Computational Imaging Group
for MR Therapy and Diagnostics

Klinische implementatie van AI

THEMADAG 2024/Catharina Ziekenhuis

28 maart 2024 — Mark Savenije

m.h.f.savenije@umcutrecht.nl

Classical radiotherapy workflow

Diagnosis and treatment choice

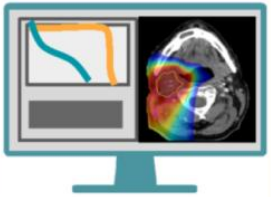
- Analysis of patient's medical records, symptoms, pathological, imaging, and genomic data
- Prediction of radiation toxicity to aid the treatment protocol decision

Imaging (simulation)

- Conversion of different image modalities (e.g. MR to CT, CBCT to CT)
- Image reconstruction
- Image registration
- Increase image quality, low-dose CT

Contouring

- Segmentation of organs and target volumes
- Fusion information from several imaging modalities
- Remove image artifacts, increase quality



Plan optimization

- Prediction of optimal dose distributions, dose-volume metrics, or fluence maps
- Planning bots with reinforcement learning
- Accelerate dose calculation

Treatment delivery and QA

- Prediction of tumor motion
- Patient-specific QA measurements
- Detection of errors during delivery
- Image guidance

Follow-up

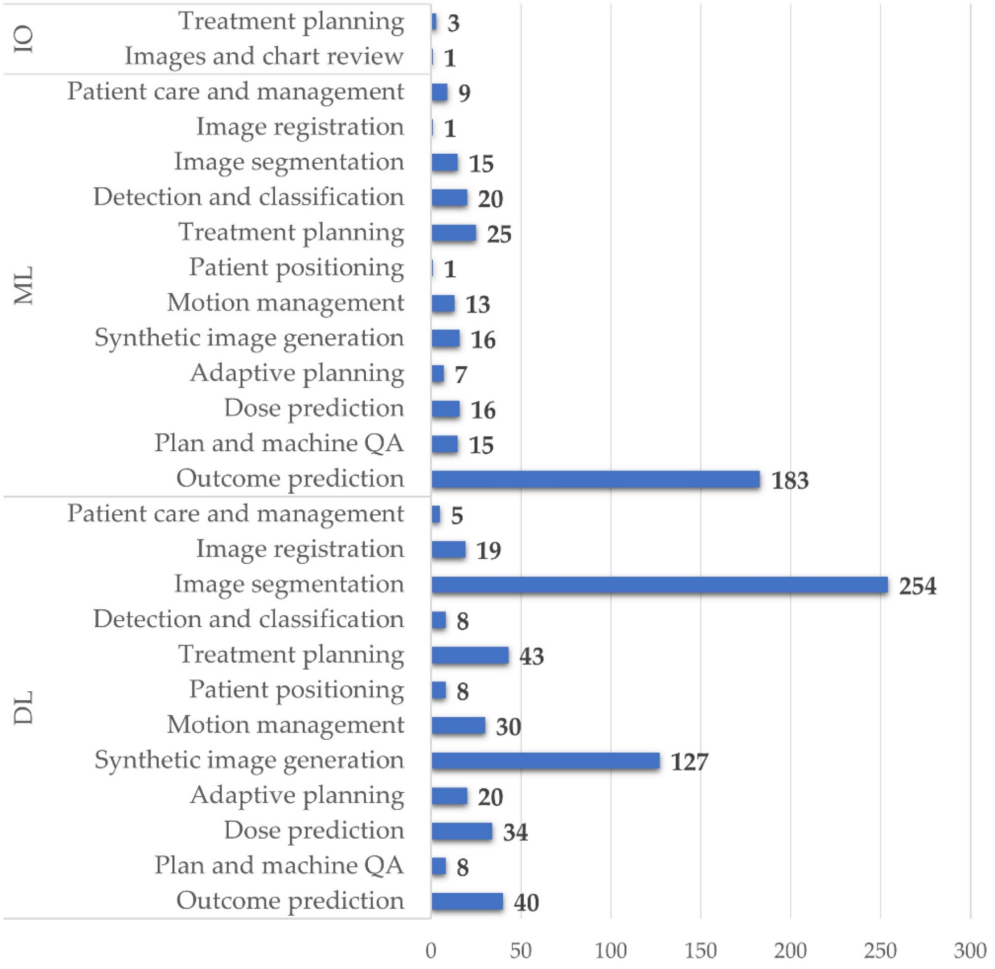
- Analysis of post-treatment images and information
- Prediction of radiation toxicity and complications
- Prediction of survival, distant metastasis and locoregional control

