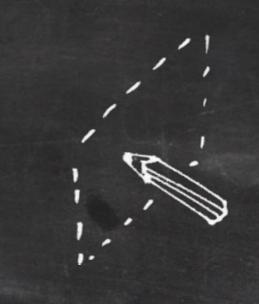
Where are the stars?



Where in the universe?



How do we draw this (in a virtual window)?

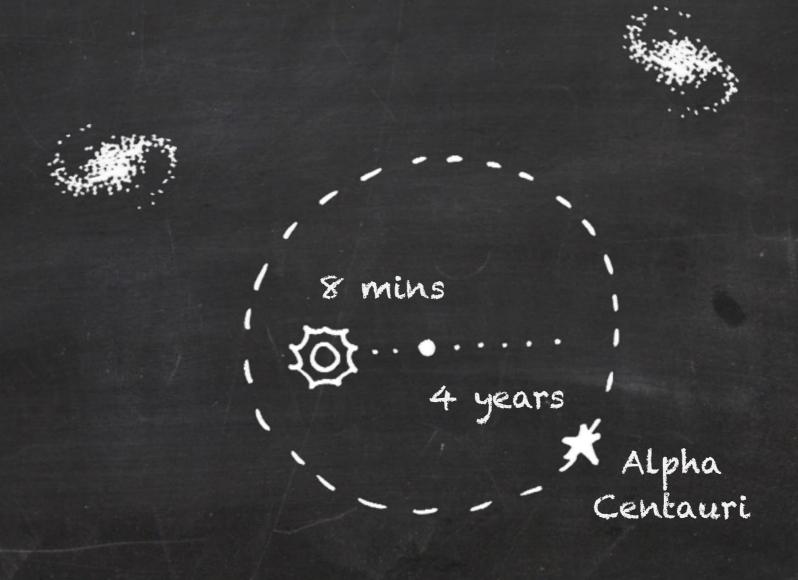


Where are you looking?



Where are you standing?

# WHERE IN THE UNIVERSE?



# WHERE IN THE UNIVERSE?

8 mins 4 years

circle to scale

# WHERE ARE THE STARS?

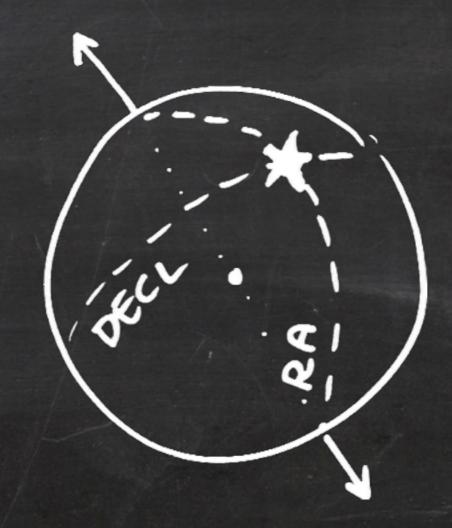


Infinitely distant

"Fixed Stars"



HYG Database



Celestial sphere

# WHERE ARE THE STARS?



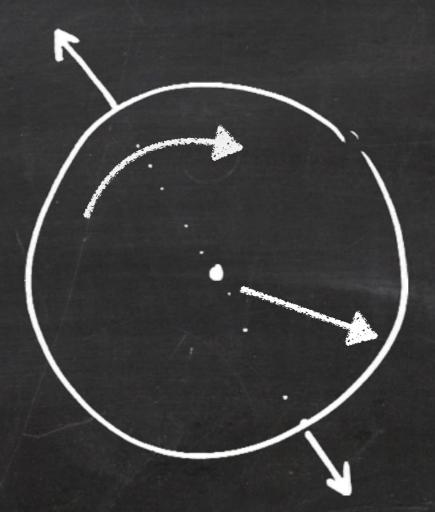
Infinitely distant

"Fixed Stars"



HYG Database

How do the stars look from the earth's surface?

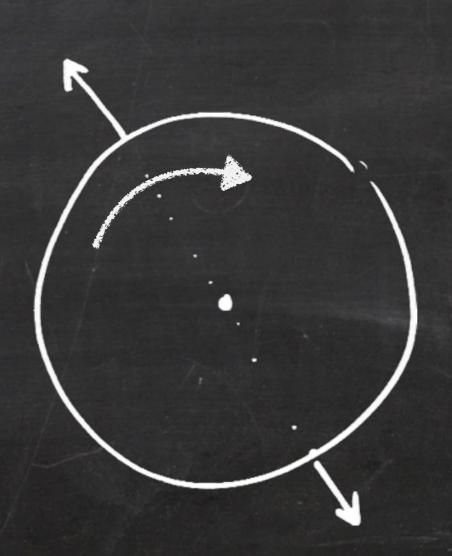


Celestial sphere

How much has the sphere rotated?

What part of the sphere is directly overhead?

