# Geocoding

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# Definitions

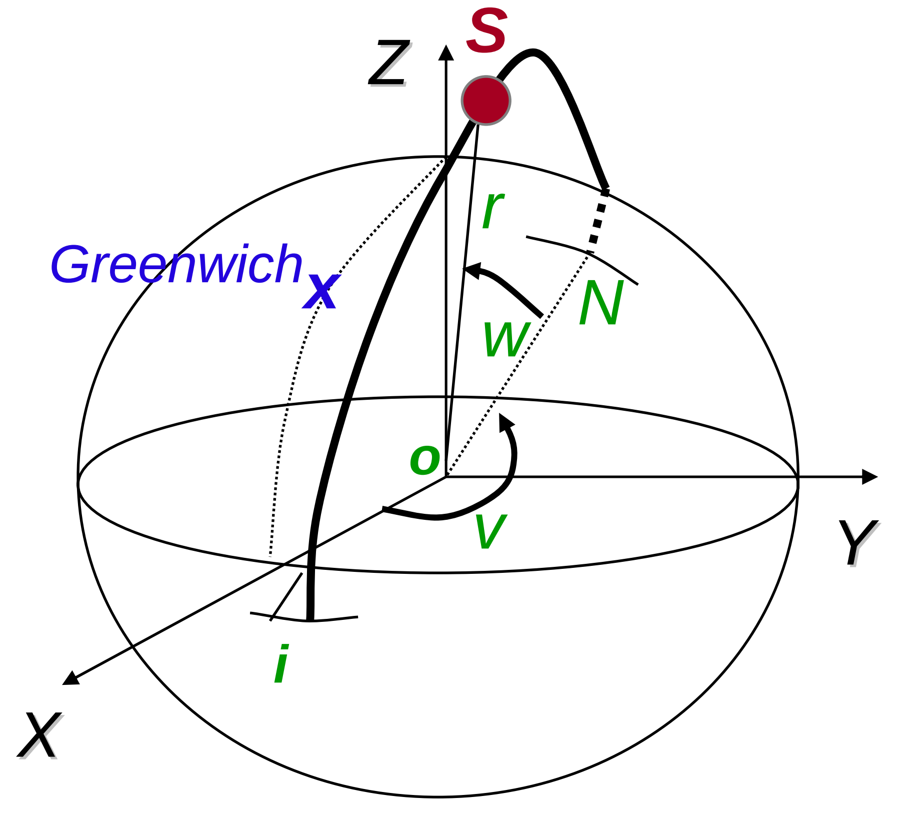
- geocoding
  - geometric transformation of an image into a cartographic map projection
- georeferencing
  - relating image coordinates to map coordinates by defining control points (usually image corners)
- geometric correction and image rectification are sometimes used synonymously
  - geocoding maybe part of geometric correction

# Geocoding by co-registration

- image to image
  - reference needs to be map projected
- image to map
  - map in raster or vector format
  - map needs to have map coordinates
- image with measured ground control points
  - ground control points (GCPs) need to be identified in the image
  - GCPs need to be known in some map coordinate system

# Sensor Geometric Model

- Sensor Model
  - sensor specific
  - analytical reconstruction of image formation using orbit and sensor parameters
  - corrects image globally
  - small number of ground control points to improve parameters
  - DEM




Geocoding

# Examples for sensor model

- optical data
  - Landsat (level 1G)
  - MODIS (level 1B)
  - SPOT (level 2A and 2B)
- radar data
  - any beam mode

# Geocoding steps



- relation between image coordinates and geographic coordinates using image geometry
  - line / sample → latitude / longitude
- conversion of geographic coordinates into map projected coordinates
  - latitude / longitude → $x_{map}$ / $y_{map}$
  - choice of map projection and datum

# Geocoding steps

- determination of a transformation function to map image coordinates into projection coordinates
  - usually quadratic, at times cubic
  - linear least squares polynomial fit
- resampling using mapping function
  - determination of pixel value in the map projected using one of the interpolation methods

# Resampling

- transformation of image coordinates into projection coordinates using a mapping function
  - usually determined as a polynomial fit
  - accounts for user defined output pixel size
- determination of the resulting pixel value using an interpolation method

# Interpolation artifacts

- ringing
  - arises because most good synthesis functions are oscillating
- aliasing
  - caused by discrete sampling below the Nyquist frequency (i.e. not enough samples to reconstruct the image sufficiently)
  - visual signatures of aliasing are moiré effects and the loss of texture

# Interpolation artifacts

- blocking
  - arises when the support of the interpolant is finite
  - synthesis functions with sharp transitions (e.g. nearest neighbor) exacerbate this effect
- blurring
  - mismatch between an intermediate data representation and their resampled version (data too coarse)