Machine learning applications

https://iopscience.iop.org/article/10.1088/1361-6560/ac678a

AI applications for RT research papers (2018-2022)

1. Contouring/segmentation
2. Outcome prediction
3. Synthetic CT's from MR/CBCT
4. Treatment planning



https://doi.org/10.3390/app12073223

Available commercial AI applications

1. Segmentation (including train on your own data)
2. Synthetic CT's from MRI and CBCT
3. Image reconstruction

Deep learning-based segmentation

Slide by Matteo Maspero

#19 Products <2024-01

Supplier	Product name	Anatomical location						Target?	Retrain on your data?	Cloud/Stand-alone/TPS	Regulatory Approval
		Brain	HN	Thorax	Abd	Pelvis	Others				
Carina AI	INTContour	CT	CT	CT	CT	CT male			Y	C/S	FDA
Ever Fortune AI	RT suite		CT			CT	All			S	FDA
GE Healthcare	Auto Segmentation						All			S/C	FDA
Hura Imaging	DV.Target	CT	CT	CT+breast	CT	CT			Y	S/C	FDA
Limbus AI	Limbus Contour	CT, MRI	CT+nodes	CT+breast	CT	CT,MRI,CBCT		CTV		S (C on demand)	FDA, CE
Manteia	AccuContour AccuLearning	CT	CT	CT		CT		CTV	Y	S	FDA, CE
MEDCOM	Prosoma DART	CT	CT							C/S	FDA, CE
MIM Software	Contour ProtégéAI+	CT+nodes	CT+nodes	CT+nodes	CT	CT,MRI prost				C/S/TPS	FDA, CE
Mirada	DLC Expert	CT	CT	CT	CT	CT				C/S/TPS	FDA, CE
MVision AI	Mvision AI	CT, MRI	CT+nodes	CT+breast +nodes	CT	CT(fe/male+nodes) MRI prost (2)	All, bones	CTV		C/S/TPS	FDA, CE
Philips	Auto contouring					MRI prost				S	FDA, CE
Quantaras	Contour Companion		CT	CT						C	FDA
RadFormation	AutoContour	CT,MRI	CT+nodes	CT+nodes	CT	CT+ nodes, MRI				C/TPS	FDA, CE
RaySearch	DL models	CT	CT	CT+breast +nodes	CT	CT			(Y)	TPS	CE
Siemens Healthineers	AI-Rad Companion	CT,MRI	CT+nodes	CT+breast	CT	CT,MRI prost				C/S/TPS	FDA, CE
	DirectORGANS									C/S/TPS	
Spectronic Medical	MRI Planner	MRI	MRI			MRI				C/S integrated MRI	FDA, CE
Synaptiq	Mediq	CT	CT	CT+breast	CT	CT				C	
Therapanacea	Annotate, AdaptBox	CT,MRI	CT+nodes	CT+breast	CT,MRI	CT,MRI(2), CBCT male	heart			C/S	FDA, CE
Vysioner	Vbrain	MRI						only		S	FDA

Only for the Chinese market: AiContour, Linking MED; CT-based pelvis, thorax

C: cloud-based; S: standalone solution
TPS: integrated in at least one treatment planning system

Synthetic CT's from MR/CBCT
MR-only radiotherapy/CBCT-based adaptive radiotherapy

- Four commercial solutions
  - 2 MRI vendors integrated, standalone/cloud
  - Brain, pelvis, head-and-neck

