

# Mobile AR: Promising innovation or misplaced trust?

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# Outline

- Importance of landmarks for visual navigation
- Principles of Augmented Reality (AR)
- Registration
- Augmented Reality at sea
- Measuring deviation (compass error)
- The results
- Implications
- A possible approach
- Conclusions

# Visual navigation

- Important in the air, on the sea, in open country
- Depends crucially on identifying landmarks
  - Either to “fix” position
  - Or to define (approach) direction
- Traditionally
  - Chart / map
  - Binoculars
  - (possibly) sailing / flying / walking guides / directions

# Recognizing landmarks

- The chart shows three “conspicuous buildings” on the coast here –
  - But which are they?



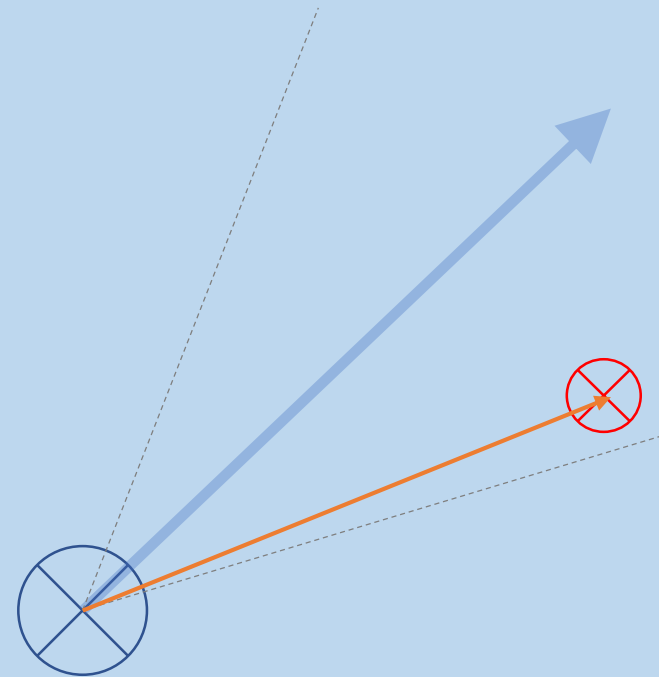
- NB: the “mega” building isn’t one of them
  - That didn’t appear on the chart until about 3 years after it had been built!

# Electronic navigation to the rescue?

- GPS (fixed) can tell you your position and velocity
- Handheld devices that are both location and aspect (i.e., which way the device is facing) aware *should* be able to help identify landmarks
- Or even do it for you
  - Adding markers to camera image
- Augmented Reality

# Principles of AR

- 2-D for simplicity
- Known position...
- .. And aspect
- Known relative position of Point of Interest
- Known camera field of view
- Place marker within camera image



