EE369C

Medical Image Reconstruction

Today

Course Mechanics
General Overview

Next Time

Models of MR Data Acquisition

Assignment

Review 369B Notes
CH 7.1-7.3
CH 8

9/25/2007

COURSE TOPICS

MODALITIES

- CT
- PET / SPECT
- MR
- ULTRASOUND

ISSUES

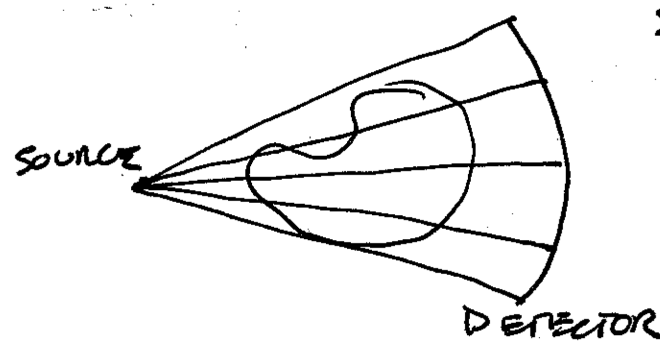
- SAMPLING
- INTERPOLATION
- MODELING + CORRECTION

CT RECONSTRUCTION

PARALLEL BEAM

FAN BEAM

MULTI-DETECTOR SPIRAL



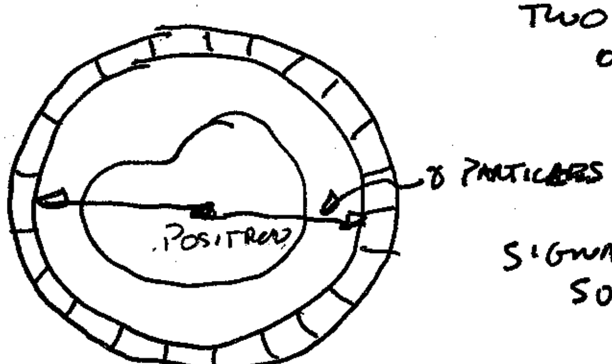
SIGNAL ~ ATTENUATION ALONG LINE

PROJECTION

PET RECONSTRUCTION

2D MULTISLICE

3D VOLUMETRIC



TWO PHOTONS, OPPOSITE DIRECTIONS

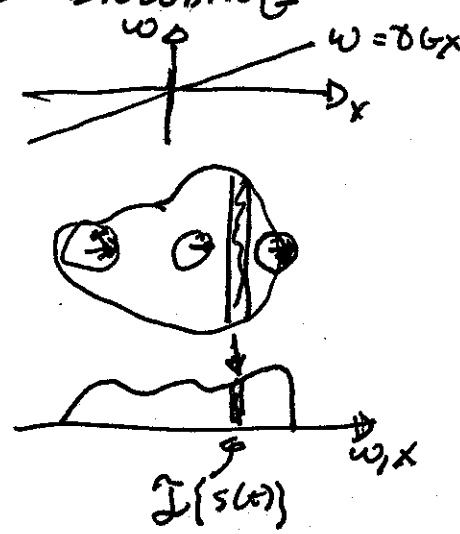
SIGNAL ~ SOURCE ALONG LINE

PROJECTION

MAGNETIC RESONANCE

GRADIENT ENCODING

RF ENCODING



$\mathcal{F}\{$SIGNAL$\}$ ~ # SPINS AT ω

⇒ # SPINS AT x

PROJECTION

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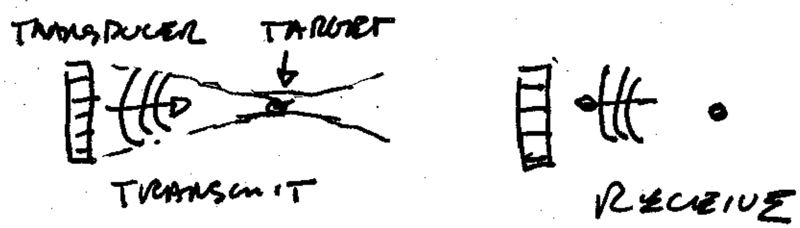
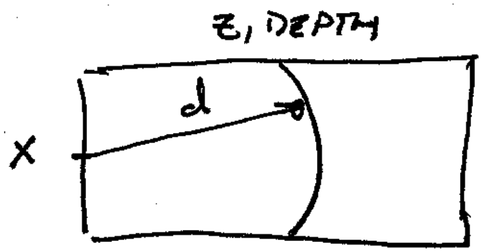
ULTRASOUND



SIGNAL ONE DETECTOR SEES



SIGNAL ~ ALL REFLECTORS AT DEPTH d

PROJECTION (ALONG A CURVED PATH!)