Company	Name	Sequence	Anatomical site	Integrated on scanner	Certification
PHILIPS	MRCAT	T1w GRE + Dixon	Pelvis, brain, head-and-neck	Y	CE FDA 2016-03
SPECTRONIC MEDICAL	MRI Planner	T2w T1w GRE	pelvis + del OARs brain, head-and-neck	cloud or on-site standalone or post-processing suite	CE 2016-06
SIEMENS Healthineers	Syngo.via. syntheticCT	Multiple sequences T1w GRE + Dixon	brain pelvis	~ post-processing in a separate suite from the scanner	FDA, CE 2018-01
THERAPANACEA Reinventing cancer care through AI	MR-Box AdaptBox	T1w GRE T1w GRE, T2 CBCT	Brain Pelvis Prostate	N, cloud or on-site standalone	CE, FDA 2021-2022 CE 2023, FDA pending

Deep learning since 2019

Vendor re-designed Their certified solutions

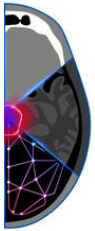
Synthetic CT's from CBCT or MR

Inherently much more difficult to accept in clinic:

- You cannot check whether is correct (esp. for MRI based sCT's)
- No tools to adapt sCT's

Very different than for auto contouring application:

- We are used to start with some base delineation (atlas based e.g.)
- Software is highly designed to make and adapt contours



SynthRAD2023

Synthesizing computed tomography for radiotherapy

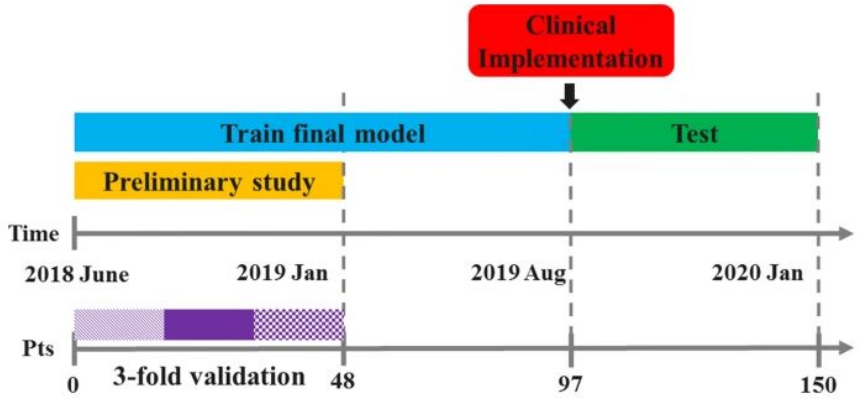
https://arxiv.org/abs/2403.08447

UMC Groningen, Radboud UMC, Eindhoven University of Technology, Wageningen Research, UMC Utrecht, Amsterdam UMC, Maastricht University, TU Delft

UMCU segmentation history

While developing the **MR-only workflow** for prostate (2016 onwards):

1. Substitute for planning CT (MR sequence, DL pseudo CT's (2017), **MRCAT)**
2. Seemed logical to delineate on source images of MRCAT (IP/W/F), 2018



Savenije *et al. Radiation Oncology* (2020) 15:104
https://doi.org/10.1186/s13014-020-01528-0