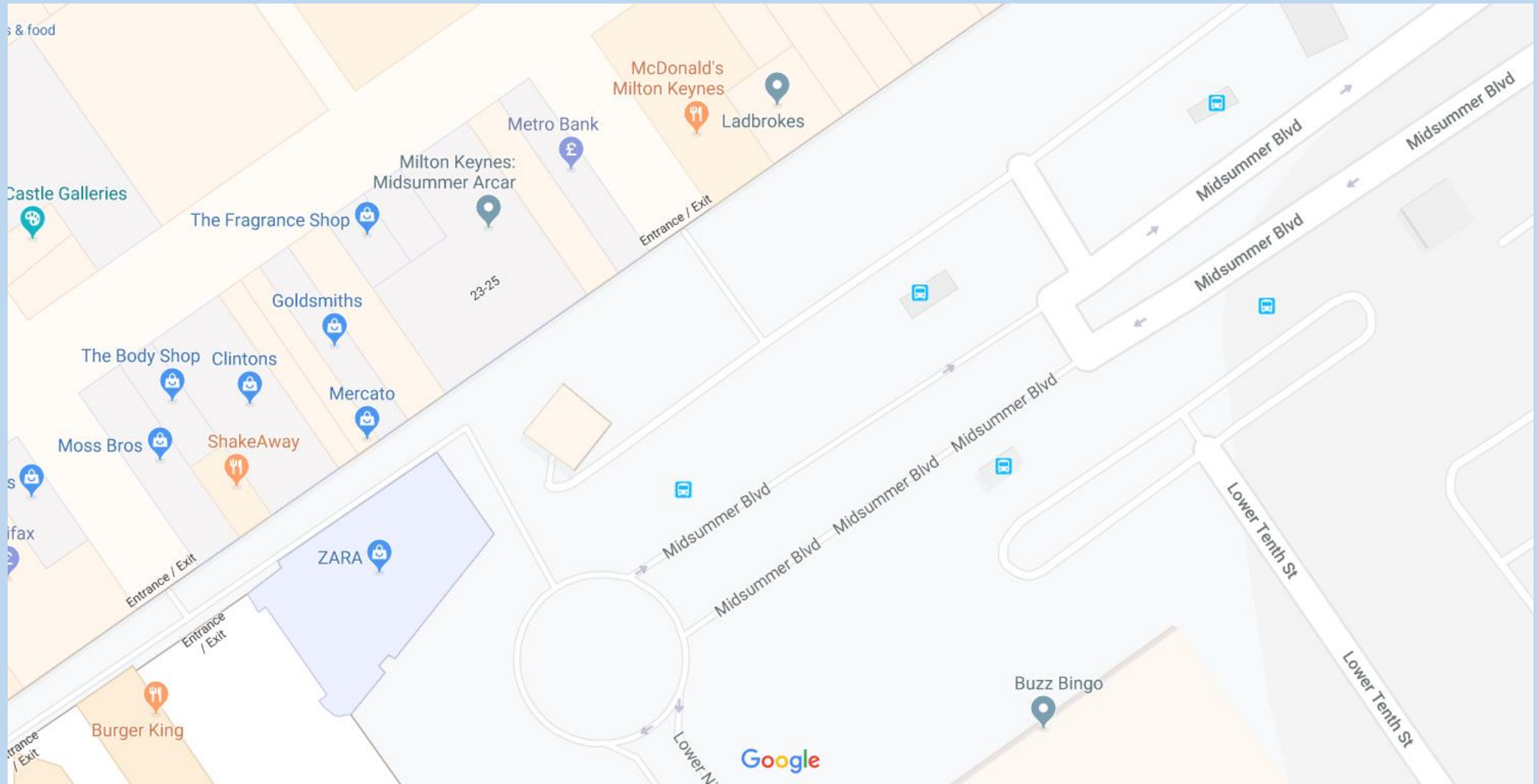


 Florence

# AR in urban environments - challenges

- GPS poor
  - Canyon effect, multi-path, screening, interference
  - 5m accuracy optimistic
  - 5m position error @ 50m  $\approx 6^\circ$
- => “Registration” of camera image
  - Limited – no universal 3D model
    - Although there are topographic maps at larger scales
  - Look for vertical edges, match against building footprints
  - Relies on limited information
    - Easily confused – e.g., by recessed doorways, canopies, lamp-posts, trees etc.

# Milton Keynes Centre...



# Milton Keynes Centre



# Augmented Reality at sea

- Vertical edges in short supply
- Coast relatively distant -  $\sim 1$  Nm
  - Small vertical angle within image
    - 100m cliff at 5 km is about one degree of vertical angle
    - Field of view  $\sim 30$  degrees
- Large open spaces
  - Few nearby objects (apart from the odd wind farm or navigation buoy ....)
- And everything is MOVING....!

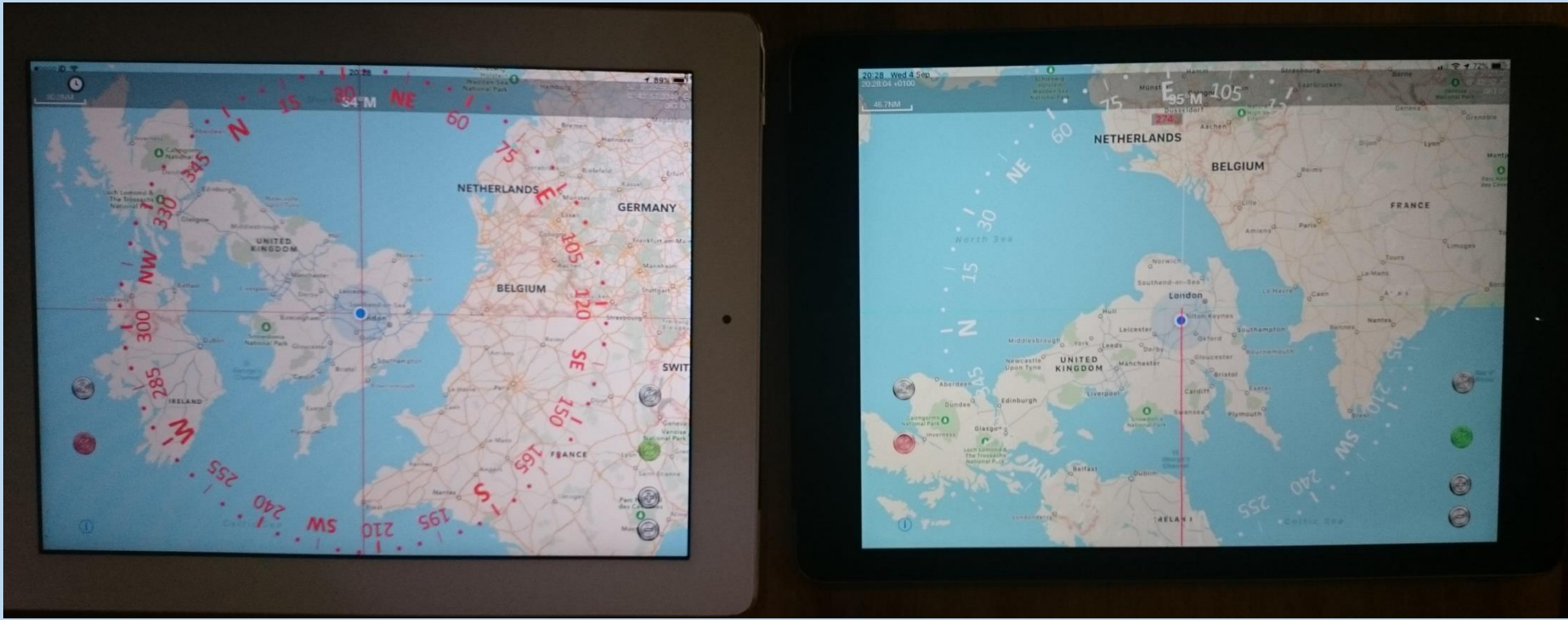


# Registration at sea?

- Challenging –
  - Foreground moving (waves)
  - Coast / clouds – if any – moving (motion of vessel)
  - Whole image moving – trying to hold a tablet still as the boat moves...
    - And the pattern of motion is almost designed to completely confuse inertial sensors
  - Not many distinguishable edges
    - Might be able to use headlands – if there are any
    - But they're still moving
  - So reliant on built-in sensors
    - **GPS** – for position – probably OK.
    - **Compass** for aspect

# Smartphone / tablet compasses

- Claim incredible precision...
- ... but how accurate are they?

