Pre-clinical phase contrast breast CT scanner

Type of project:

- Content complexity:
  - Underlying physical mechanisms not clear in beginning
    - Effect of Compton scattering on phase signal (now after 2 years slowly)
    - Dedicated performance evaluation and comparison between phase and absorption never done for large scale and high energies
  - Technology not ready (detector, tube, gratings), all need to be developed/build
  - Signal retrieval and post-processing not available
    - no fast non-phase stepping method existing
    - Spiral CT reconstruction needs to be adapted (no in-house know-how)
  - Image processing not on competitors level
- Context complexity:
  - Work with and supervise group members (students, colleagues) working on
    - Reconstruction (Students)
    - Detector
    - Gratings (grating fabrication PhD project parallel)
    - Theory (high energy PhD project parallel)
  - Work with multiple internal groups
    - Engineers/Technician for designing positioner system, small mechanical components, providing electrical support and infrastructure
    - Detector development (out sourced now)
  - Work/hire external companies
    - Gantry development (only 2 options worldwide, mayor cost factor)
    - Detector development in collaboration with spin-off (capable yes, common goals/end product not clear)
    - X-ray tube development (with/from external vendor, now canceled (too much cost, now an similar prototype exists and is available))
    - Reconstruction algorithm implementation (small scale in house, large scale from company, software engineers etc.
  - Work with hospital for samples/evaluation, later potential patients/clinical studies (not part of PhD project)
  - Potential high impact (on many patients), but only of cost (gantry, gratings) to benefit ratio is high enough

Thus, high content and high context complexity

System Analysis:

Conditions:

- Theoretical understanding of physical processes
- Theoretical evaluation and optimization of phase contrast breast CT (vs. absorption)
- Phase contrast spiral CT reconstruction algorithm for large field of view (FOV) (theory and implementation)
- High performing grating interferometry (GI) based phase contrast system
    - Dedicated high energy detector (photon counting, fast, large FOV)
    - Dedicated tube (cone beam geometry, power, cooling, kVp)
    - Large area, high performing gratings
    - Stable, compact alignment stages for gratings
- Scan protocol (tube voltage, current; exposure times; trajectory)
- Approval radiation safety and mechanical/electrical safety
- Approval fresh mastectomy samples

Resources:

- Hardware budget (Gantry, Detector, Tube, Hardware, Gratings)
- Postdocs (Phase contrast experts, detector expert)
- PhDs (PM, high energy, reconstruction (not cone beam), grating manufacturing, 2D/mammography)
- Students (semester, master projects)
- In-house technical support (infrastructure, engineers, technicians)
- Computer scientist (reconstruction algorithm implementation)
- Detector company
- Gantry company
- X-ray tube, other hardware vendors
- Computational power for reconstruction
- Mastectomy samples from hospital collaborations

Expertise:

- Physics behind Grating Interferometry
- Detector know how
- X-ray know how (generation, dosimetry)
- Mathematical understanding of CT reconstruction
- Phase retrieval development
- Computer science/programming know-how
- Mechanical engineering understanding
- System engineering
- Good organization, communication

Attributes:

- Attenuation coefficient and phase shift of breast tissue
- Sample sizes

- Detector performance (efficiency, noise, speed)
- Tube performance (flux, spectrum, cone beam geometry)
- Gantry stability/performance
- Number of projections, spiral trajectory (CT reconstruction performance)
- Dose delivered to sample, exposure time (image quality, SNR/CNR)
- Dose-weighted sensitivity of absorption and phase contrast

Tools:

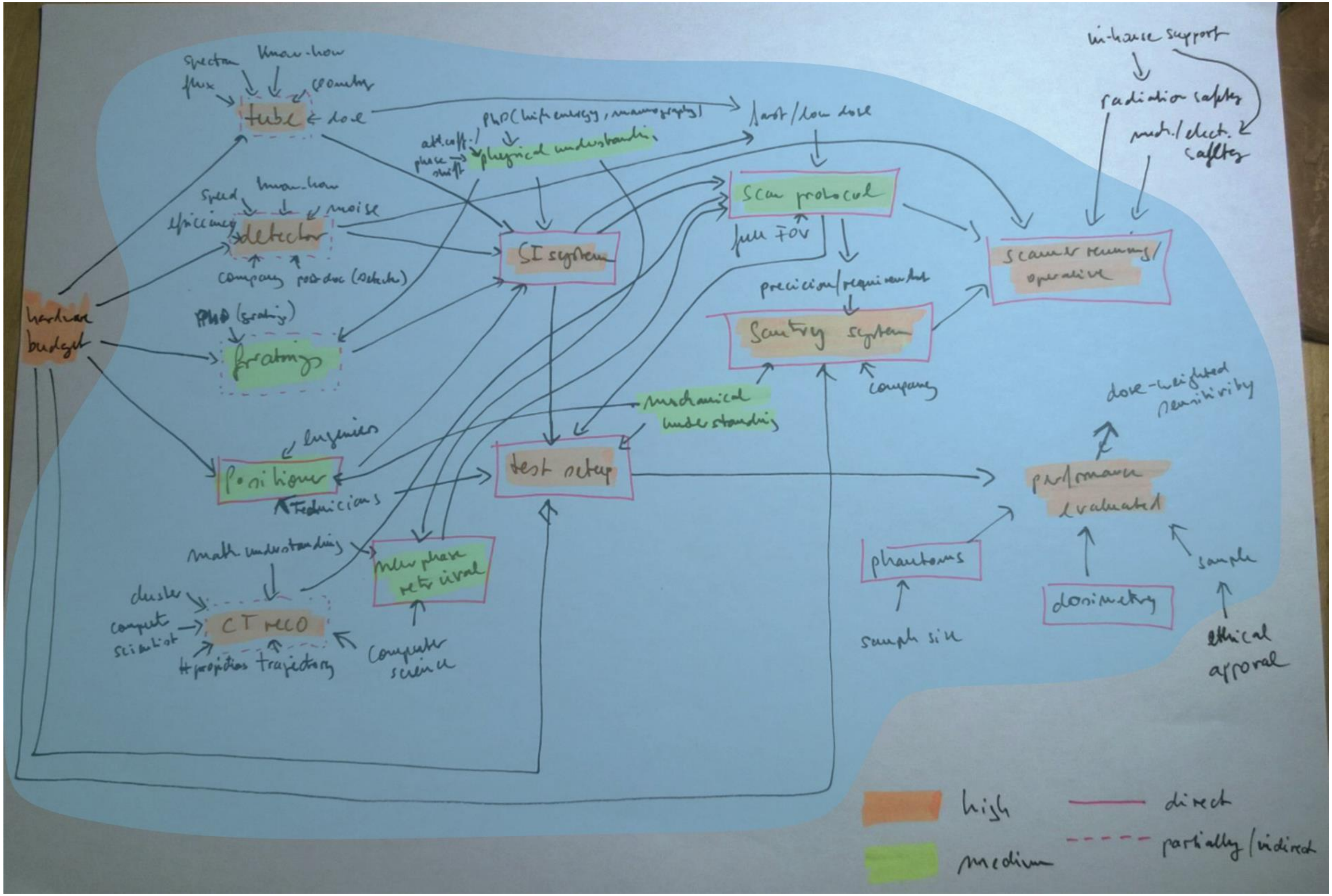
- Dosimetry (Simulated and measured)
- New phase retrieval algorithm
- Phase contrast spiral CT reconstruction algorithm for large samples
- Breast phantoms
- Gratings
- Tube
- Detector
- Positioners
- Gantry
- Test setup to evaluate
    - tube and detector
    - positioners
    - gratings
    - Phantoms
- Prototype consisting of dedicated tube, detector and gratings (plus stages)
- Radiation protected working space with complete infrastructure (electrical, mechanical and IT)