Radiation Onco

RESEARCH Open Ac

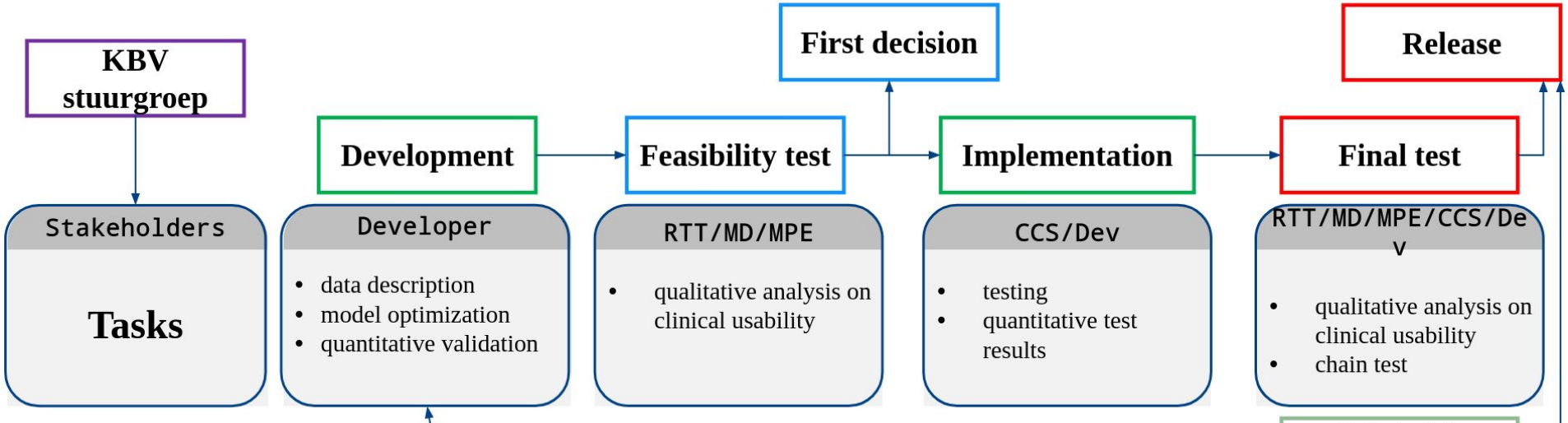
Clinical implementation of MRI-based organs-at-risk auto-segmentation with convolutional networks for prostate radiotherapy

Mark H. F. Savenije[1,2†], Matteo Maspero[1,2*†], Gonda G. Sikkes[1], Jochem R. N. van der Voort van Zyp[1], Alexis N. T. J. Kotte[1], Gijsbert H. Bol[1] and Cornelis A. T. van den Berg[1,2]

Locally developed segmentation applications:

1. **Group effort!** Set up a group of people with different roles:
   RTT's, clinical image processing department, clinical computer scientists, medical physicists, medical doctors, developers. **Participation!**
2. Make **inventory of wishes/requests**, can you buy application?
3. Training with your **own data**, contouring guidelines, planning templates (mostly better results than commercial solutions)
4. **MDR/QMS**
5. Computing infrastructure, integration and deployment
6. **Instruction** for RTT's
7. Now focus on **adaptive** RT (e.g. MRLinac) **speed constraints!**

Software life cycle



RTT := radiation therapy technician
MD := medical doctor
MPE := medical physic expert
CCS := clinical computer scientist
Dev := developer

- Report quantitative
- List patients
- Location data

- Understand why, e.g. changes imaging/runtime errors

Medical Device Regulation (MDR) 2017/745

AI application: medical device? Medical device definition:

Any instrument, apparatus, appliance, **software**, implant, reagent, material or other article **intended by the manufacturer** to be used, alone or in combination, for human beings for one or more of the following specific medical **purposes**:

1. Diagnosis, prevention, monitoring, prediction, prognosis, treatment, compensation or alleviation of disease, injury or disability
2. Investigate, replacement or modification of anatomy or a physiological or pathological process

If a software app has an **influence** on patient treatment, it is a **medical device**!

MDR and hospitals

Manufacturing, modifying and using devices in-house **is allowed**, **no CE** marking needed, but:

- Software is not transferred to another legal entity
- Show and document that other commercial software is not available for the target patient group's specific needs
- Publicly declare that the software meets the general safety and performance requirements (**GSPR**) Openbare MDR verklaring - UMC Utrecht
- **Software is developed and used under an appropriate quality management system (QMS)**

Quality Management System (QMS)

QMS is/seems like a lot a work, but:

- Provides risk, quality, development procedures
- Supplies all kinds of forms
- Stores risk, verification, validation, test data
- Secures all kinds of norms