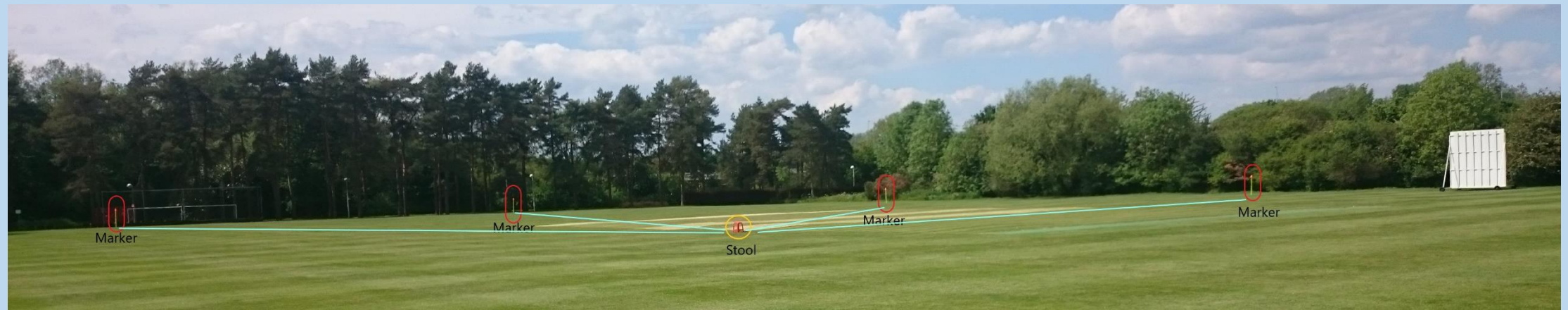
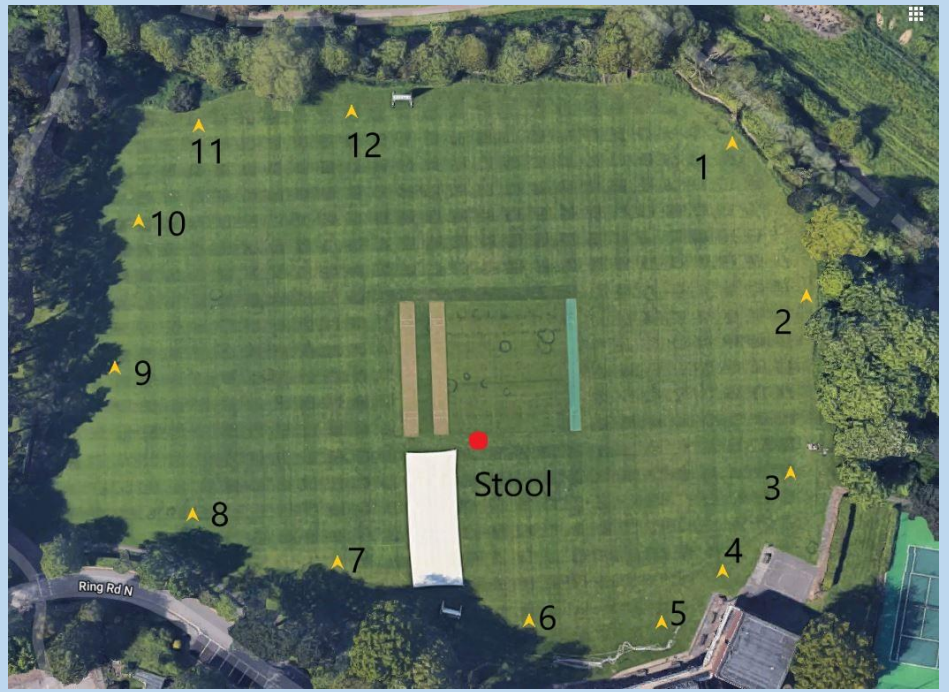