Environments:

- Radiation safety
- Mechanical/electrical safety
- Absorption-based breast CT companies (2 systems ready)
- Mammography/Tomosynthesis developments

Success:

- Gantry system compatible with GI system
- All system components operative
- Scanner running
- Scan of full FOV possible
- Low enough dose/fast enough scan protocol
- Performance evaluated



spectrum
flux
know-how
geometry
tube
dose
fast/low dose
PhD (high energy, mammography)
att.coeff./phase shift
physical understanding
speed
know-how
efficiency
noise
detector
company
postdoc (detector)
hardware budget
PhD (grating)
gratings
SI system
scan protocol
full FOV
precision/requirements
gantry system
company
scanner running/operative
in-house support
radiation safety
med./elect. safety
engineer
positioner
technicians
test setup
mechanical understanding
performance evaluated
dose-weighted sensitivity
math understanding
cluster
computer scientist
CT reco
#projections
trajectory
computer science
phantoms
sample size
dosimetry
sample
ethical approval
high
medium
direct
partially/indirect

Stakeholder Analysis:

- Project team: PhD student (PM), Postdoc (supervisor), Professor (supervisor), PhD (high energy), PhD (gratings), PhD (Mammography), Postdoc (Detector), Master students, Technicians
- Mechanical support (internal): mechanical engineers
- Technical support (internal): (electrical) infrastructure, (radiation) safety/regulation
- External partners: Detector company, gantry company
- Suppliers: motors/controllers, X-ray tube
- Public: Patients, Radiologists, CT Vendors, Health Insurances

Interest	low	medium	high
high	Patients Radiologists	Postdoc (Detector) Master students	PhD student (PM) Professor (supervisor) Gantry company
medium	CT Vendors Health insurances	Postdoc (supervisor) PhD (CT reconstruction) Technicians	Detector company
low	PhD (Mammography) Support: infrastructure Support: safety/regulation Motors/controller vendor	PhD (high energy) PhD (gratings) Mechanical engineers X-ray tube vendor	

Influence

Stakeholder	Interest/Stake	Influence/Power	Attitude	Measure
PhD student (PM)	h	h	0	Increase attitude: Project is standing still (since months) waiting for funding and strategic decision by Prof -> move decision process forward
Postdoc (supervisor)	m	m	0	
Professor (supervisor)	h	h	1	
PhD (high energy)	l	m	0	Increase interest: PhD is finishing and focusing on scatter problems, phase contrast not of interest to him
PhD (gratings)	l	h	0	Increase attitude: Show potential of project and how their involvement will benefit
PhD (Mammography)	l	l	0	
PhD (CT reconstruction)	l	m	0	Increase interest: Briefly worked by co-supervising Master student for spiral CT reconstruction, now finishing and no interest
Postdoc (Detector)	h	m	-1	Increase attitude: Get deal with detector company done and ensure his involvement/project leader position (Prof is negotiating this)
Master students	h	m	1	
Technicians	m	m	1	
Mechanical engineers	l	m	0	Increase attitude/interest: Work faster on evaluating their system (has been