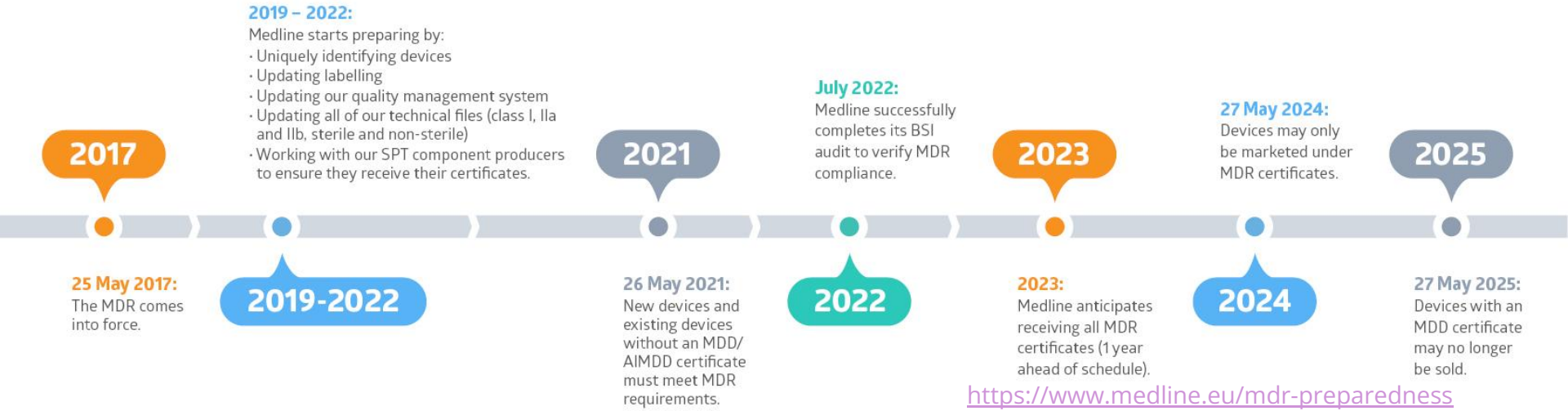
- OPTIONAL: A QMS can be certified
  - Guaranteed **compliance** with norm
  - **Incentive** to keep following the formal procedures
  - Easier **collaboration** with industrial partners
- UMCU radiotherapy QMS operational since 2017 and ISO 13485 certified since 2019

AI/ML applications w.r.t. QMS

- QMS: No specific AI / DL norms available
- Not a “regular” software development process