# Measuring compass error

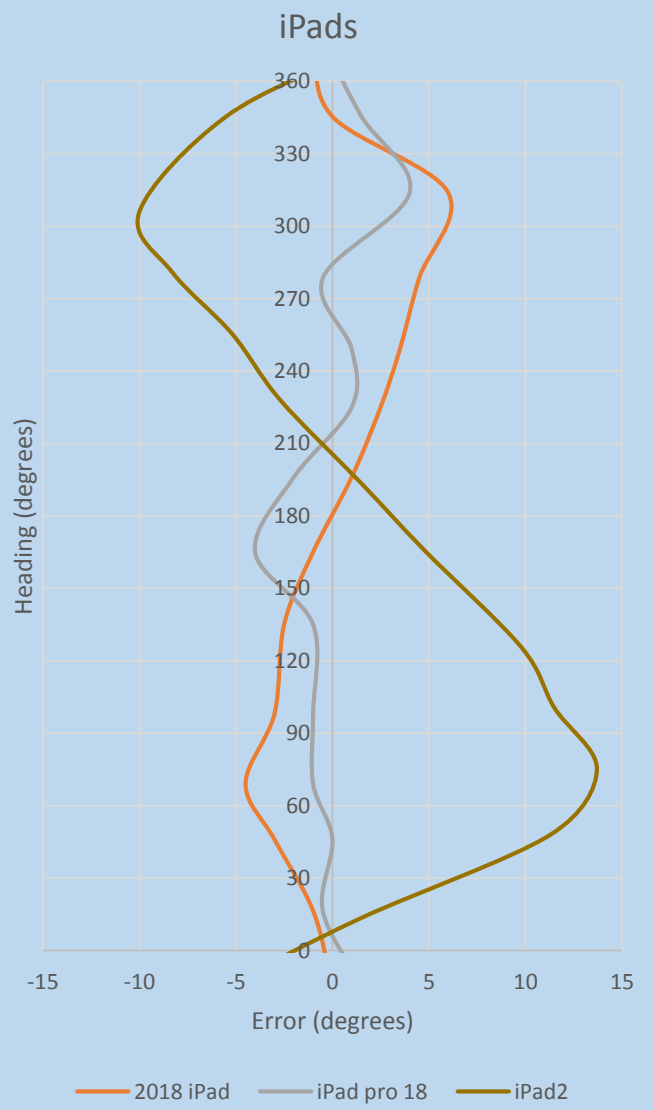
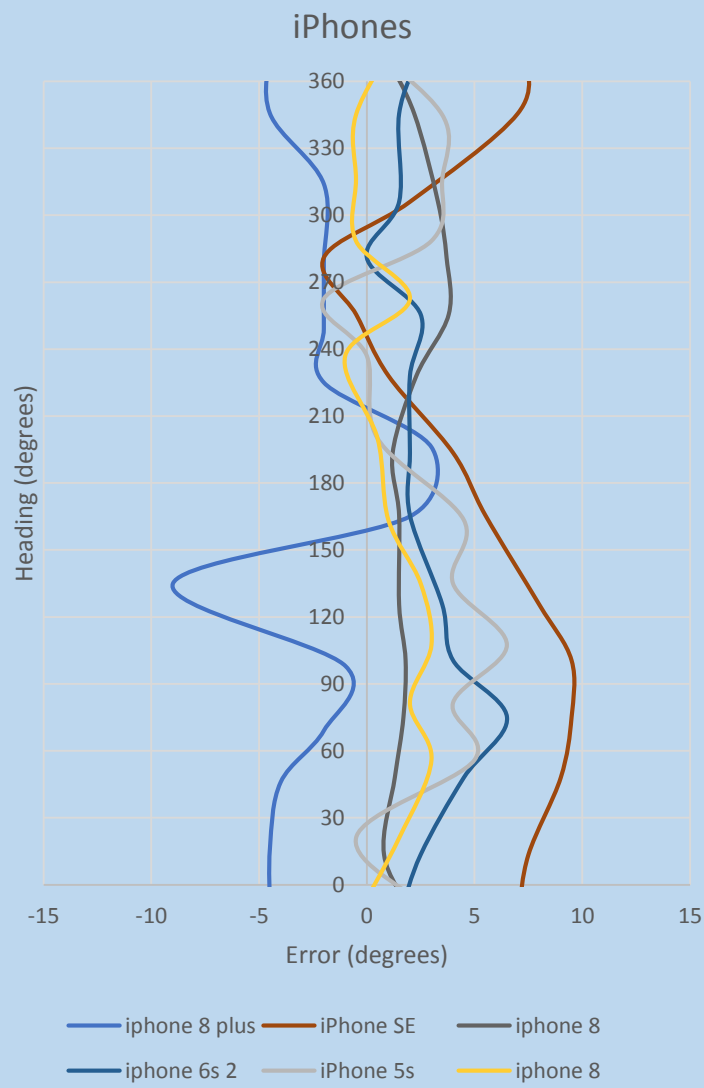
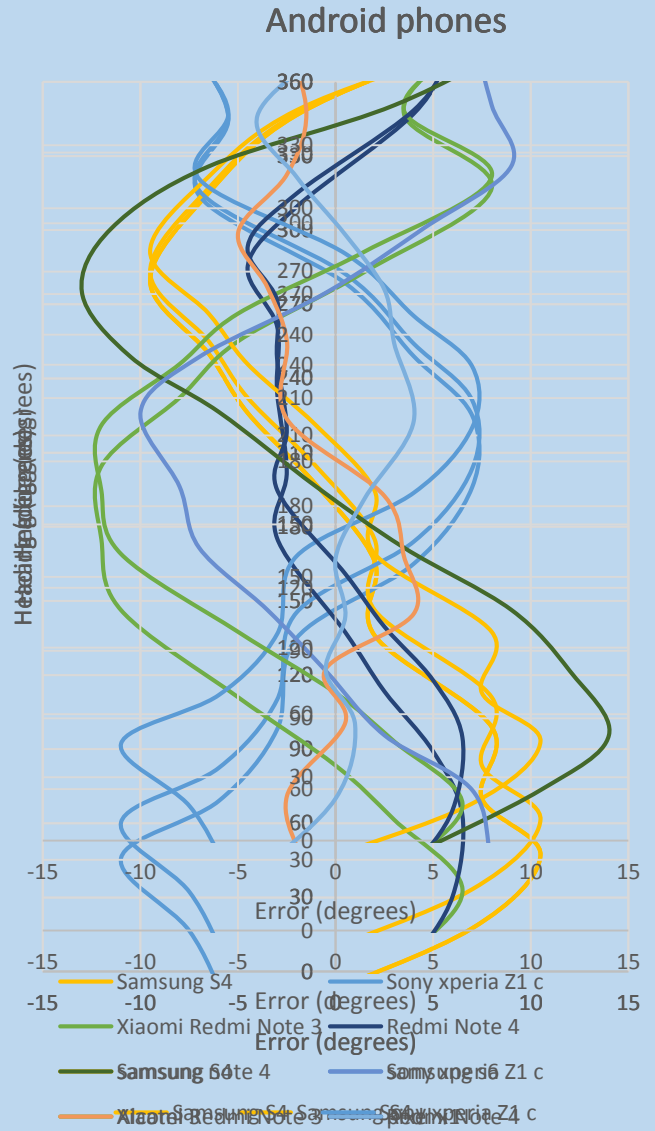
- Classic operation of “swinging the compass”
- Measure “deviation” by comparing compass reading with series of known directions
- “Deviation curve” shows deviation against direction (aspect)
- Not a simple linear error
  - Known since 18<sup>th</sup> century to be harmonic curve
    - “soft iron” – period of 360°
    - “hard iron” (magnetised) – period of 180°
    - Linear offset
    - Multiple contributions
      - Including currents flowing within device!

# Experimental Design

- A dozen markers placed round cricket field
- Bearings measured by compass and sextant
- Subjects sit on plastic stool
- Measure bearings to markers