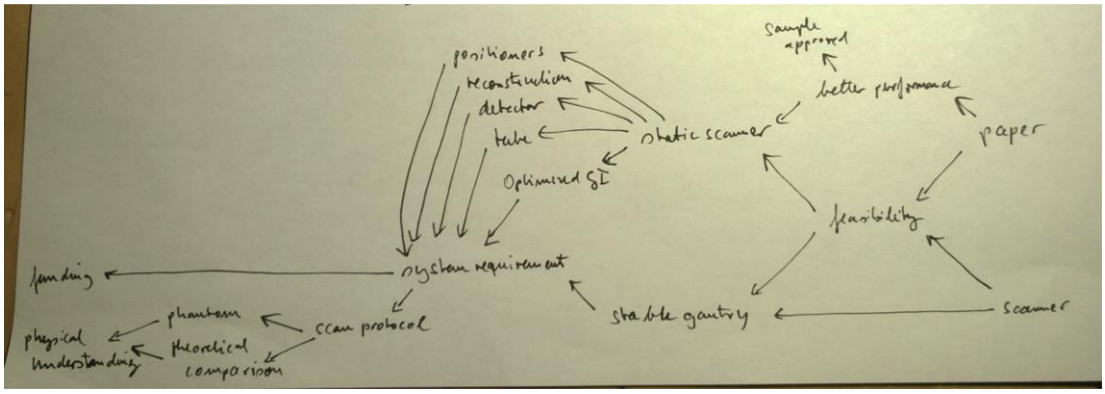
				delayed for months since PM is focusing on moving the overall project further)
Support: infrastructure	l	l	1	
Support: safety/regulation	l	l	1	
Detector company	m	h	0	Increase interest: Show why our project is ideal to promote their new detector (Prof working on it)
Gantry company	h	h	1	
Motors/controller vendor	l	l	0	
X-ray tube vendor	l	m	0	
Patients	h	l	0	
Radiologists	h	l	0	
CT Vendors	m	l	0	
Health insurances	m	l	0	

Objectives:

Objective	Indicator	Measure	Deadline	Priority
Pre-clinical phase contrast breast CT system (breast pCT) on rotating gantry	Whole system assembled and operational	CT scans acquired and reconstructed	September 2018	Need-to-be
Feasibility of GI operated on fast gantry shown	Result of simulation and test	Within specifications	Mai 2018	Need-to-be
Better performance (sensitivity, dose efficiency compared to absorption CT) shown	Result of performance analysis	CNRp/CNRa >1, SNRp/SNRa >1, DOSEp approx. DOSEa	December 2017	Should-be
Mastectomy samples approved	Answer to request	approved	June 2017	Should-be
Mechanical stable gantry system compatible with GI	Result of simulation and test	Within specifications	March 2018	Need-to-be
Static Pre-clinical phase contrast breast CT system (breast pCT) without gantry	Whole system assembled and operational	CT scans acquired and reconstructed	September 2017	Should-be
Optimized grating interferometer (GI)	Theoretical performance	CNRp/CNRa >1, SNRp/SNRa >1, DOSEp approx. DOSEa	June 2016	Should-be
Dedicated X-ray tube for breast geometry and breast pCT spectrum	Result of tests	Flux, spectrum, geometry within specifications	June 2017	Should-be
High energy detector for breast pCT spectrum	Result of tests	Energy range, efficiency, size, speed within specifications	September 2017	Need-to-be
Spiral pCT reconstruction algorithm implemented	Result of tests	Accuracy and scalability shown	December 2016	Need-to-be
	Result of tests	Precise and stable enough	September 2016	Need-to-be
Define breast Phantoms	Absorption coefficient and phase shift	Same as mastectomy sample	September 2016	Need-to-be
Define scan protocol	Required number of projections, exposure time, pitch feasible	Mechanical possible and compatible with reconstruction and system requirements	December 2016	Need-to-be
Define system requirements	All parameters fixed	Optimal parameters found	December 2016	Need-to-be
Theoretical evaluation and optimization of phase contrast breast CT (vs. absorption)	GI parameters defined based on dose efficiency	Parameters optimized	Mai 2016	Need-to-be
Theoretical	High energy	Thesis proofed	March	Need-to-be

understanding of physical processes	research done		2016	
2 articles published (theoretical vs. actual performance, new phase retrieval/CT reco)	Answer of journal	Accepted	September 2018	Should-be
Funding for gantry, detector, gratings and hardware secured	Amount	750000 Euro + 200000 CHF + 100000 CHF + 130000 CHF	Mai 2016	Need-to-be

Connect/order objectives:



WBS:

Will follow as soon as possible