# WHERE IN THE SKY?



Celestial sphere

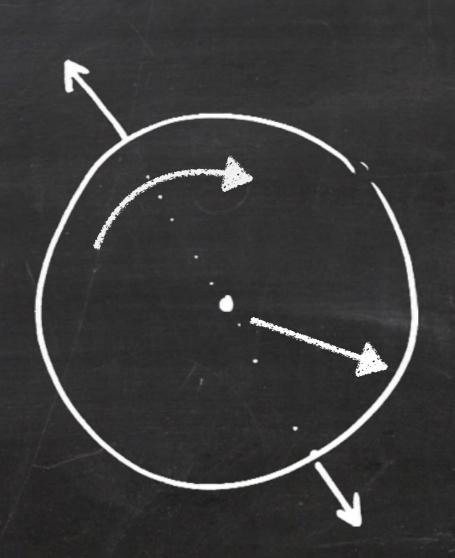


+ Date
Siderial Time
+ Longitude

Time

LOCAL SIDERIAL TIME

# WHERE IN THE SKY?



Celestial sphere



Time + Date Siderial Time + Longitude

> LOCAL SIDERIAL TIME

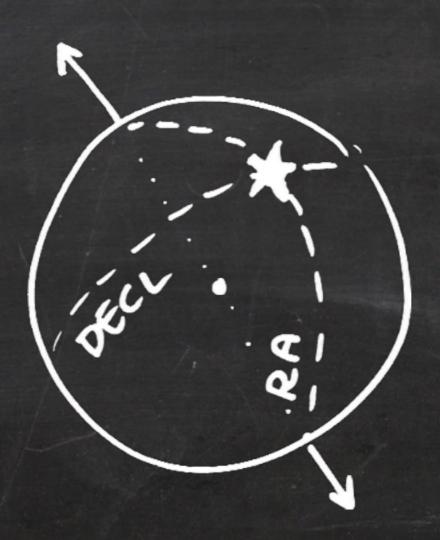
LATITUDE

# WHERE IN THE SKY?

Azimuth Elevation



Terrestrial observer



Celestial sphere