MDR (2021) implications for UMCU

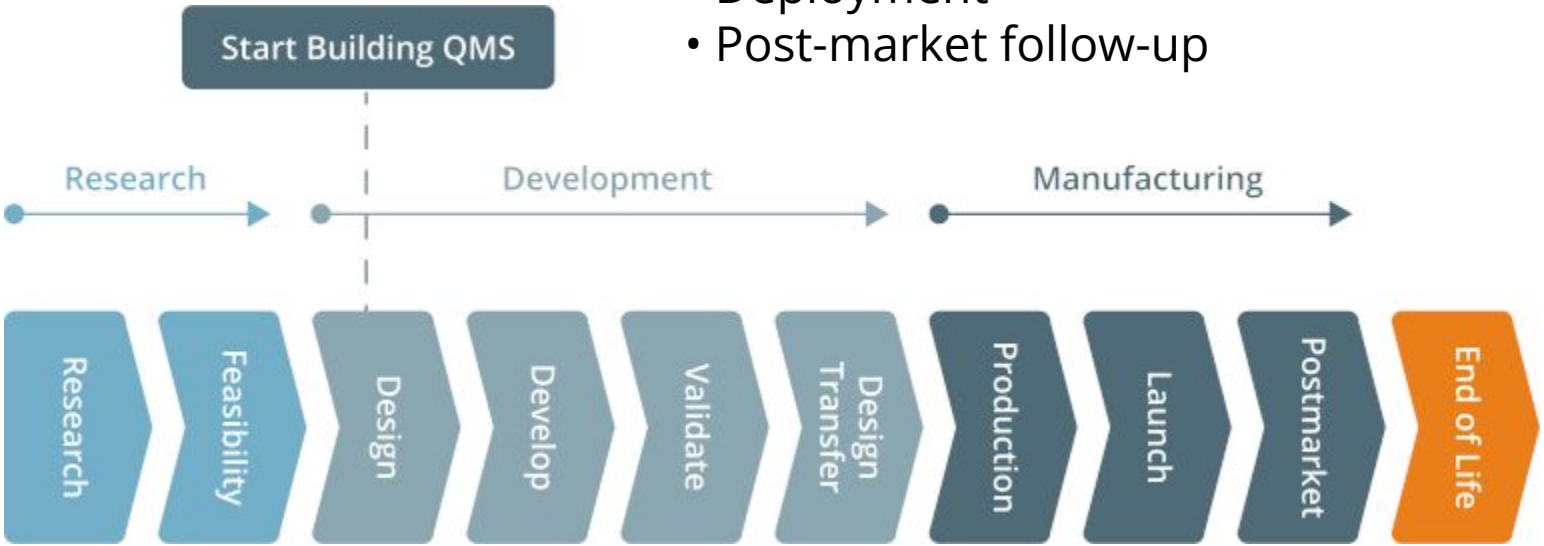
- Change delineation software (inhouse developed VolumeTool) to MIM
- Atlas based solution (ABAS/Elekta) will NOT be CE marked
- AI based segmentation solutions from MIM underperformed, and/or posed significant changes in planning templates (local scanners, local delineation guidelines, local etc.)



https://www.medline.eu/mdr-preparedness

QMS: software development process

- Global description / (development) planning
- Requirements / design input
- Risk analysis / management (MDR **class 2b**)
- Development
- Verification and Validation
- Clinical evaluation (**per model**)
- Deployment
- Post-market follow-up