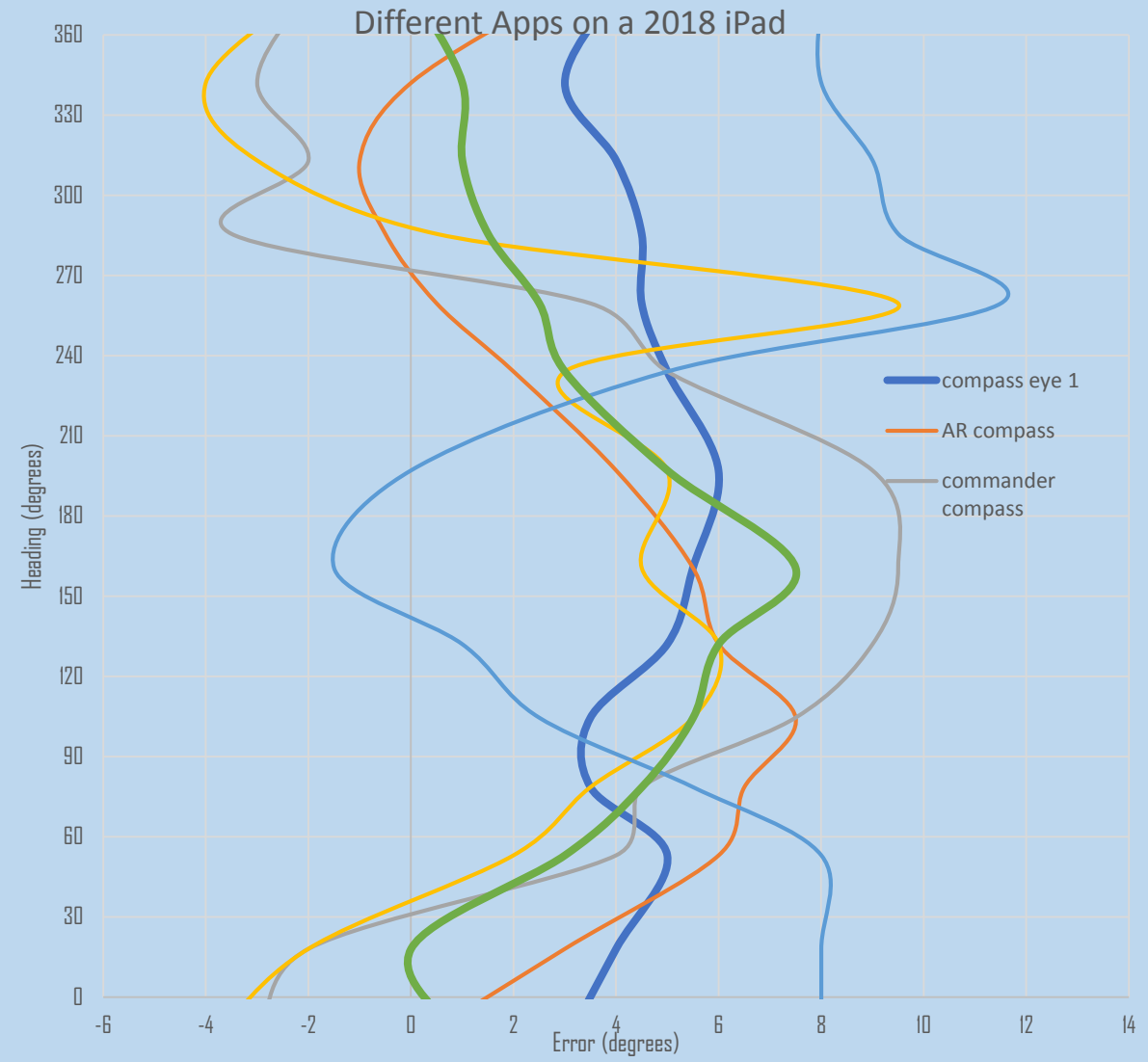
# The results – for “calibrated” devices



# Calibrated data

Android				iPhone			
	offset	amp	RMSE		offset	amp	RMSE
Samsung S4		10.00	6.37	iPhone 8 plus	2	6.00	2.99
Sony Xperia Z1 c	-2	9.00	5.81	iPhone SE	5	5.75	3.89
Redmi Note 3	-2	10.00	6.94	iPhone 8	2	1.50	0.96
Redmi Note 4		5.50	3.91	iPhone 6s	3	3.25	1.65
Samsung Note 4		13.50	9.32	iPhone 5s	3	4.25	2.47
Samsung S6		9.50	6.42	iPhone 8	1	2.00	1.40
Alcatel 3	-1	4.50	2.76				
Pixel x1		4.00	2.15				
<b>mean</b>	<b>-1.67</b>	<b>8.25</b>	<b>5.46</b>	<b>mean</b>	<b>2.67</b>	<b>3.79</b>	<b>2.23</b>
median	-2.00	9.25	6.09	median	2.50	3.75	2.06

# And different apps on the same device...



# Uncalibrated data

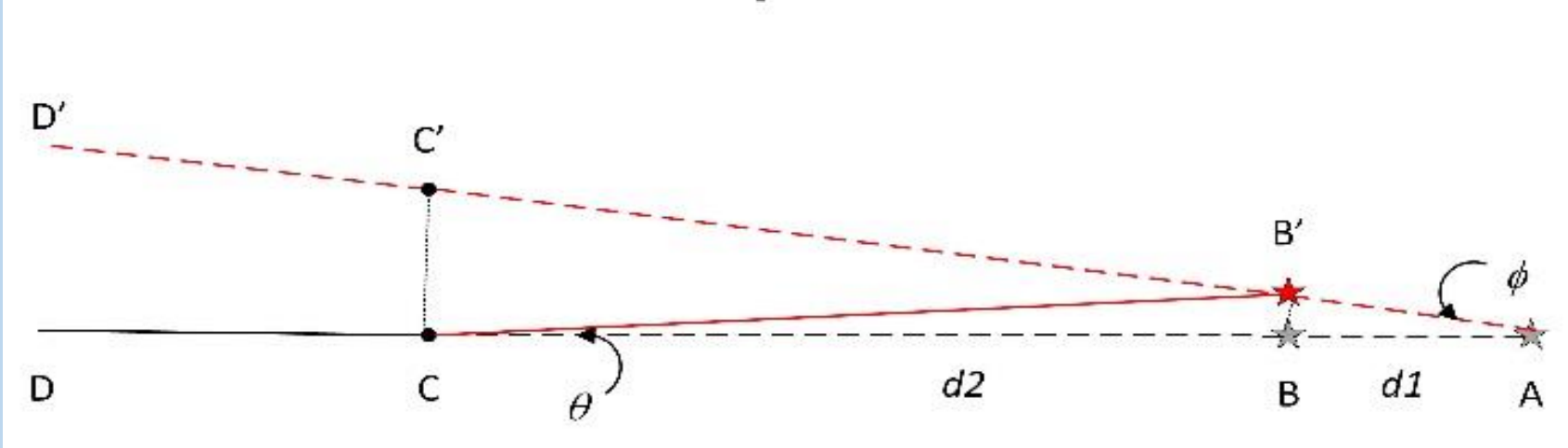
iphones			
	offset	amp	RMSE
iPhone 8 plus		2.25	1.17
iPhone SE	7	4.25	2.93
iPhone 8	22	117.5	99.37
iPhone 6s	5	3.75	2.70
iPhone 5s	3	7	3.34
iPhone 8	96	6.25	4.59
<b>mean</b>	<b>26.60</b>	<b>23.50</b>	<b>19.02</b>