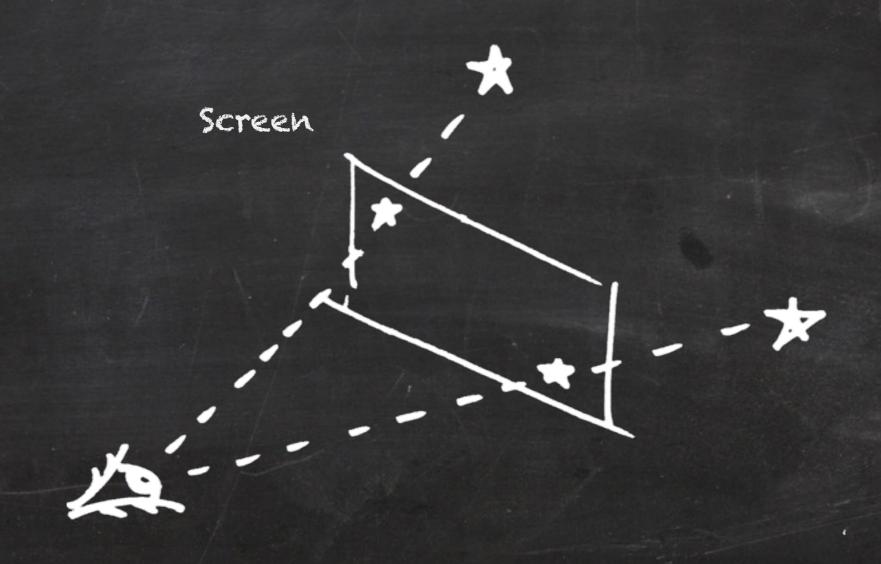


Time + Date Siderial Time + Longitude

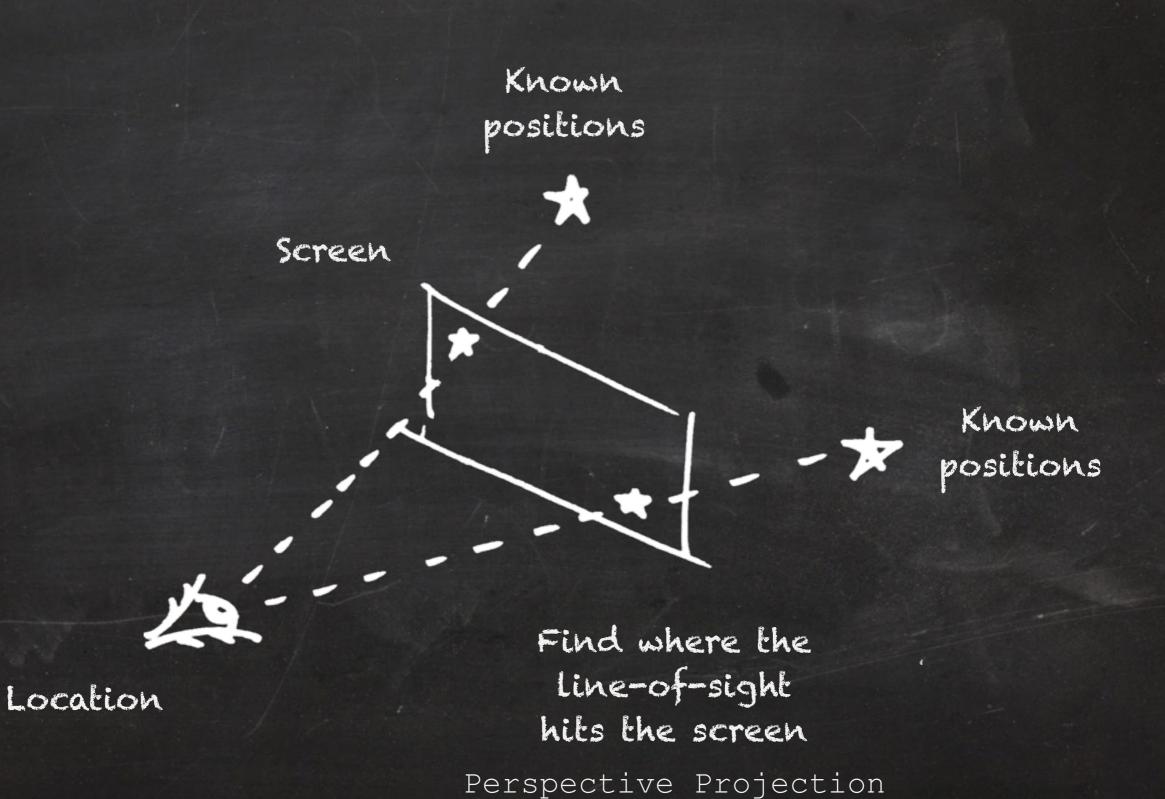
LOCAL SIDERIAL TIME

LATITUDE

## DRAWING IN A VIRTUAL WINDOW

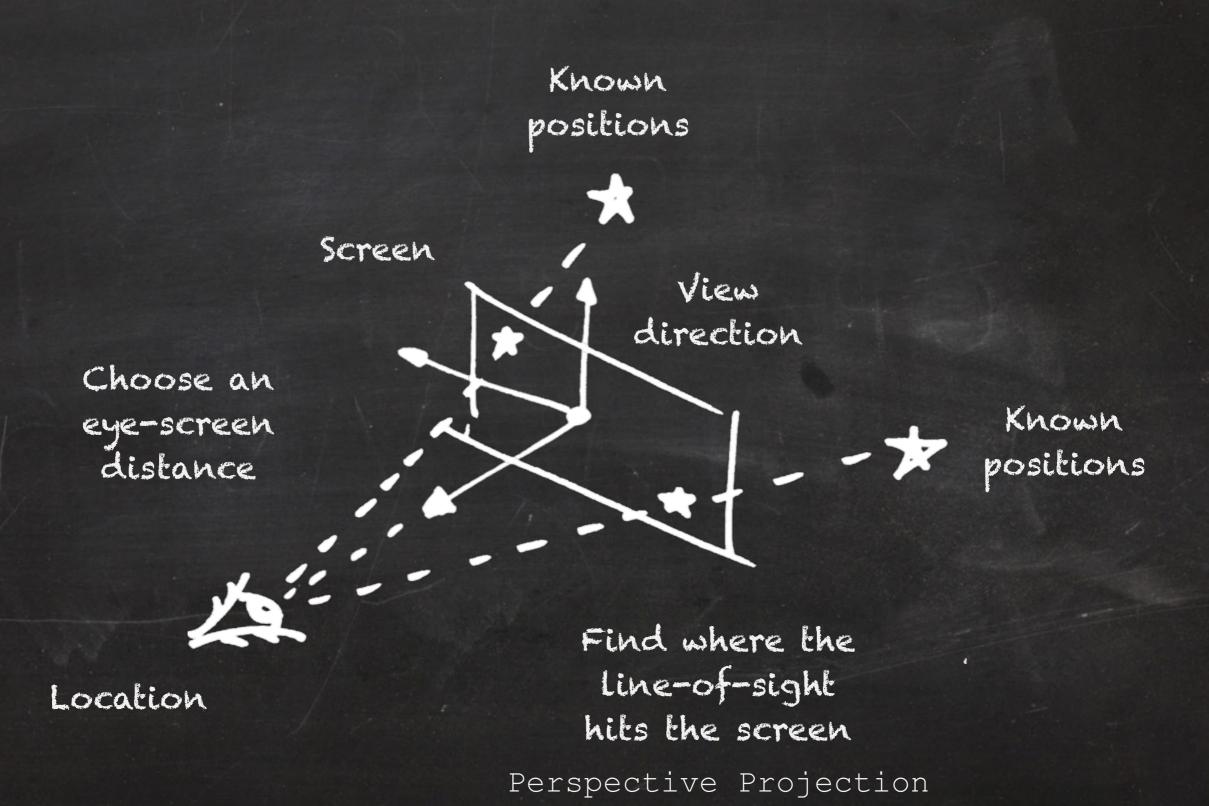


## DRAWING IN A VIRTUAL WINDOW



14

## DRAWING IN A VIRTUAL WINDOW



## WHERE ARE YOU STANDING?



GPS satellites



Cell towers