https://www.simplerqms.com/medical-device-quality-management-system/

DeepMedic's EU MDR Document

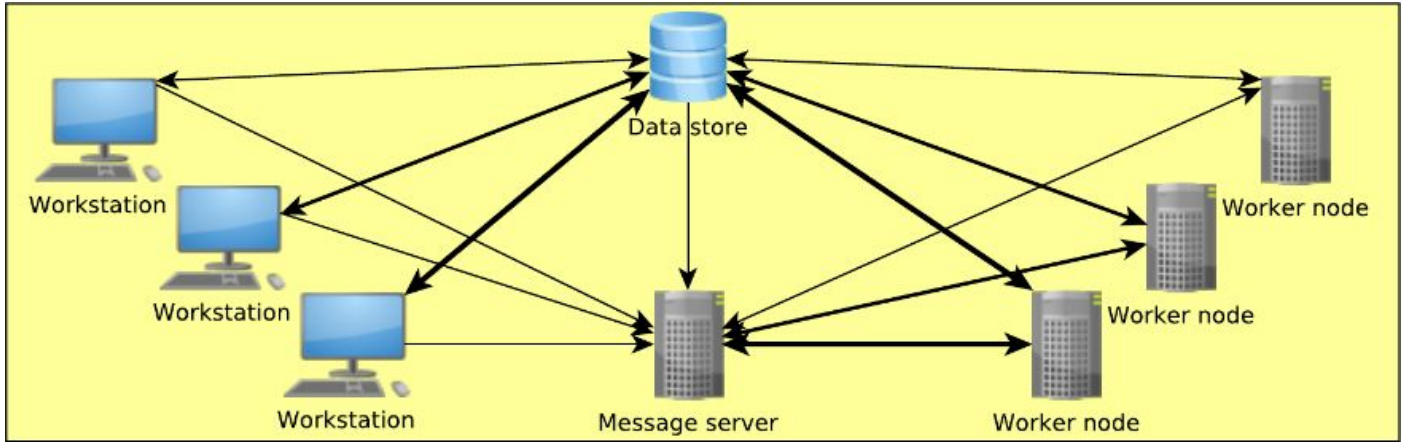
Contents

Clinical deployment UMCU: components

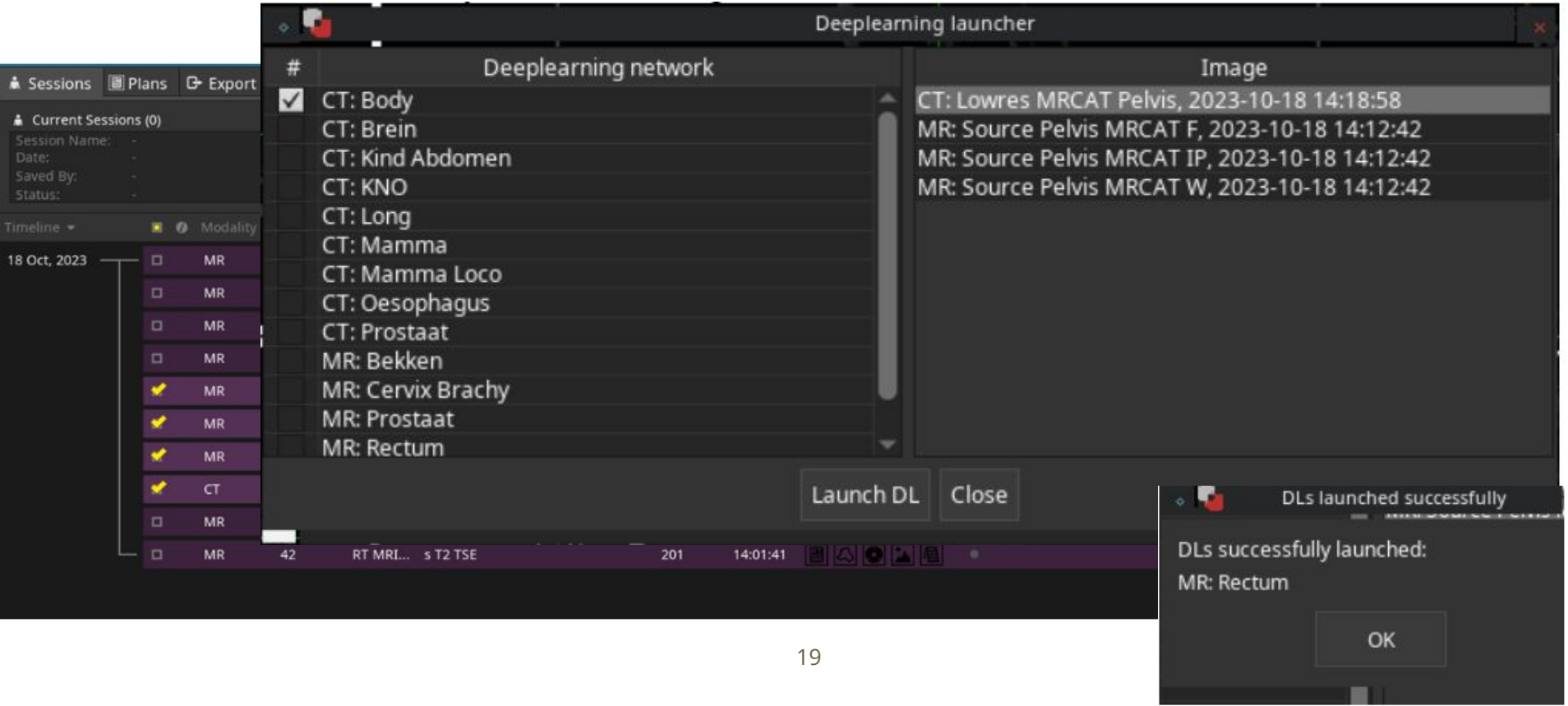
Desktop nodes (end users)
- Start DL procedure
  - MIM
  - Research software (VT)
- Receives DL results
  - MIM / Research software
- Controlled environment
- No direct access to DL networks