# A couple of comments

- Calibration –
  - “figure of 8” motion
    - Not a very definitive algorithm...
  - Comparison of change in compass “reading” with gyro/accelerometer
  - Can detect inconsistent rotational measurements, but not linear offsets
  - Appears not to persist...!
- Fabrication
  - No guarantee that true 3 axis compass
  - 2D compass is normal silicon fabrication
  - Third dimension *may* have different characteristics
  - May explain difference between Android and Apple (/Google)

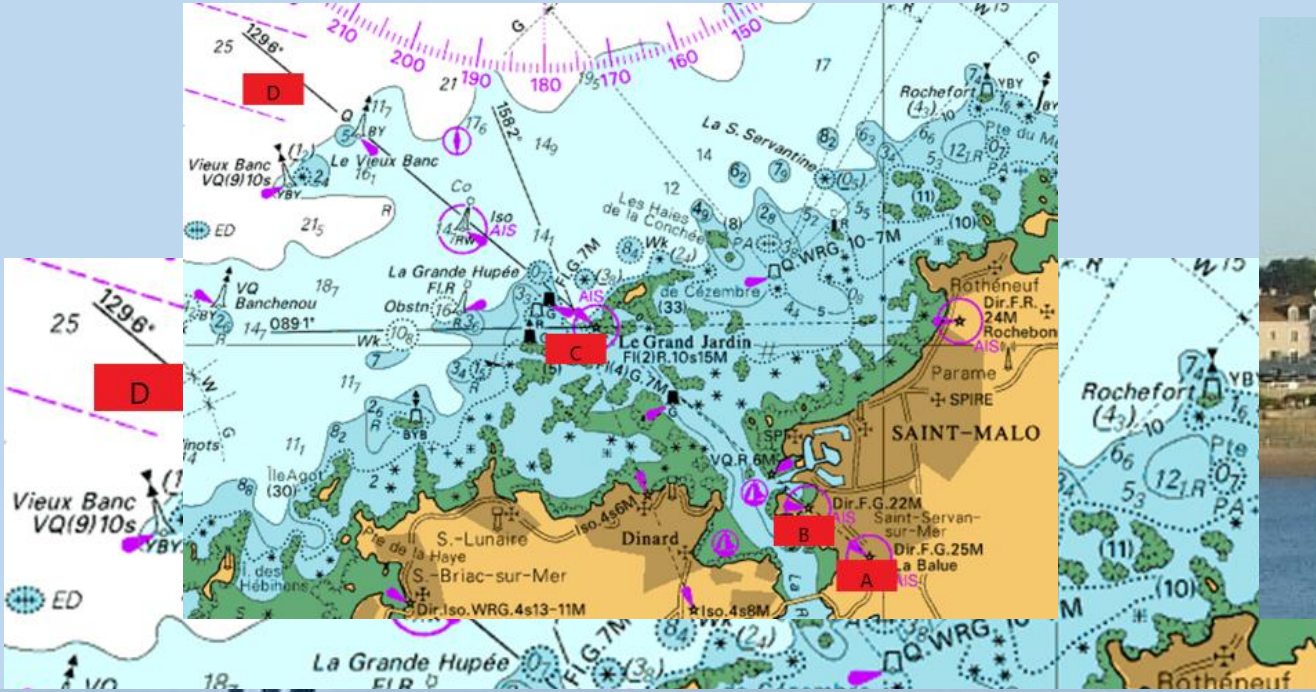
# Does it matter?

- One key use of landmarks is to define a leading line (approach vector)



- Leading (approach) line from ~D to C
- Using the approximation  $\tan \theta \approx \theta \approx \sin \theta$ , for  $\theta$  less than about 0.1 radian
- Error in identifying front mark B due to compass error  $\theta$  gives error in leading line  $\phi$ , where

$$\phi \approx \theta \cdot d2/d1$$



# So – what do we need to solve?

- Want to place annotations / markers
- Limited / no possibility of registration
- Significant / unknown / varying compass errors
- Hence, markers almost certainly in wrong place
  
- Likely to use AR only when unfamiliar with location
  - Wrongly positioned markers could lead to major navigation errors
  
- This is a **real safety risk**
  
- How should we represent / manage the errors?



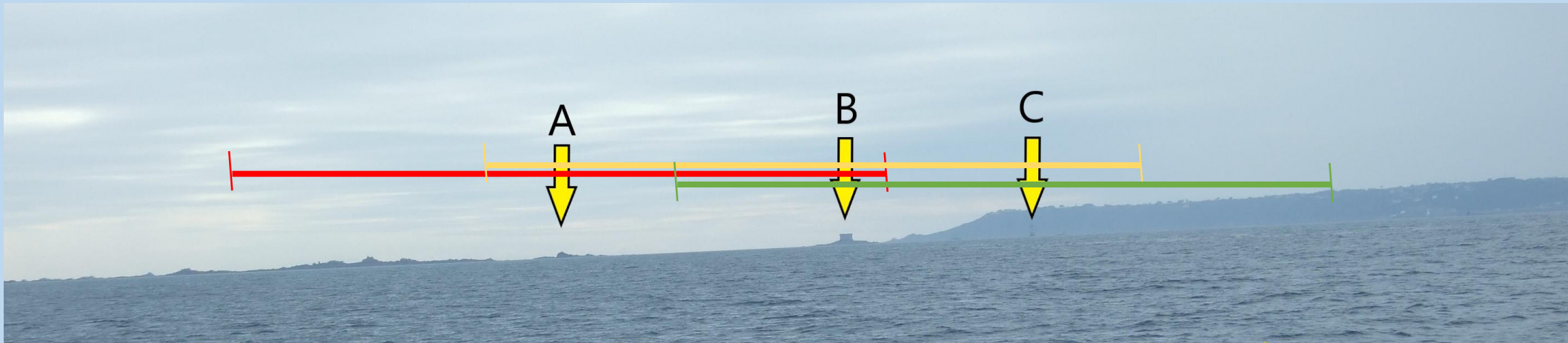
# Approaching St Peter Port (CI)