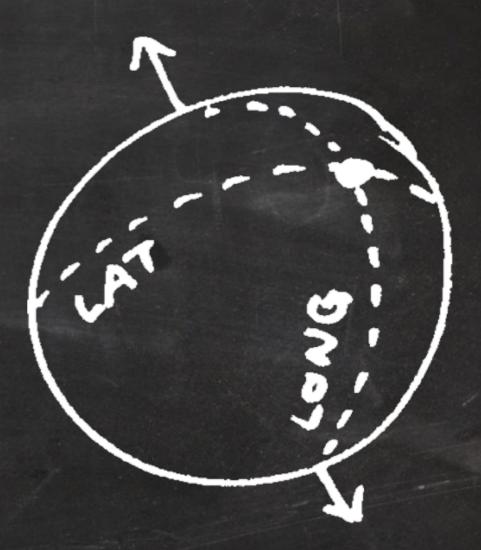




CLLocationManager



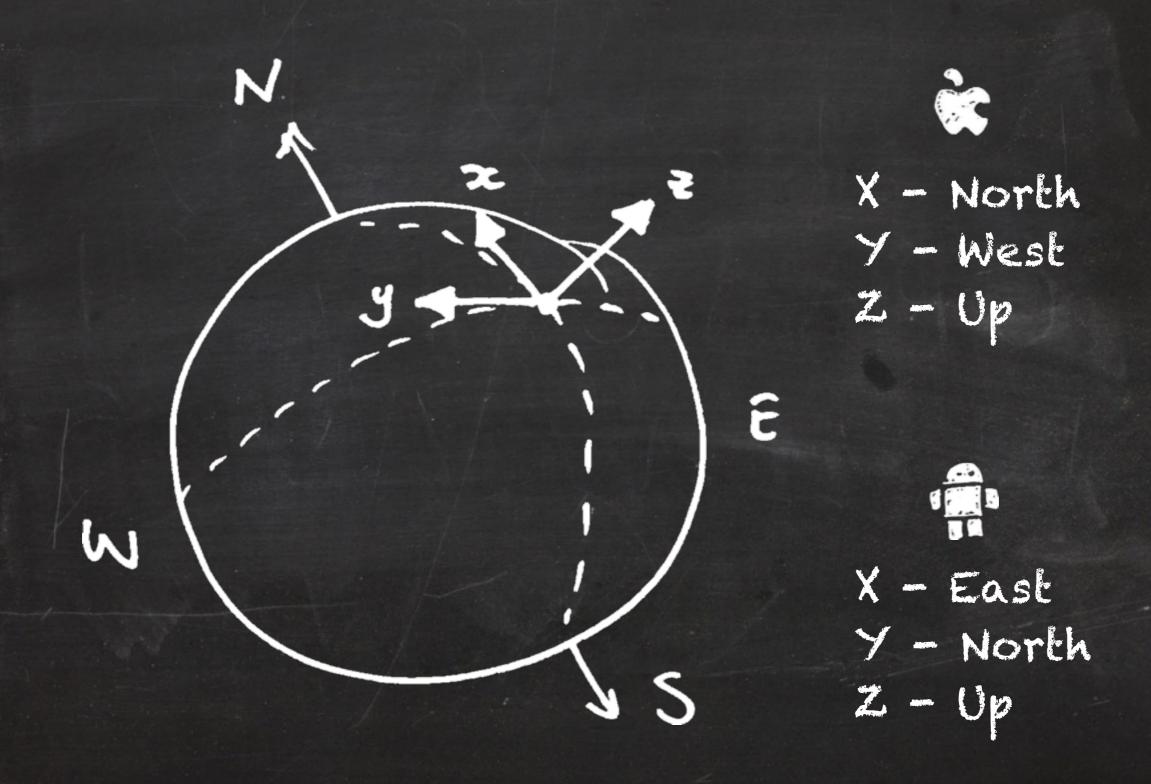
LocationManager

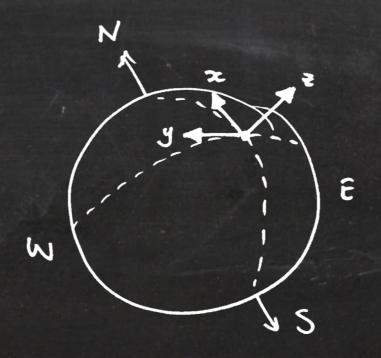




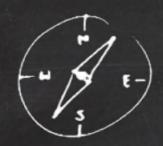
Wifi access points

## DEFINES LOCAL REFERENCE FRAME





...with respect to local reference frame



Magnetometers





SensorManager

Register for updates & getOrientation()

