

Motion quality of mobile displays

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Contents

- Portability, screen size, devices with large field of view
- Application categories
- Graphical user interface and its legibility
- Luminous environment
- Necessary resolution for moving images
- Motion quality and spatio-temporal display characteristics
- Objective evaluation and metrics of motion quality
- Conclusion

Portability

- Low weight
- Pocketable footprint
- Screen area relative to device area
- Max 4" 16:9 or 4.5" 2:1
- Viewing distance: 300-400 mm
 - Field-of-view: $7.1 \sim 9.5 \times 12.6 \sim 16.8$ deg



Portable devices with large field of view (FOV)

FOV: > 30 x 15 deg



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Applications that require high motion quality

- Map browsing/navigation
- Augmented reality
- Internet browsing (page scroll)
- Games
- Video and TV (?)
- Rendering speed: 30 → 60 FPS
- Scroll speed: 10-15 px/frame (PPF)
- Quality limited by video compression and low frame rate



Navigation and map browsing

- Free navigation bundled with most Nokia products from 2010
- Car and pedestrian use
- Voice guidance, search, position sharing via Facebook etc
- Automatic information update on events, traffic, weather, travel guides (eg Michelin)



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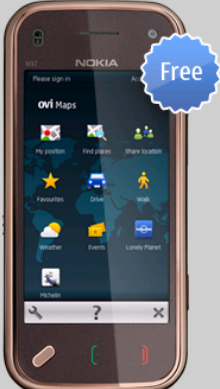
Mobile navigation for everyone
Ovi Maps takes you where you want to be and shows you what you want see, with navigable maps for over 70 countries worldwide. All this with only one click. **And it's all free.**

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- Free Lonely Planet guides
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And much more

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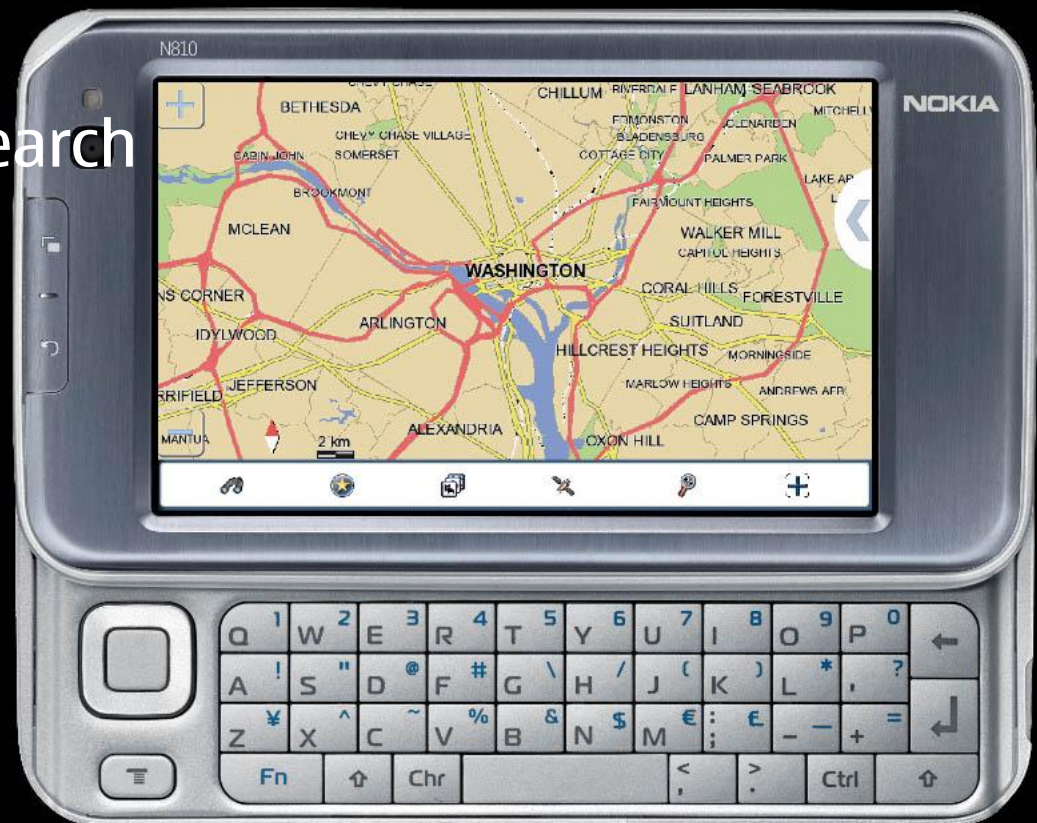
Compatible devices: Nokia X6 32GB, Nokia X6 16GB,



<http://maps.nokia.com/>

Map browsing

- Target: same browsing experience as on a paper map
- BUT: Max screen size 4-5”
- Serendipitous vs targeted search
- Scroll operation necessary
- Small text legibility an issue