- Pale blue/white – probably enough water to float
- Green – rocks – call the RNLI
- Yellow – land – call the AA
- Interested in three landmarks
- Separated by only a few degrees (from current position)
- Not a lot of scope for error



# Representing the errors

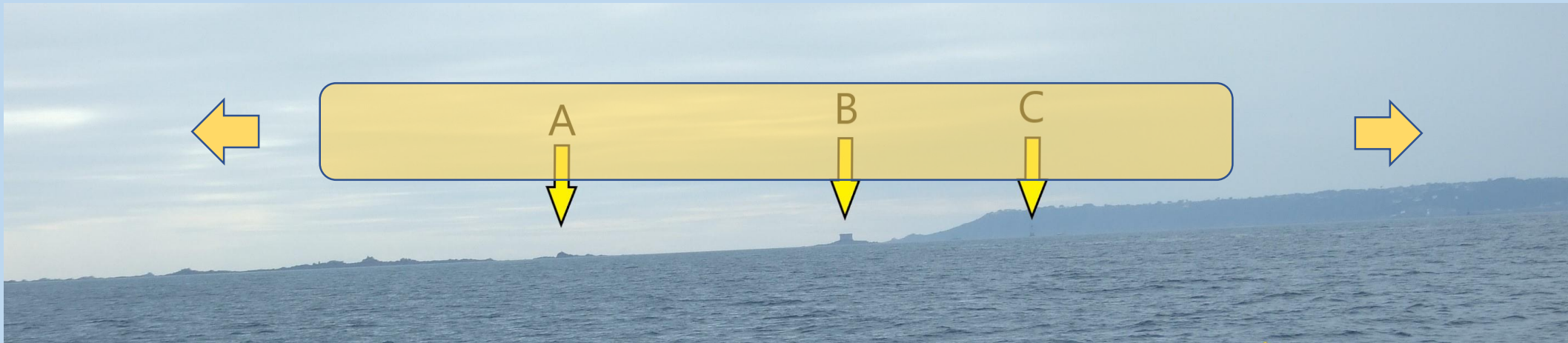
- Use error bars?



- Error bars will probably overlap...
- And, in any case, error is unknown
- But – errors *are* correlated
  - The deviation is the same for each landmark for a given aspect

