# Nuclear Medicine Physics and Health Physics Field

Supervisors: Professor Masahiro FUKUSHI, Associate Professor Kazumasa INOUE

The Nuclear Medicine Physics and Health Physics Field at Tokyo Metropolitan University focuses on the development of novel nuclear medicine imaging techniques in clinical and small animal SPECT and PET, including SPECT/CT, PET/CT and PET/MRI multimodal imaging techniques, and development of clinical image assessment techniques. Our field also focuses on identifying environmental radiation from natural and artificial radionuclides including naturally occurring high level environmental radiation areas and areas contaminated from the nuclear accident of the Fukushima Daiichi Nuclear Power Plant; development of novel radiation dosimeters using artificial intelligence (AI); and identification of the mechanisms of health effects due to chronic low dose rate radiation exposure by using genome analysis. Besides these research activities, our main activities include conducting clinical training and educating radiological technologists and medical physicists at major hospitals in Japan.

We have had about 70 publications appear in academic journals including the *Journal of Nuclear Medicine*, *Radiation research* and *PloS One*, and we have received over 20 honors from professional societies for our contributions to nuclear medicine and health physics. More detailed information about supervisors are: "https://researchmap.jp/read0038122/?lang=english" and "https://researchmap.jp/kzminoue/?lang=english". Our supervised students have received 16 doctoral degrees and 35 master's degrees, and all of them are active in the field of clinical research and education as of FY 2018. We also have attracted outstanding foreign students from Thailand, Vietnam, India and Egypt over the years. We are always recruiting highly motivated research students.

Major collaborative research and education institutes: University of Tokyo, National Institute of Radiological Sciences, Japan National Cancer Center Hospital and Hospital East, Harvard Medical School (USA), Pondicherry University (India) and Cho Ray Hospital (Vietnam).
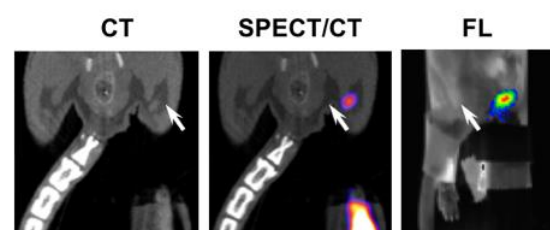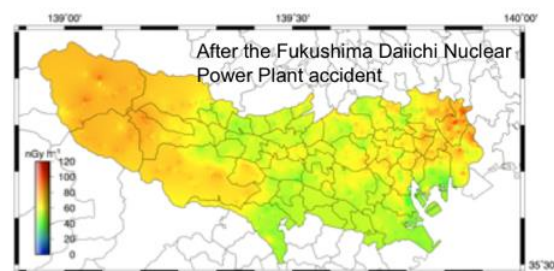

Respiratory-gated PET/CT imaging
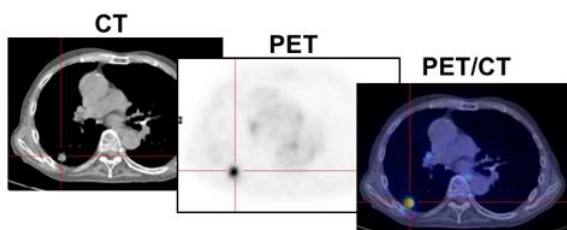
Multimodal imaging

Genome analysis
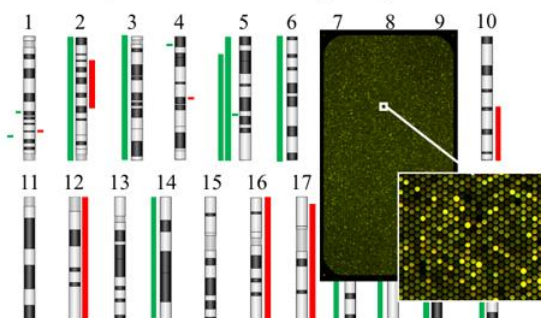
Absorbed dose rate in air in Tokyo

After the Fukushima Daiichi Nuclear Power Plant accident

Radiation Oncology Physics A

Supervised by Hidetoshi Saitoh (Prof., Ph. D.)

We conduct education and research on the latest issues on physics, engineering, technology for radiation therapy. Especially, interesting are latest radiation theory, patient information, properties of therapeutic beam, algorithm of treatment planning, dosimetry, quality assurance related cutting edge radiation therapy.

By taking recommended subjects in the field of Radiation Oncology Physics, you can acquire most credits required for completing the medical physicist education course accredited by the Japan Board for Medical Physicist Qualification (JBMP).