WindowManager

Device default orientation

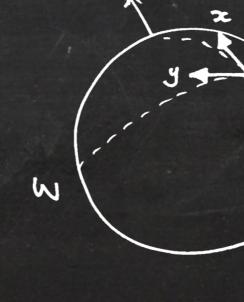




CLLocationManager For heading

CMMotionManager

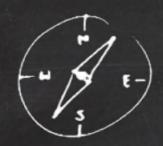
RefFrameXTrue NorthZVertical



...with respect to local reference frame



Gyroscopes



Magnetometers



Accelerometers



Gyroscopes





SensorManager

Register for updates & getOrientation()

WindowManager

Device default orientation

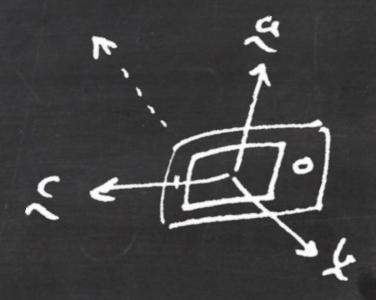


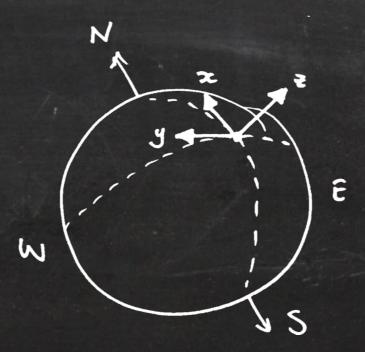
CLLocationManager

For heading

CMMotionManager

RefFrameXTrue NorthZVertical

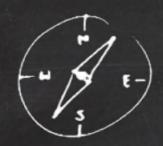




ay by cy ay ay be ca

Device rotation matrix...

...with respect to local reference frame



Magnetometers



Accelerometers



Gyroscopes





SensorManager

Register for updates & getOrientation()

WindowManager

Device default orientation

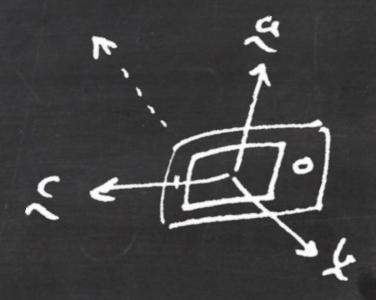


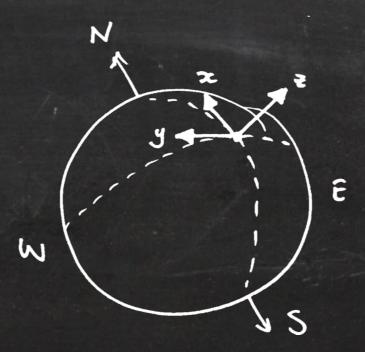
CLLocationManager

For heading

CMMotionManager

RefFrameXTrue NorthZVertical





ay by cy ay ay be ca

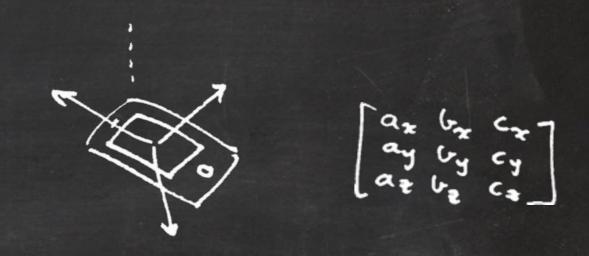
Device rotation matrix...

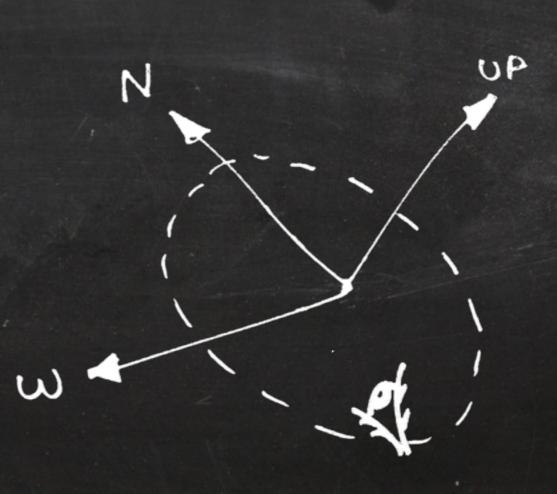
...with respect to local reference frame

Azimuth Elevation Till



Obtained from device rotation matrix





# REVIEW

Once per universe\*

Once per session

Every

Once per session

[RA & DECL]
(Fixed stars)

[Azimuth & Elevation]
(LST & Lat)

Device rotation matrix (APIs)

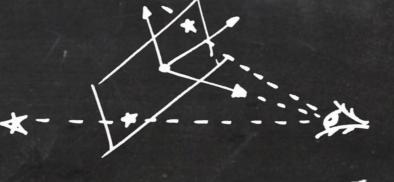
Device location (APIs)



Where in the universe?