IN EACH CASE WE HAVE

$$\underbrace{s(t)}_{\text{SIGNAL}} \sim \int_{\underline{x}} \underbrace{m(\underline{x})}_{\text{SOURCE}} \underbrace{k(\underline{x}, t)}_{\text{KERNEL}} \, d\underline{x}$$

GIVEN $s(t)$

HOW DO WE GET $m(\underline{x})$?

SUCCESSFUL MODALITIES MAKE THIS EASY:

BACKPROJECTION FOURIER INTERPOLATION	} CT, PET
2DFT	} MR
BEAM FORMING	} ULTRASOUND

HOW HARD CAN IT BE?

VERY! (OPTICAL TOMOGRAPHY, BIOMAGNETIC IMAGING)

PROBLEMS

1) DATA IS USUALLY IN WRONG COORDINATE SYSTEM

   CT DATA IS POLAR, IMAGE IS CARTESIAN

2) HOW MUCH DATA DO WE NEED?

   LESS DATA ⇒ FASTER ACQUISITION
   ⇒ HARDER RECON

3) WHAT IF THE DATA IS IMPERFECT

   ARTIFACTS + RESOLUTION LOSS

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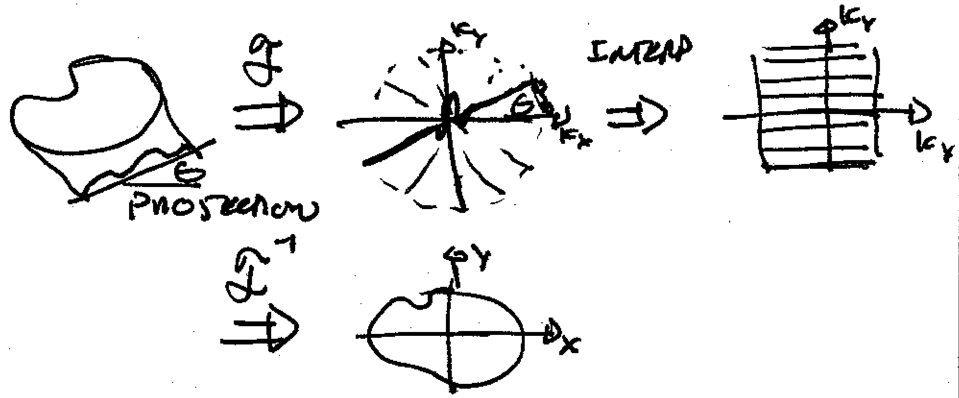
PROBLEM 1

DATA IS USUALLY IN WRONG COORDINATE SYSTEM

PARALLEL BEAM CT:



SIMPLE PROBLEM:

2D RADIAL/ANGLE DATA
⇒ 2D CARTESIAN DATA

FASTER THAN BACKPROJECTION!

NO-ONE DOES THIS (UNTIL RECENTLY).

WHY?

DIFFICULTIES

1) RECON MUST BE VERY HIGH FIDELITY

MINIMIZE ARTIFACTS/SHADING

2) RECON MUST BE EFFICIENT

WE WILL SPEND A LOT OF TIME ON INTERPOLATION + RESAMPLING

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PROBLEM 2

HOW MUCH DATA DO YOU NEED?