# Representing the errors

- Connect markers using Yoke

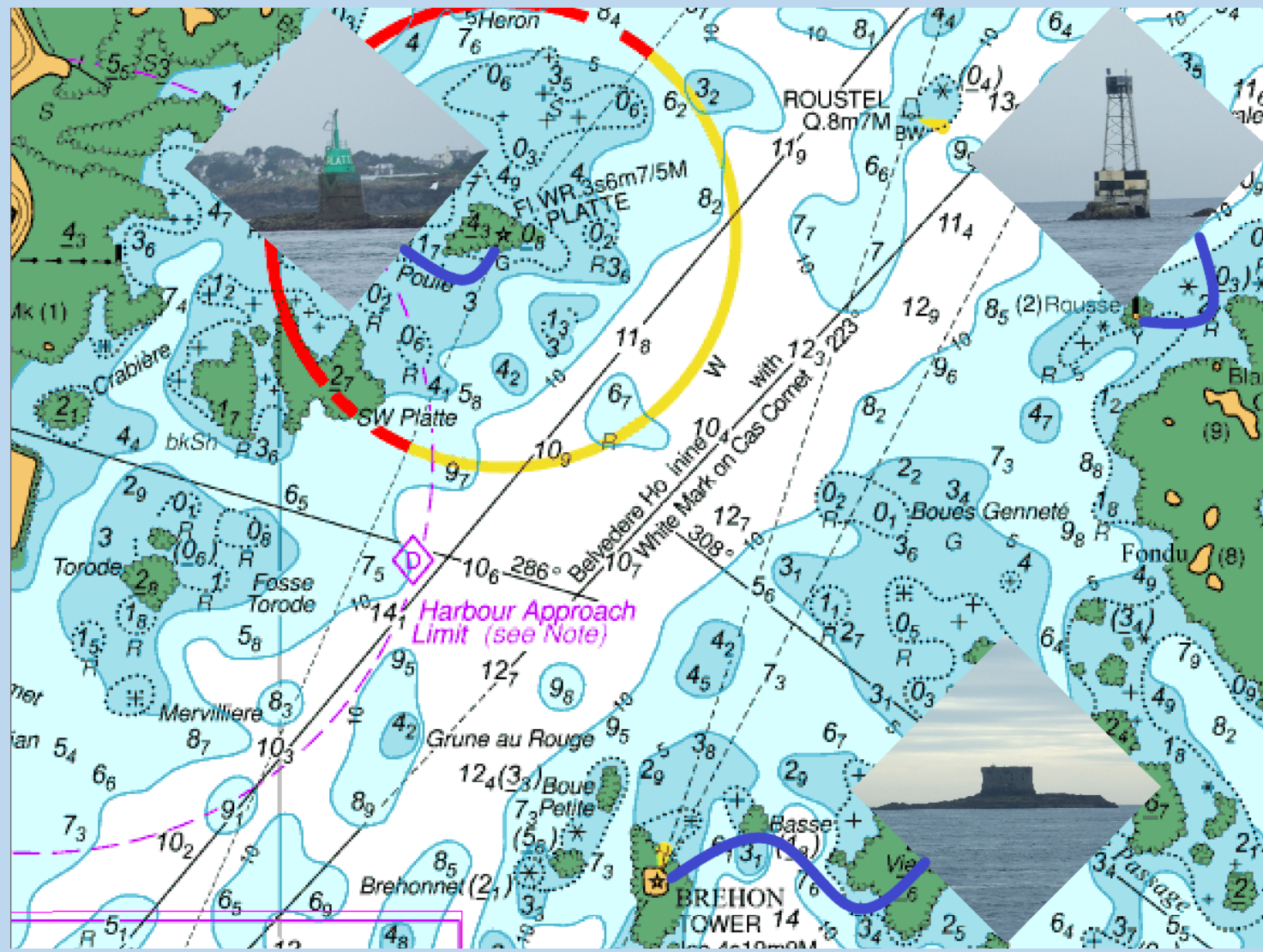


- Nudge arrows to align one of the markers visually
  - (while holding the thing still...)
  - In which case the others will also be correct
  - But only for that aspect

# Aligning the markers

- Bring the human into the equation
  - Harness remarkable ability of humans to recognise objects
  - Avoids “head-down” navigation (major concern for RNLI...)
- Display image(s) of landmark(s)
  - Where?
  - When?
  - Which?
    - Selected or automatic?
    - How respond if change aspect of device?

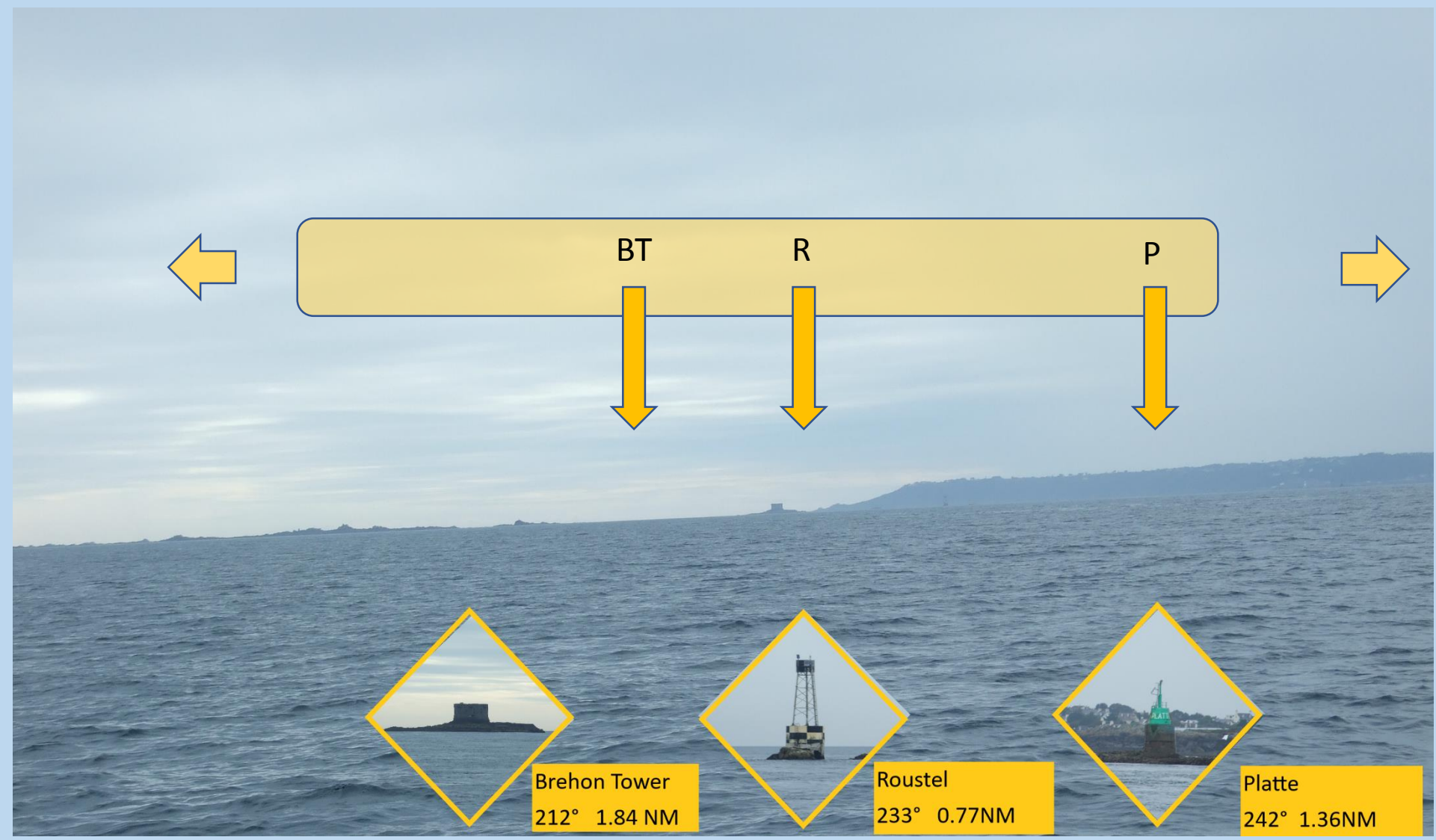
# Pop-ups on chart?



# Inset in display image?



# Combine with “yoked” markers



# Questions to explore

- Overall format of display
  - Usability
  - Non-ambiguity
  - Robustness
- Reference images
  - Direction
  - Lighting conditions
  - Weather (visibility etc.)
- User-centred approach essential

# Conclusions

- Mobile Augmented Reality offers impressive technical opportunities
- BUT has to rely on internal sensors if registration not feasible
  - Only sensors available for marine navigation – gps and compass
  - Compasses really are inaccurate
- Users need to understand better limitations intrinsic to devices
  - And developers must design apps (including navigation apps) appropriately
- Limit impact of intrinsic errors by working with users
  - not just providing on plate
- Exploit human ability to recognise objects
  - will also avoid “head-down” navigation

Thank you