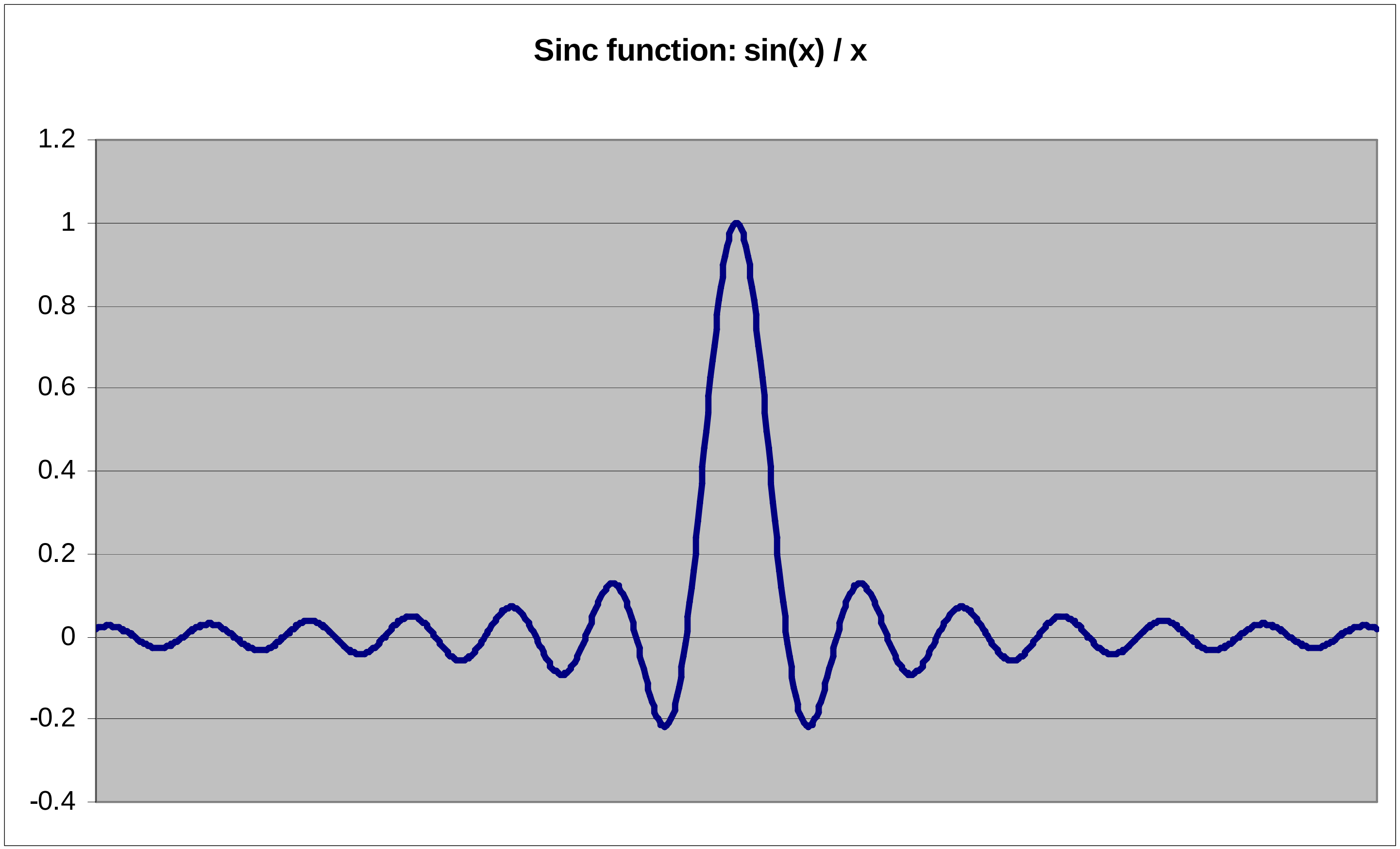
# Standard interpolation methods



- Nearest neighbor interpolation
  - takes pixel value closest to calculated location
  - preserves original pixel values
- Bilinear interpolation
  - weighted average (2x2 kernel)
  - smoothing effect
- Cubic convolution
  - third degree polynomial fit (4x4 kernel)
  - essentially low-pass filter