Example of research theme

- High speed and accuracy calculation algorithm of absorbed dose distribution
- Improvement of dosimetry using various detectors
- Imaging for high precision radiation therapy
- Activation of medical accelerator
- Development of e-learning materials for education on Medical Physics
- etc.

Apparatus and equipment can be used for your research

- Electron linear accelerator (Varian Clinac 21EX, Fig. 2)
- Radiation therapy planning system (Elekta XiO, Varian Eclipse)
- Various kind of ionization chambers and electrometers
- Radio-photoluminecent glass dosimeter
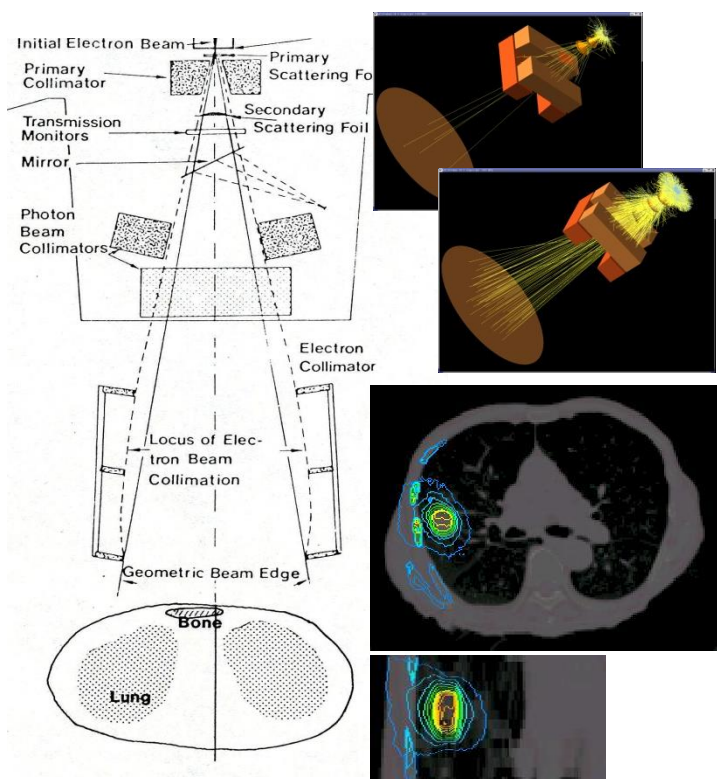- Various kind of phantoms, etc.

Fig. 1 Examples of Monte Carlo simulation on research field

Fig. 2 Electron linear accelerator available for education and research not for clinical use

放射線治療物理学分野

担当教員　齋藤秀敏

　最先端の放射線治療に関する物理学、工学、治療技術に関する最新の理論および患者情報、治療ビーム情報、治療計画、吸収線量計算、解析、精度管理における最新の課題について教育と研究を行っています。

　放射線治療物理学分野の推奨科目を受講することによって、医学物理士認定機構によって認定された医学物理士教育コース修了に要するほとんどの単位を取得することができます。

次のようなテーマに関する研究を行っています。

- 体内吸収線量計算の高速化・高精度化に関する研究
- 各種検出器による吸収線量計測精度向上に関する研究
- 高精度放射線治療のための画像利用に関する研究
- 医療用加速器の放射化に関する研究
- 各種情報を利用した体内線量分布再構成に関する研究
- 医学物理のためのe-learning教材の開発