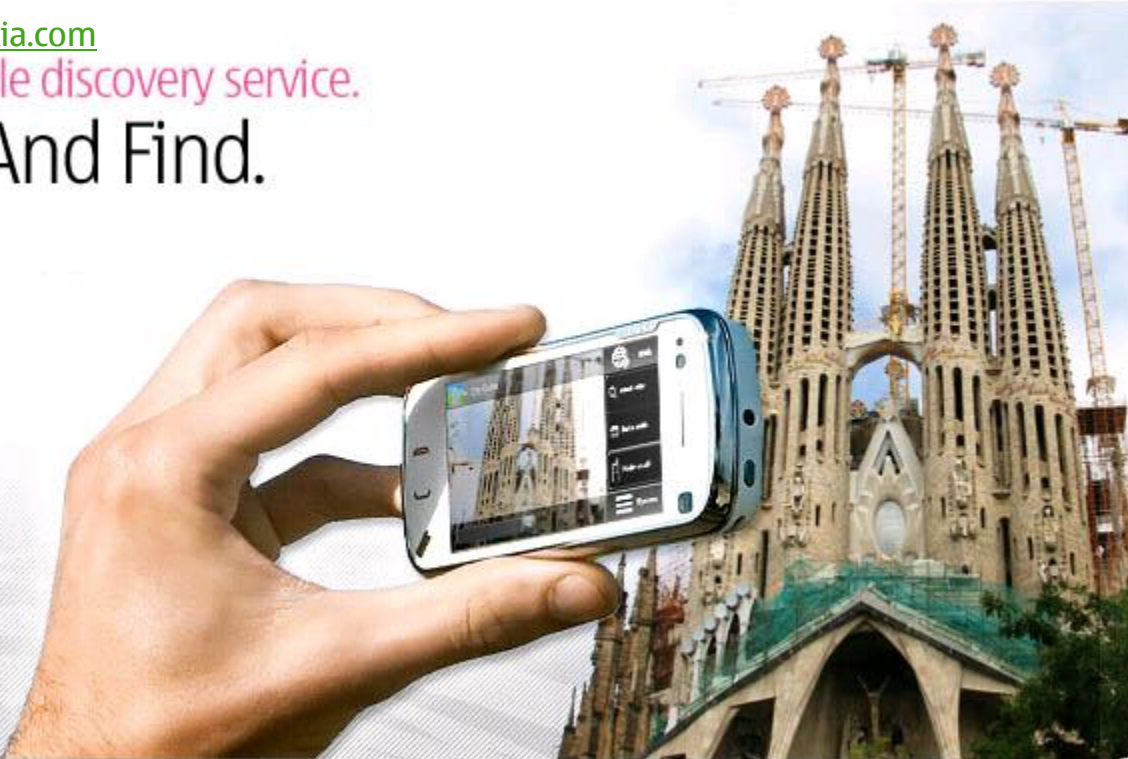
Map browsing with 60 fps rendering



Mobile augmented reality

<http://pointandfind.nokia.com>
The ultimate mobile discovery service.
Just Point. And Find.

▶ Play Video



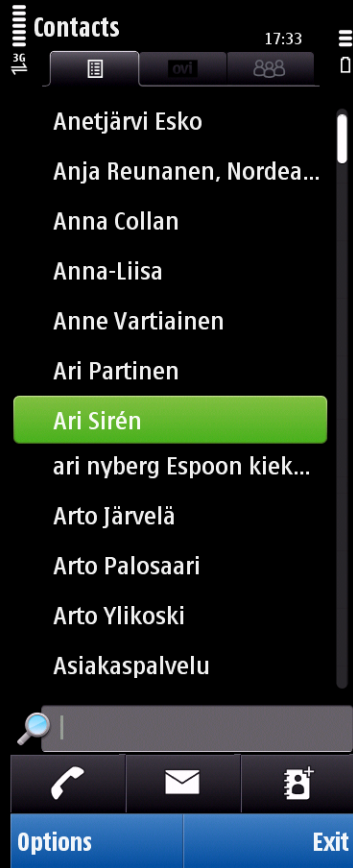
- Goal: reality experience
- Window-like feeling
- Transparent displays?
- 60 fps viewfinder
- High motion quality display