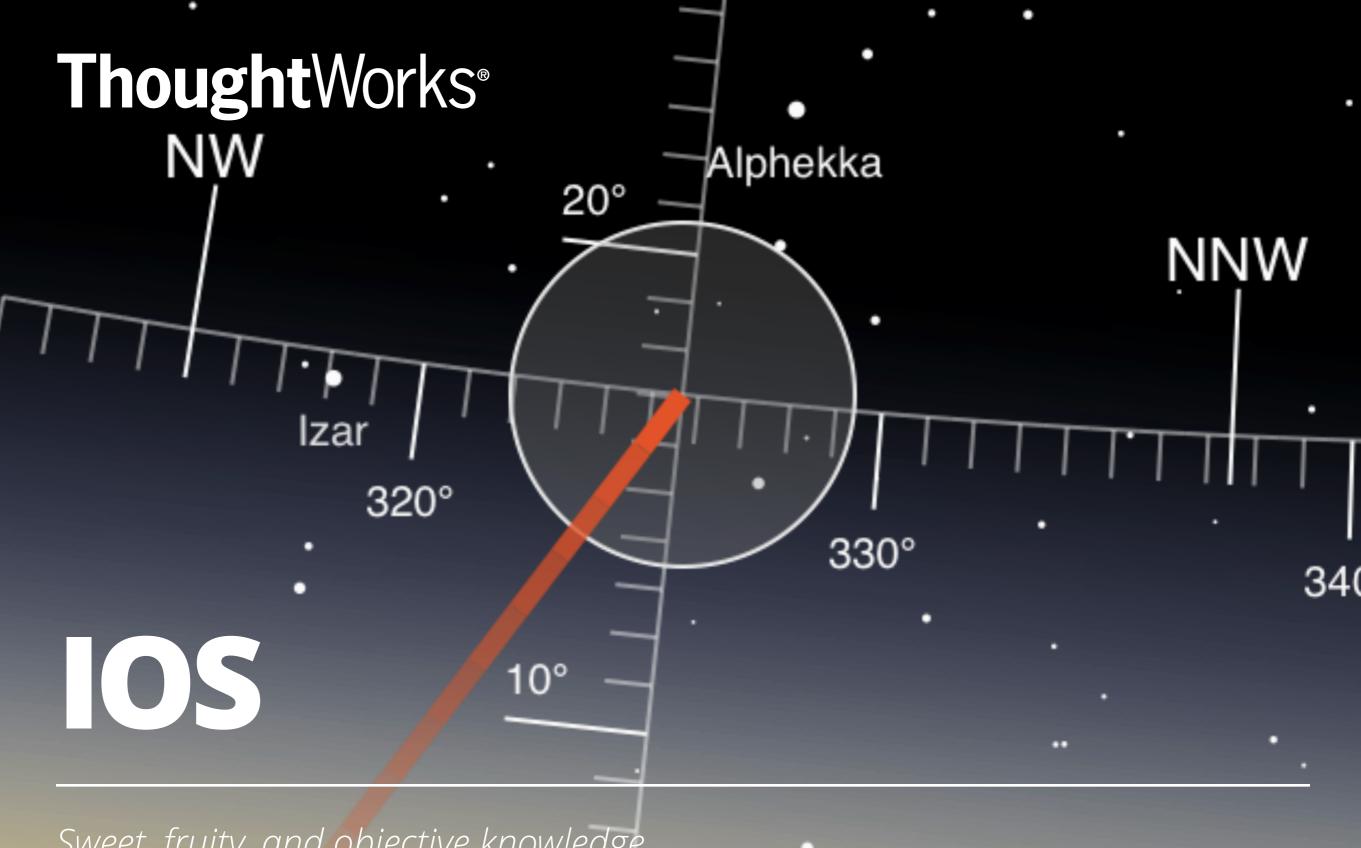
Where in the sky?



Where are you looking?



Where are you standing?



Sweet, fruity, and objective knowledge

#### **IOS INGREDIENTS**

## **Core Location & CoreMotion**

CLLocationManager latitude - longitude

CMMotionManager azimuth - elevation - tilt

- Using CMAttitudeReferenceFrameXTrueNorthZVertical reference frame
- The API-provided pitch, roll and yaw were not used (pitch and yaw don't compensate for roll). Used deviceMotion.attitude.rotationMatrix directly instead.
- □ Reference frame 'drifts' over time, periodic resets resolve this.