SIMPLE ANSWER

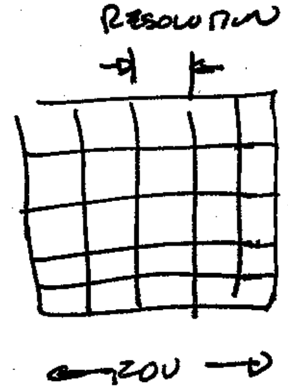


IMAGE REQUIRES

$$\sim \left(\frac{FOV}{RESOLUTION}\right)^2$$

SAMPLES

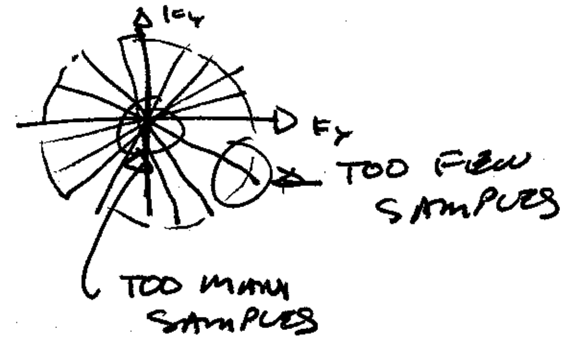
INDEPENDENT, UNIFORMLY SPACED

IN PRACTICE

DATA IS REDUNDANT

DATA IS NON-UNIFORMLY SAMPLED

EXAMPLE: CT



OVERSAMPLED DATA

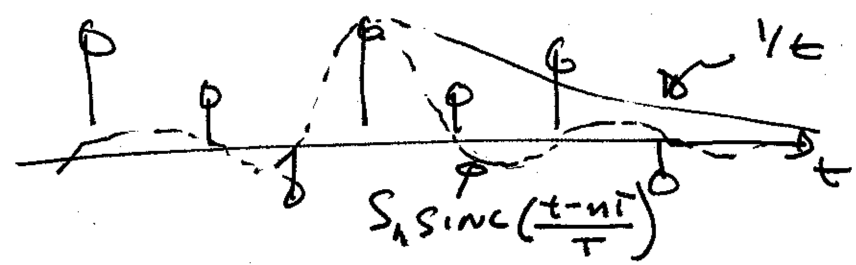
SIMPLEST RECONSTRUCTION CASE

MUCH REDUCED COMPUTATION

WE WILL USE THIS OFTEN

CRITICALLY SAMPLED DATA

DIFFICULT TO DO WELL, EVEN FOR 1D, UNIFORM CASE



OPTIMUM INTERPOLATOR IS A SINC(·)

DECAYS VERY SLOWLY

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UNDERSAMPLED DATA

RECONSTRUCTION NOT UNIQUE

WE NEED TO

MAKE UP DATA

- OR -

CONSTRAIN RECONSTRUCTION

THIS WILL TURN UP OFTEN IN THIS COURSE

EXPLOIT PRIOR KNOWLEDGE

IMAGE IS REAL OR POSITIVE

FINITE FOV

TIME SERIES

NATURAL IMAGE WITH POWER SPECTRA $\sim 1/k_r^2$

$\Rightarrow$ COMPRESSABLE

COMPRESSED SENSING

ANY REASONABLE MEDICAL IMAGE IS COMPRESSABLE, BY A FACTOR

$f \sim 4$ to 10, or more

REALLY ONLY NEED

N/f

SAMPLES TO REPRESENT IMAGE

CAN WE ONLY COLLECT N/f SAMPLES?

REMARKABLY, YES!

HOWEVER, CAN'T SAMPLE UNIFORMLY!

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PROBLEM 3

DATA IS NEVER PERFECT

- SYSTEM ERRORS
- INADEQUATE MODELS
- SUBJECT VARIATIONS

RESULT IS

- IMAGE ARTIFACTS
- RESOLUTION LOSS

SOLUTION

BETTER MODELS

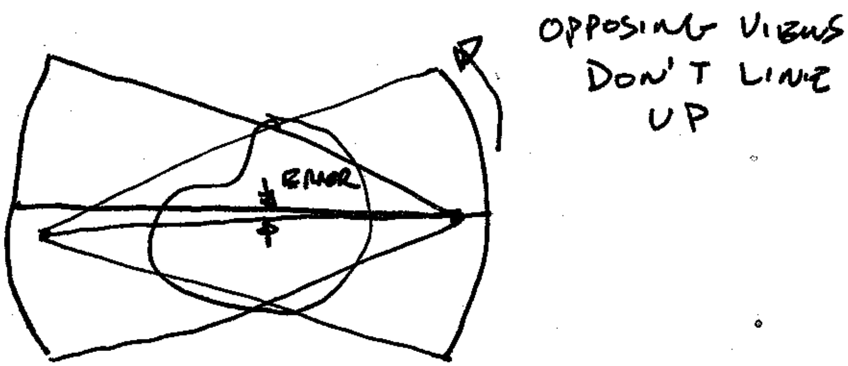
MEASUREMENT / ESTIMATION OF ERRORS
⇒ CORRECTION

DESIGN FOR IMMUNITY TO ERRORS

THIS IS AN ESSENTIAL PART OF MEDICAL IMAGING

CT EXAMPLE

PROJECTION MISALIGNMENT

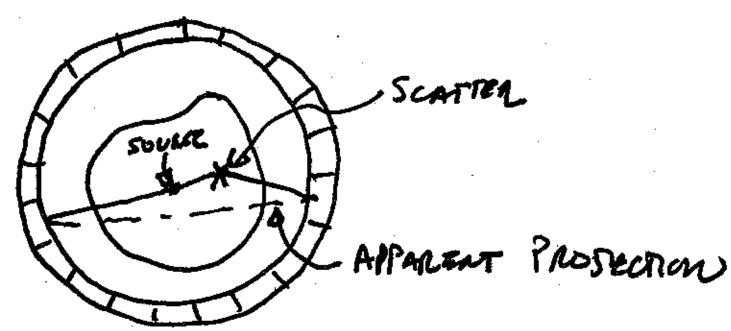


RESULT:

- CHARACTERISTIC BLURRING
- CORRECTABLE IN RECONSTRUCTION

PET EXAMPLE

SCATTERED PHOTONS



RESULT

- BLURRING
- CORRECTABLE IN ACQUISITION + RECONSTRUCTION

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MR EXAMPLE

MANY

NEXT TIME:

MODELS OF MR ACQUISITION

REVIEW EE369B NOTES