Example of mobile augmented reality



http://studierstube.icg.tu-graz.ac.at/handheld_ar/media/WWSignpost_DivX_20Mb

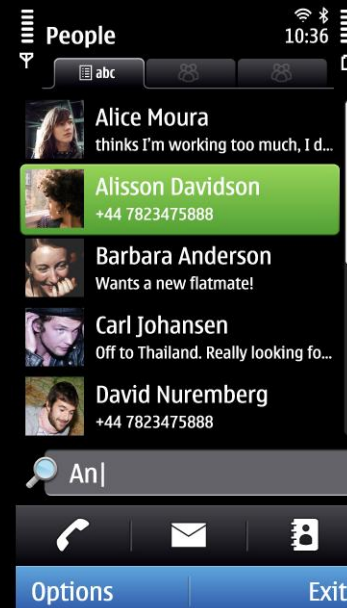
Example of touch UI



Contacts



Album

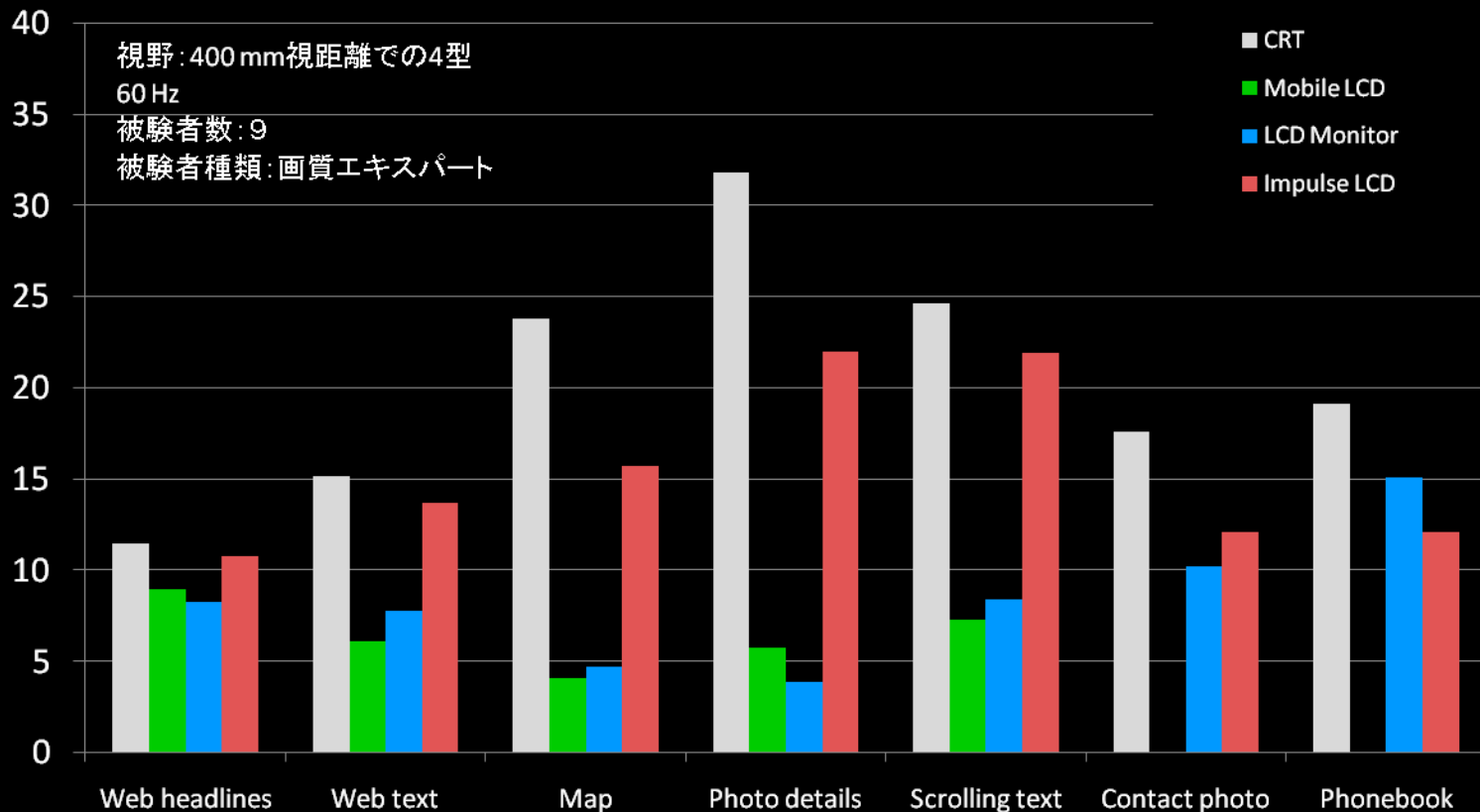


Contact photos