#### **IOS INGREDIENTS**

### Accelerate/vecLib library hardware-accelerated vector maths

- vecLib uses the Advanced SIMD instruction set implemented by NEON on ARMv7 devices (iPhone 4 and above, iOS 4.3 and above), with fallbacks for older devices
- □ 2-10x performance bump over standard

#### Objective C

- Avoided overhead of classes/GC in calculation code
- Work well with Accelerate library's C interface
- Rendering code is Objective-C

#### **IOS INGREDIENTS**

#### CoreGraphics

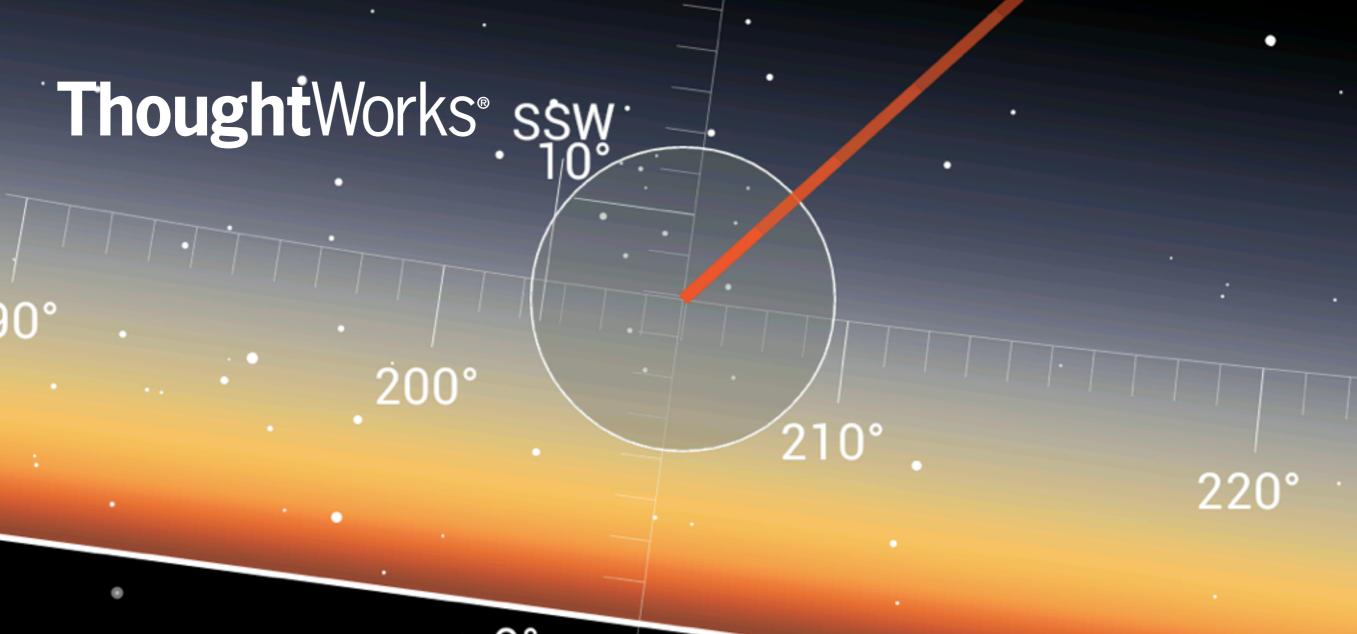
- ☐ CPU-based 2d rendering
- Minimal development effort with reasonable flexibility
- Was an expected (and realised) performance bottleneck
  - OpenGLES would provide dramatically improved performance, at higher development cost.
- ☐ Final performance was good on iPhone5 devices

Graceful degradation was added for iPhone4 - stars are rendered as squares rather than circles, star labels are not rendered and the horizon image is thinner.

#### **IOS IMPLEMENTATION**

### So many options to improve performance...

- Optimise use of Accelerate library via bulk calculations
- □ OpenGLES (eg. Cocos2D or SpriteKit) for rendering
- Multithreading
- □ Full GPU implementation of star-positioning calculations



# ANDROD

Developing for the bot with the lot

#### **ANDROID INGREDIENTS**

## Which API?

SensorManager is the home for all sensors in Android

Lots of change in this area of the API

Reference examples use deprecated ORIENTATION SENSOR

Hand-rolled sensor fusion of accelerometer and compass

Take a look at the ROTATION VECTOR Sensor

Adjust resulting vector for current and default orientation

#### **ANDROID INGREDIENTS**

### How do I draw them?

We use a regular SurfaceView

We use a Timer targeting 60FPS instead of an explicit thread

Draw on a regular 2D Canvas

Not hardware accelerated

Code split into set of renderers

Toggled FPS renderer for performance testing

Room for improvement

#### **ANDROID IMPLEMENTATION**

## Coding Style

Optimised vector math libraries not as mature

Embrace some functional paradigms, separate state and behaviour

Multi-threading is an option

Beware the garbage collector

Profile all the things, these are limited resources

Many ways to skin a cat with vastly different performance

#### **ANDROID - HERE BE DRAGONS**

## Fragmentation exists

Expect it and deal with it

Eligible for installation on 3606 devices

Pick a baseline and work out what you are in for

Don't expect the API to be consistent

## Get some real devices

Lowest and highest target OS versions

Lowest and highest screen sizes - resolution and physical size

Lowest performance - slow single-core phones

Fall back to emulator only for sanity check on look and feel



On both Android and iOS

#### **TESTING**

#### EXPLANATION

The oval opening in the disc represents the particular which this Planisphere is constructed, namely, the London, 51½°N.