# Interpolation using Sincs

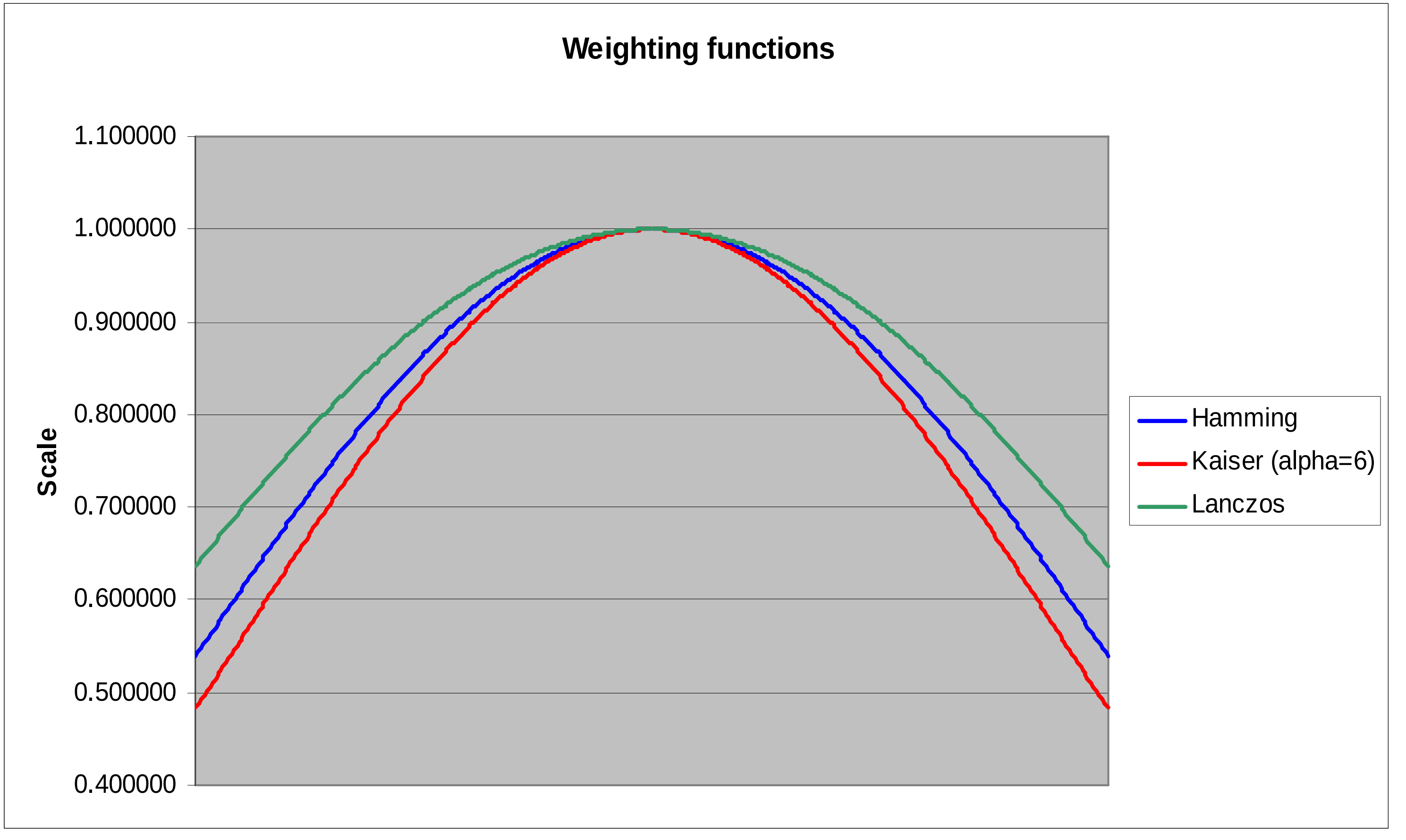




# Interpolation using Sincs

- theoretically ideal filter
  - provides error-free interpolation of the band-limited functions
- problem: no function can be at the same time band-limited and finite-support
- solution: truncation
- practical problem: slowest of the slowest as it requires large kernel sizes

# Weighting functions



# Weighting functions

- Hamming

$$\text{Hamming}(x,\tau,\alpha) = \begin{cases} \alpha + (1-\alpha)\cos\left(\pi \frac{x}{\tau}\right) & for\,|x| < \tau \\ 0 & else \end{cases}$$

  - $\alpha$ usually 0.54
- Kaiser

$$Kaiser(x,\tau,\alpha) = \begin{cases} \dfrac{I_0\left(\alpha\sqrt{1-(x/\tau)^2}\right)}{I_0(\alpha)} & for\,|x| \le \tau \\ 0 & else \end{cases}$$

  - where *I0(x)* is the zeroth order modified Bessel function
- Lanczos

$$\text{Lanczos}\,(x,\tau) = \begin{cases} \dfrac{\sin\left(\pi \frac{x}{\tau}\right)}{\pi \frac{x}{\tau}} & for\,|x| < \tau \\ 0 & else \end{cases}$$