Moving image legibility for different technologies

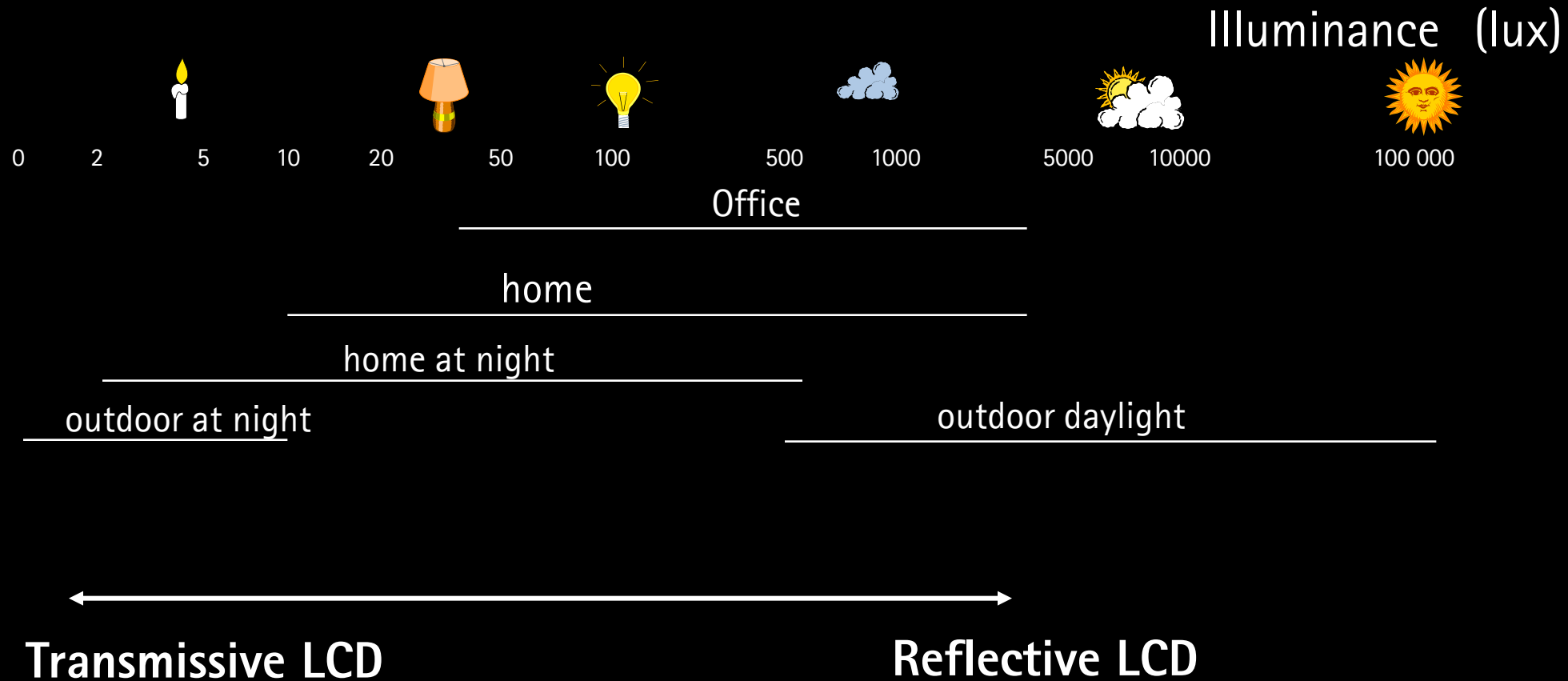
Maximum scroll speed (PPF) with legibility

最大スクロール速度 (PPF)

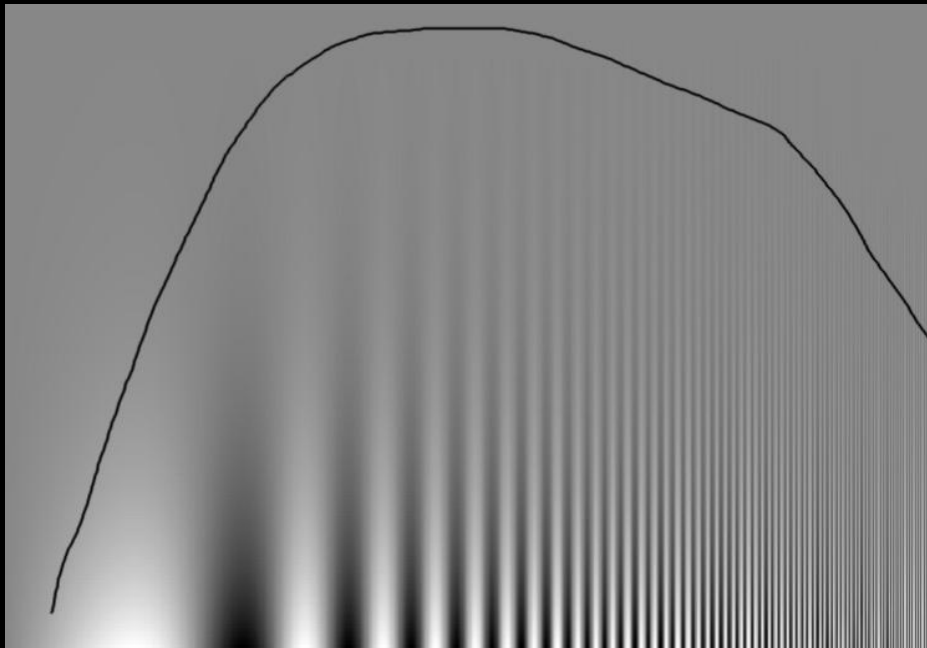


- CRT, impulse-LCD: scroll speed limits legibility
- Mobile LCD, LCD monitor: display blur limits legibility