Communication node
Connects
- Storage node
- Worker nodes
- Desktop nodes
- RabbitMQ
- Platform independent
- Messaging and queueing mechanism

Worker nodes
- Servers running the DL networks
- Uses VMs / containers (LXC)
- Resource sharing (GPU)
- Dedicated environment for each DL network
- Centralized configuration

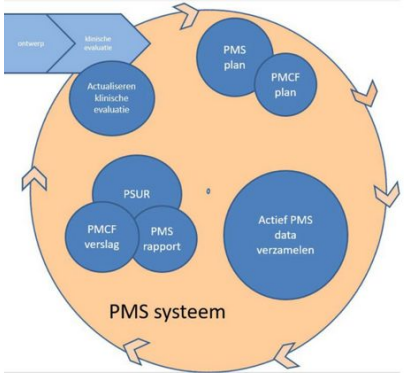


Clinical deployment in MIM and VolumeTool



DL Auto segmentation dashboard, a.k.a. PMS

Post-market surveillance (PMS) is a collection of activities that the manufacturer must perform to monitor the safety and performance of the device it sells.

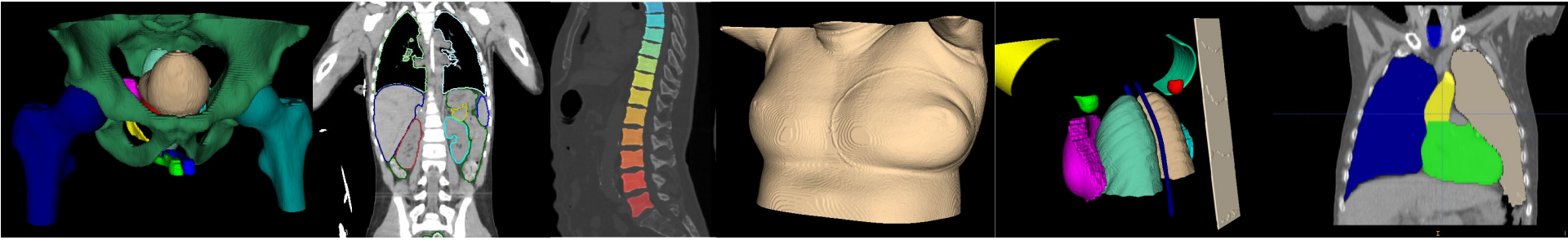


Random remarks from practice

1. Clinical software must be **MDR compliant**: You cannot choose a new platform/package for every task.
2. Hardly any changes in workflow if coming from atlas based segmentation. RTT's & doctors are used to review the segmentations & correct them.
3. Segmentation networks need **maintenance** (imaging, setup, etc.)
4. Trained networks are not very robust for changes in acquisition settings.
5. As RT department 1000's of treated patients = **very valuable data** Images, delineations, dose and planing files. Keep them accessible.

Some numbers from our department

- First clinical DL segmentation: July 2019 (prostate on MR (MRCAT) images)
- ⟹See presentation of Geja
- Based on DeepMedic (no software updates for three years, 👍, 👎)
- Networks need maintenance! Some networks already in 3rd iteration



Deep learning core team of the Computational Imaging Group for MRI Therapy & Diagnostics

Matteo Maspero
Assistant Professor

Flavio Meliado
PhD

Nico van den Berg
Professor

Maarten Terpstra
Postdoc

Mark Savenije
Computer Scientist

See https://www.cig-utrecht.org

Credits

AI LAB FOR IMAGING AND IMAGE-GUIDED INTERVENTIONS

Matteo Maspero (+ misc. slides)
Gijsbert Bol (+ slides MDR/QMS)
Alexis Kotte
Geja Schimmel-de Kogel
Gonda Sikkes
Nico van den Berg
Flavio Meliado
Anette Houweling
Mariëlle Philippens
Wietse Eppinga
Patricia Doornaert

Thank you for your attention

online presentation
https://tinyurl.com/CZE-March24