# Cubic B-Splines



- piecewise polynomial function of degree three
- very good approximation of sinc function
- generally as fast as cubic convolution

➔ best bang for the buck

# Example: Original image



Source: ITC

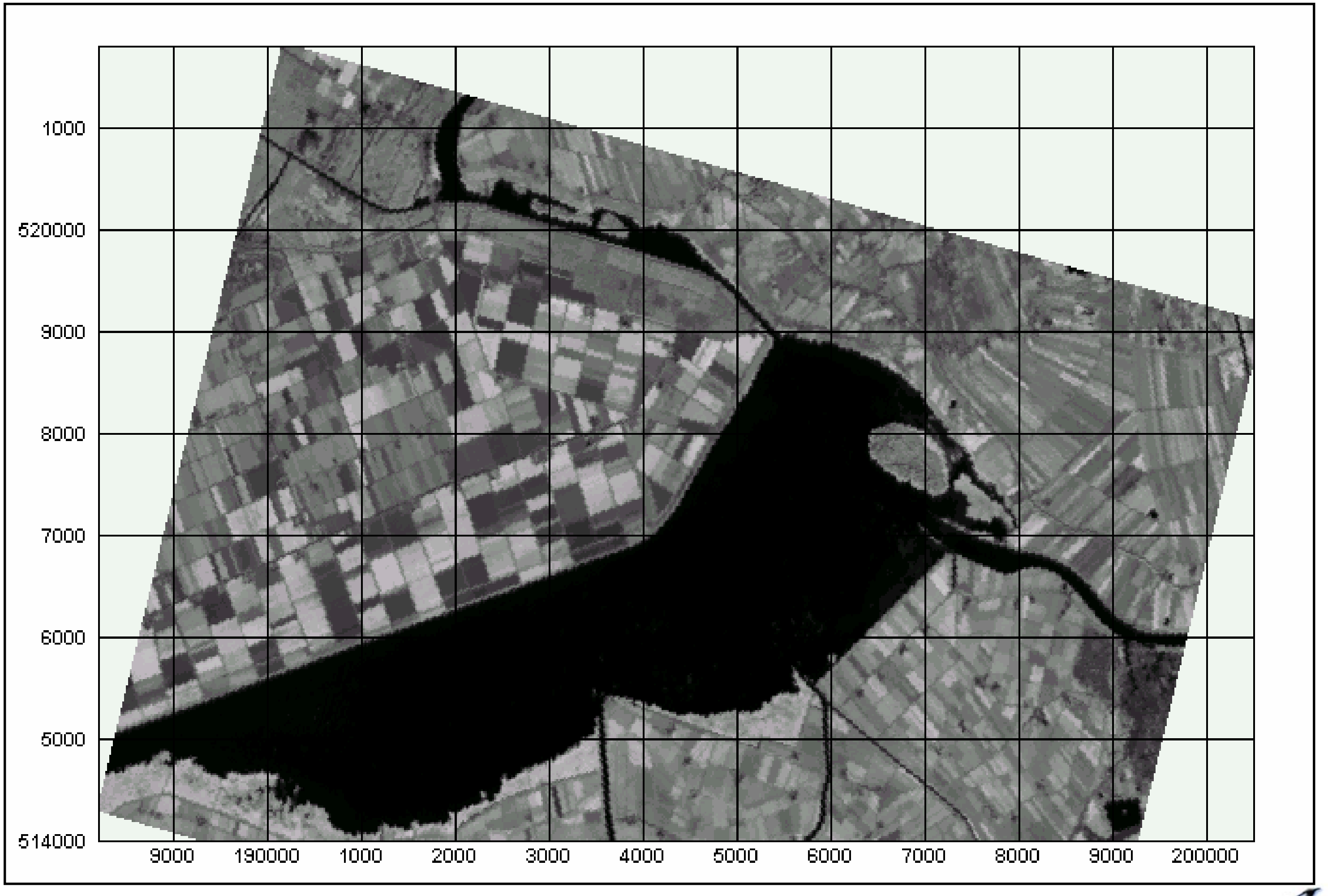
# Example: Transformed image



Source: ITC

# Example: Geocoded image

Geocoding




Source: ITC

# More background information

- image processing literature
  - medical imaging
  - astronomy
  - signal processing
- remote sensing data providers
  - product descriptions for the various satellite imagery

# Summary

- geocoding SAR data usually using sensor model
  - ease of use
  - alternative methods cumbersome – requires identification of control points
- trade-off between accuracy and speed
- cubic B-splines method of choice for interpolation