Luminous environments of mobile device use



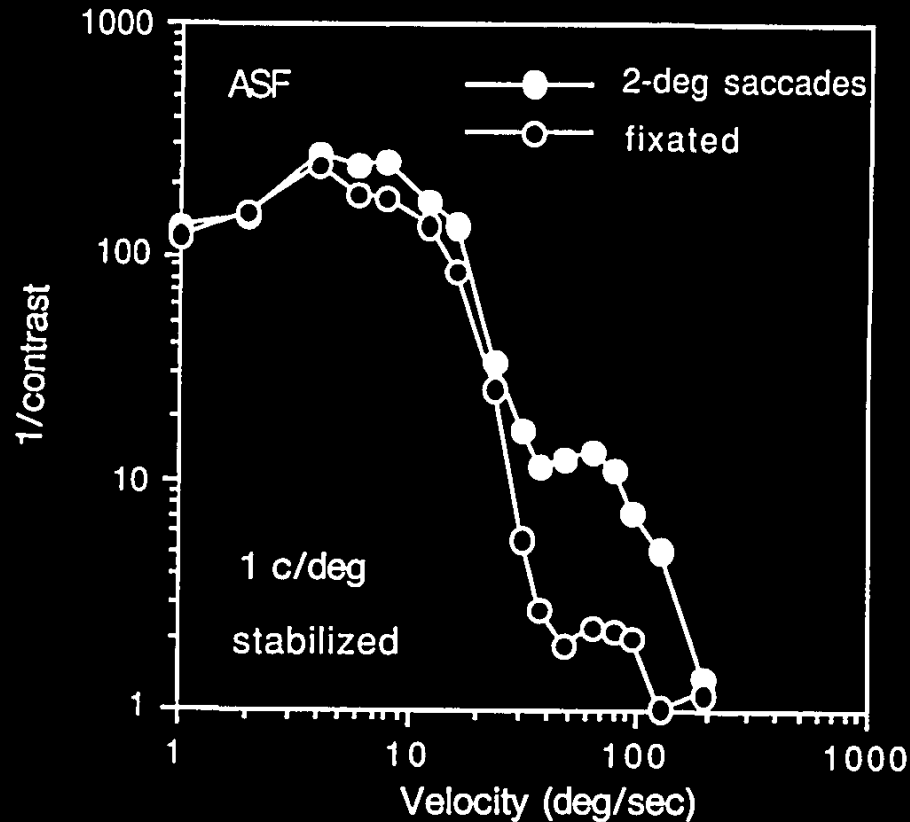
Resolution reduction at lower lightness contrast



Contrast sensitivity function

- Surface reflections from touch panel, protective windows etc
- Highly reflective industrial design
- Highly reflective background (eg snow, beach)
- Adaptation from spots in FOV that are brighter than display
- Reduction in lightness contrast

Contrast reduction by motion

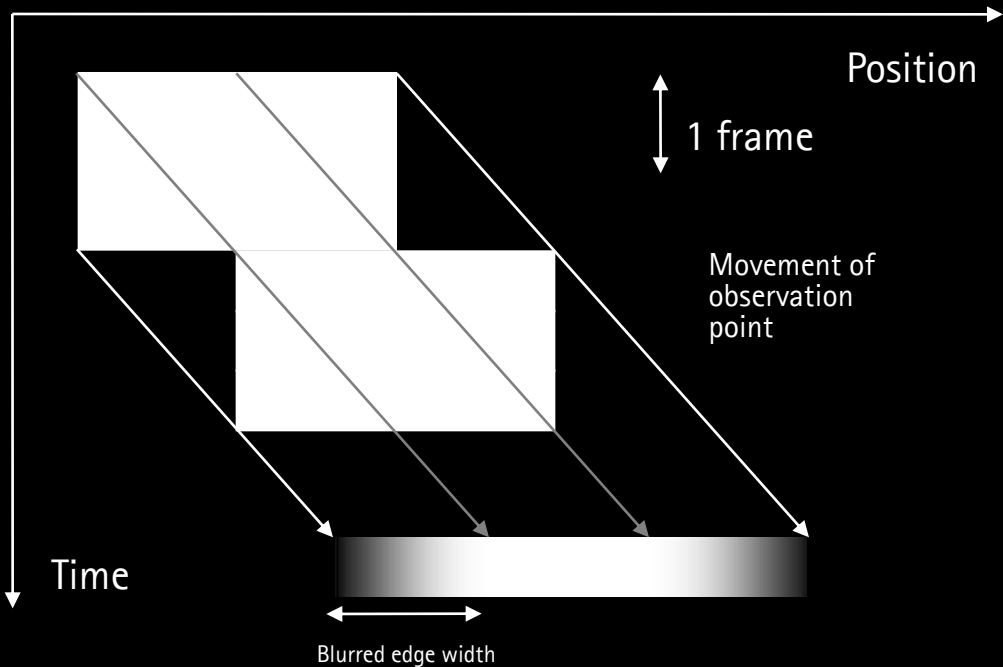


D.H. Kelly, "Moving gratings and microsaccades",
Journal of the Optical Society of America A, 7(12),
2237-2244 (1990)