On the edge of the disc are marked months while Greenwich time is indicated round the outer mask. In using the Planisphere convert summer tim wich time where necessary.

 To see the stars on the Planisphere in their prop to the stars in the heavens.

Hold the Planisphere overhead but face down midnight on the mask pointing due north yourself.

The Pole Star will be seen at its proper altituwith the eastern and western horizons respect right and left. Owing to difficulties of project Planisphere they appear to be a little to the no true position.

It should be noted that the altitude of the always equal to the latitude of the observer.

South will be directly behind your back in the direction. The zenith, or point directly overhead, centre of the opening.

To understand the Constellations, and their apparent daily meconvenient to map out the sky into sections. The system most accepted is that which starts from the Terrestrial Equator as curve. The plane of the Terrestrial Equator being produced in marks on the apparent dome of the heavens the position of the Equator, which divides the heavens into two homispheres: the A Earth being also produced to infinity marks the Poles of the hea Celestial Equator and the Meridians are divided, like the T Equator, into Degross, Minutes and Seconds. The lessial or Zen the Celestial Equator is the point of the Vernal Equitors, which first coint in Aries.

This division being based on the daily rotation of the Earth of her or on the apparent motion of the starry heavens in the contrary draw the stars seem to us to move round the Pole in the same director as Sun does, viz.: from East to West, at the sate of 15° each high degrees grow smaller and the apparent stotion slower as we approach Pole, which appears at rest. Polaris, or the Pole Star, being very near

## Use real devices

eastern horizon and Aquila on the western horizon, while

Performance differs from emulators

Draw an imaginary line from the North Pole to any given late on the perimeter of the fixed disc. The point where

Sensor data not available in emulators

to the eastern horizon and reading off the time at the edge of the movable disc opposite the chosen date. Similarly the

## Test in the real world

Charles' Wain, consisting of seven brilliant stars, four of which form a constitutional and store a curved line, ralled the short. A straight line down

The acid test for an AR app

modelle of this, then we see on the right hand Capella, and on the left hand Vega. When these key stars are known it is easy to find the remaining groups on the Chart.

The different positions of the Milky Way are seen by merely turning the Chart trouvel.

#### A SELECTION OF PHILIPS' POPULAR ASTRONOMICAL AIDS

#### PHILIPS' PLANISPHERES

POCKET PLANSPORMS (NORTHERN HEMSTERS) only 5 inches in Diameter

NORTHERN PLANSPIERS; SOUTHERN PLANSPIERS 10 inches in Dismeter

CHART OF THE STARS Designed by E. O. TANCOCK, B.A. T.R.

Paper, folded to pocket size
Paper, folded to 12 by 15 inches, with eyelets
the start, folded to packet size

On cloth, folded to pocket sire On cloth, with rollers, varnished or unvarnished

On modern cettle steed, with tilted axis

PHILIPS 12-1 FLESTIAL GLORE. On plantic to 7 with Giled asis Revised by H. P. Wilkins, F. R. A.S. Showing principal physical feature with descriptive notes. 274 by 20 inches.

SIGNED T. TO THE STARS. By P. R. Burner. A good and clouds like

duction. 12 pages. T<sub>1</sub> by 5 meters. A novel and ample out

northern heavens. 7 by 5 inches SYARTING ASTRONOMY. By E. O. TANCOCK, B.A., F.R.A.S., A.

POPULAR GUIDE TO THE HEAVENS By Six Robert Mall, LL.D. F.R.A.S. New (5th) edition, revised by E. Agan Burr, B.Sc., F.R.A.S. Societary of the British Astronomical Association. A summary of the solar system, with star-maps, drawings and photographs. 12-page

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# Think about usage

No wifi or cell towers in the outback

## Don't block the user

While you find their location

# Enough is enough

Know the required accuracy, and stop when you have it

# Stop wasting their battery (Android)

Turn off location services on app hide

#### **DEVICE ROTATION**



## Differences in APIs

Android vs iOS

## Frame of reference

True North or Magnetic North?

(Does it matter in Perth?)

# Smoothing

How to filter noise while preserving a responsive signal

# THANK YOU

For questions or suggestions:

dcolls@thoughtworks.com njones@thoughtworks.com brward@thoughtworks.com

# **Thought**Works®