- 4" display viewed at 400 mm
- Web/map browsing: 15-20 deg/s
- TV: 5-6 deg/s (average in Japan TV)
- Game: > 20 deg/s
- Large FOV devices: >30 deg/s
- Sufficient resolution for moving content: ~150 PPI
- Still image, text: 200-300 PPI

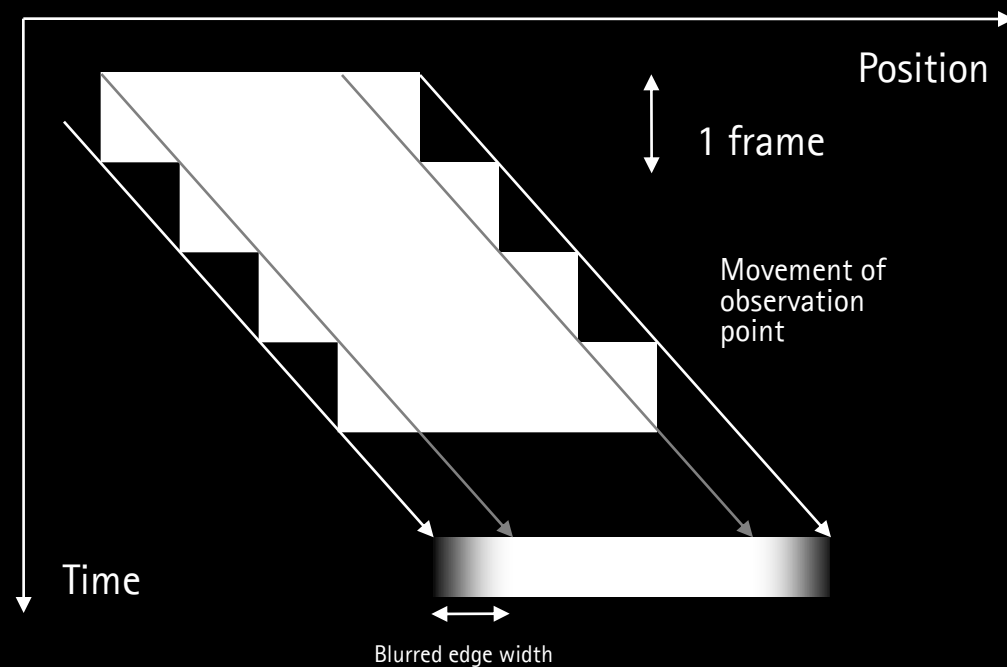
Sampling rate and eye-pursuit motion blur

30 Hz sampling, 60 Hz refresh



Observed image

60 Hz sampling, 60 Hz refresh

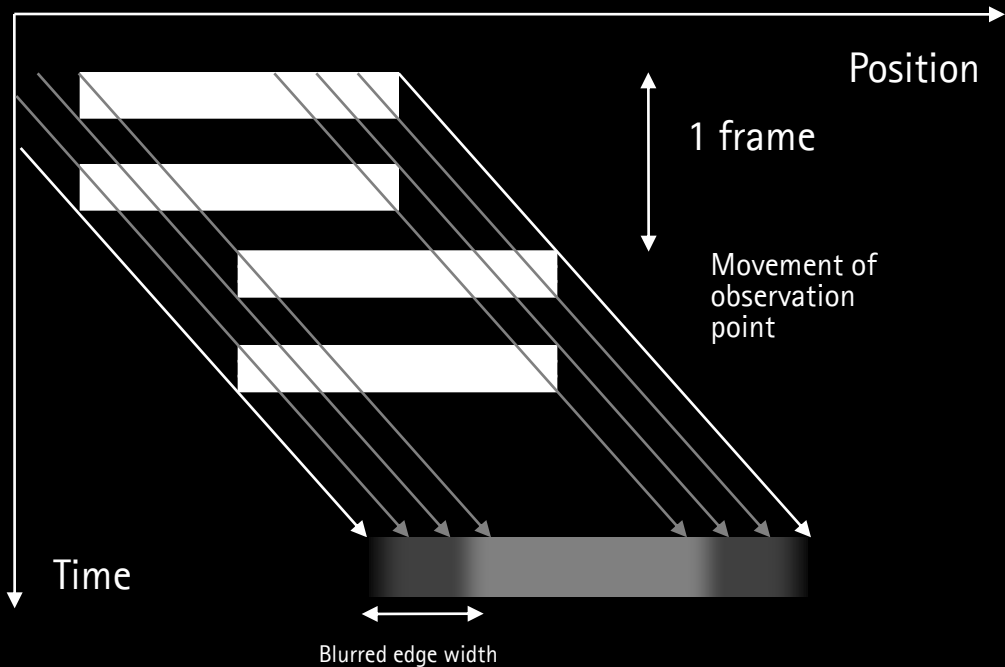


Observed image

Continuous motion anticipated by the eyes – intensity averaging along the arrows

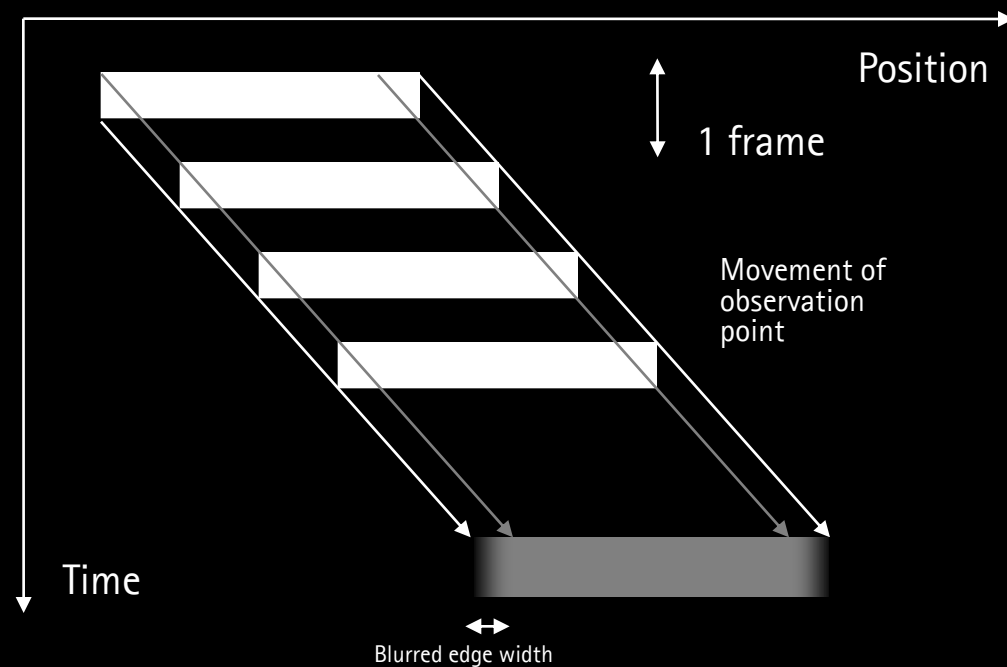
Black field insertion and eye-pursuit motion blur

30 Hz sampling, 60 Hz refresh, 50% BFI



Observed image

60 Hz sampling, 60 Hz refresh, 50% BFI



Observed image

Continuous motion anticipated by the eyes – intensity averaging along the arrows

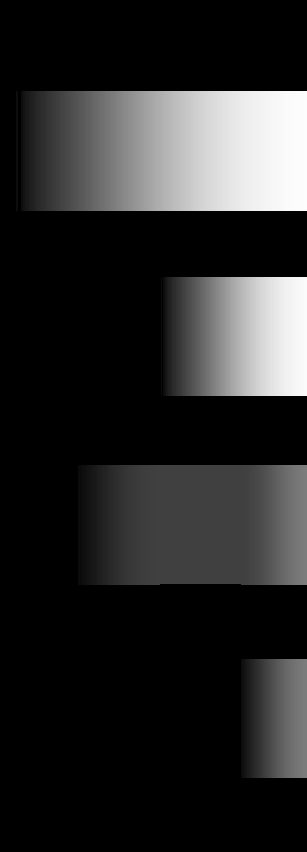
Comparison of blur edges for different drivings

30 Hz sampling, 60 Hz refresh

60 Hz sampling, 60 Hz refresh

30 Hz sampling, 60 Hz refresh, 50% black field insert

60 Hz sampling, 60 Hz refresh, 50% black field insert



Text readable at 6x higher scroll speed on a CRT compared to an OLED !

Evaluation by moving image resolution

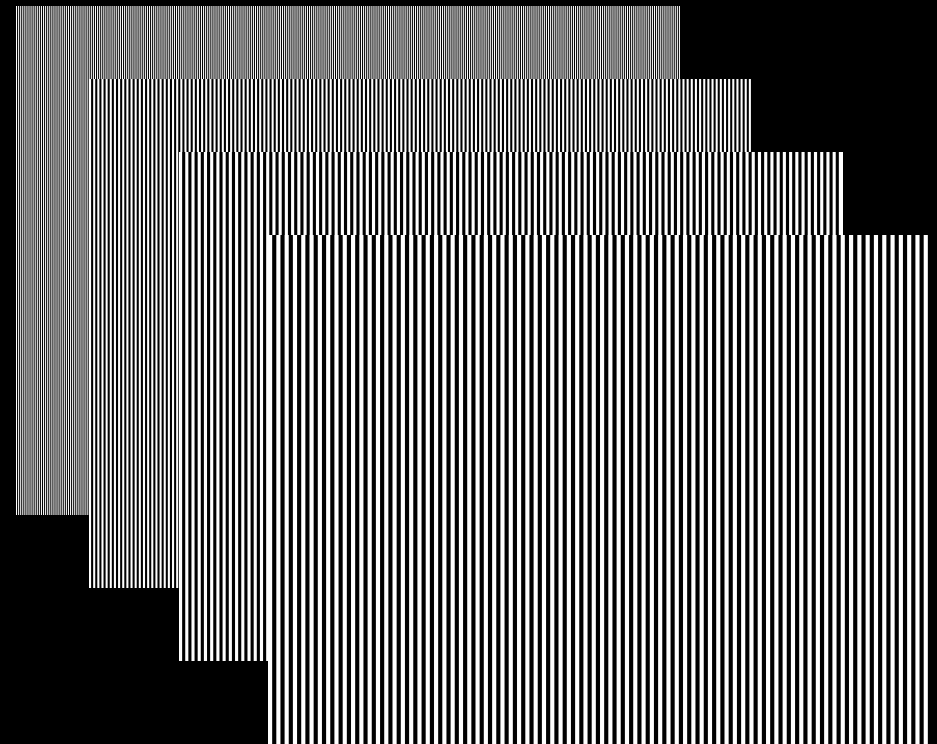
- Resolution def 1: pixel density, pixels/dots/lines per inch
- Resolution def 2: Resolution at some min. contrast modulation
- Correlation with subjective resolution
- Useful for both still and moving images → more intuitive metric than response time [ms] or blurred edge width [px]

Moving image resolution - issues

- Response time/curve depends on LCD start/end grey levels
- Motion on retina (angular scroll speed) must be defined – dependence on screen size and viewing distance
- Apply test patterns relevant to contents and scroll speed

Existing metric: effective resolution

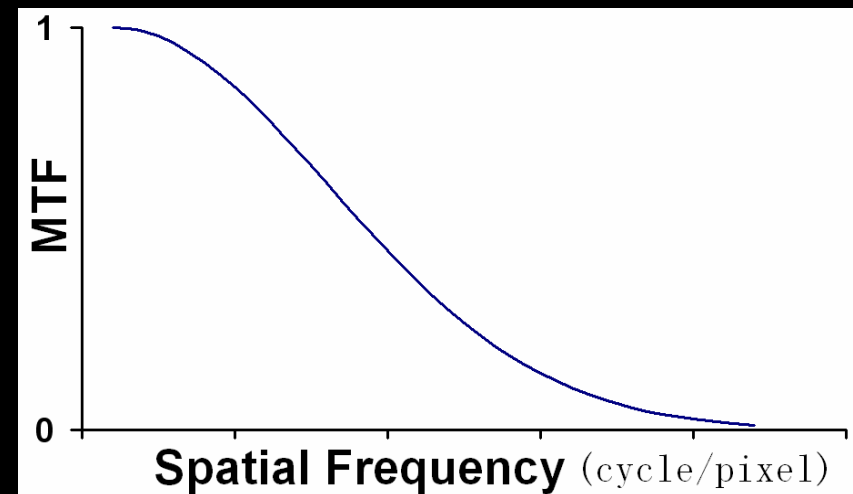
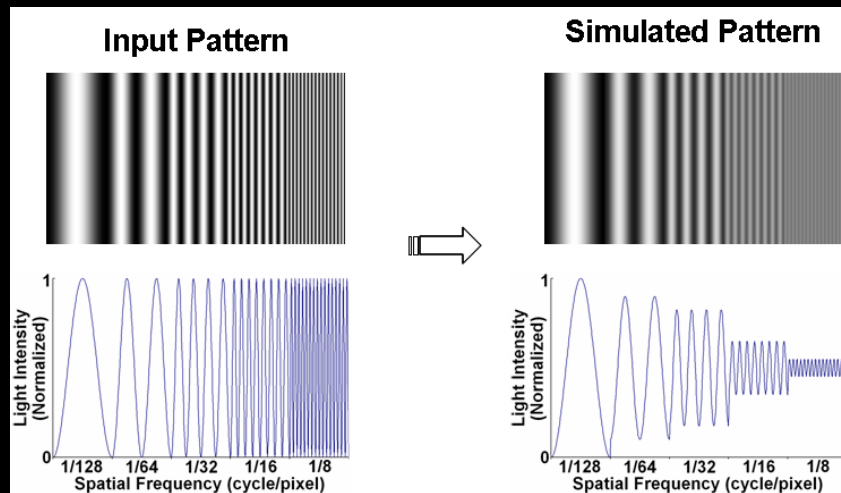
- Contrast modulation as a function of spatial frequency (number of lines)
- Threshold depends on task: text, photo, video,...
- Effective number of pixels = $1/n_r$ x number of display pixels



Example of grilles

Resolution dependence on gray level dispersion

- Black/white grille pattern → sinusoidal pattern
- Display pixel count a limitation for direct measurements – works best for HDTVs (1920x1080)
- Can also be obtained from pixel temporal response, retinal averaging, and blur simulation of a sinusoidal image



Courtesy of Prof Xiaohua Li, Display Research Institute, South-East University, China

Summary

- Field of view on par with that of living room TV
- High motion quality necessary for kinetic touch UI, augmented reality, map browsing, and navigation
- 120 fps rendering/frame interpolation challenging in mobile devices
- Impulse driving makes high-speed scrolled images crisp
- Resolution is a valid metric also for moving images