学内で利用できる機材

- 医用電子直線加速器
  （Varian Clinac 21EX、図2）
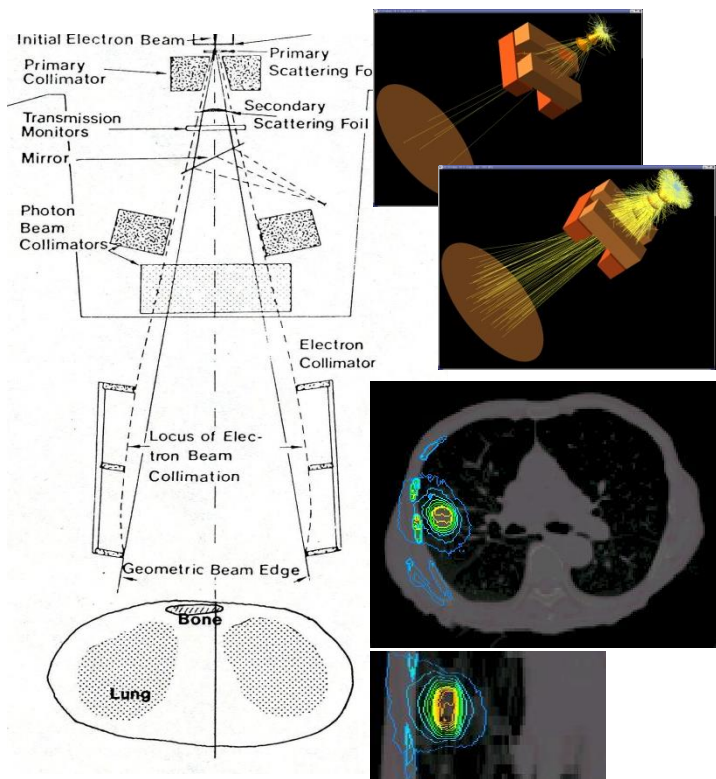- 放射線治療計画コンピュータ（XiO 7台）
- 各種電離箱線量計
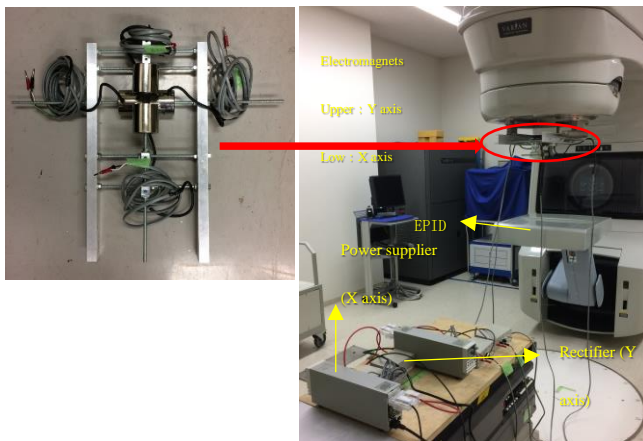- ガラス線量計
- 各種ファントム、他

図1　研究の概略図

図2　大学内で利用できる電子直線加速装置
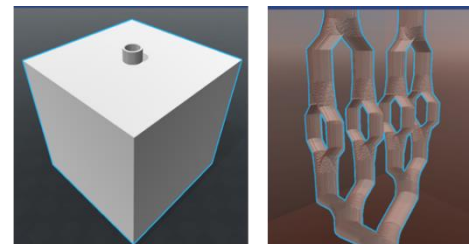
放射線治療物理学分野

担当教員　明上山　温

　放射線治療に関係した研究として、高精度放射線治療のための新しい装置の開発、高エネルギーX線・電子線による高画質イメージング、安全な放射線治療のための自動患者認証など最新のテーマを、理学・工学的な知識とプログラミングにより実現する研究を行っています。

主な研究テーマ

- MV-CBCT の高画質画像再構成
- 加速器による新しい画像の撮像法
- 新しい血管走行ファントムの開発
- GPU を用いた放射線物理シミュレーションの高速化
- 体内線量分布計算のためのモンテカルロ計算の高速化

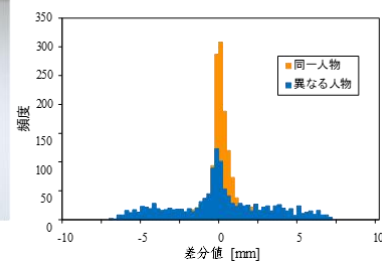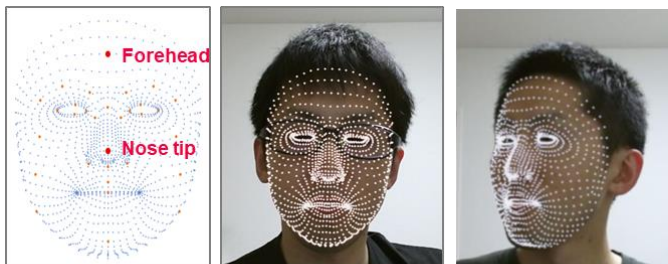電磁石を用いた電子線の偏向による画像取得装置の開発
電子線の偏向によるバーチャルボーラスの開発


生成したファントムの3Dモデル　ファントム内部

3Dプリンタ　造形後のファントム

新しい血管走行ファントムの開発

Kinect を用いた顔認証による患者認証の自動化

Radiation Oncology Physics

Faculty in charge: Atsushi Myojoyama

As research related to radiation therapy, we research and develop new devices for high-precision radiation therapy, high-energy imaging by X-rays and electron beams, automatic patient authentication for safe radiation therapy. We accomplish those themes with knowledge of radiation physics and programming.

● High-quality MV CBCT image reconstruction
● New imaging method using linear accelerator
● Development of new blood vessel phantom for multi-modality
● Improvement of quality of portal images using high-energy X-rays
● Development of fast Monte Carlo simulations to calculate dose distribution

3D phantom model   blood vessel model
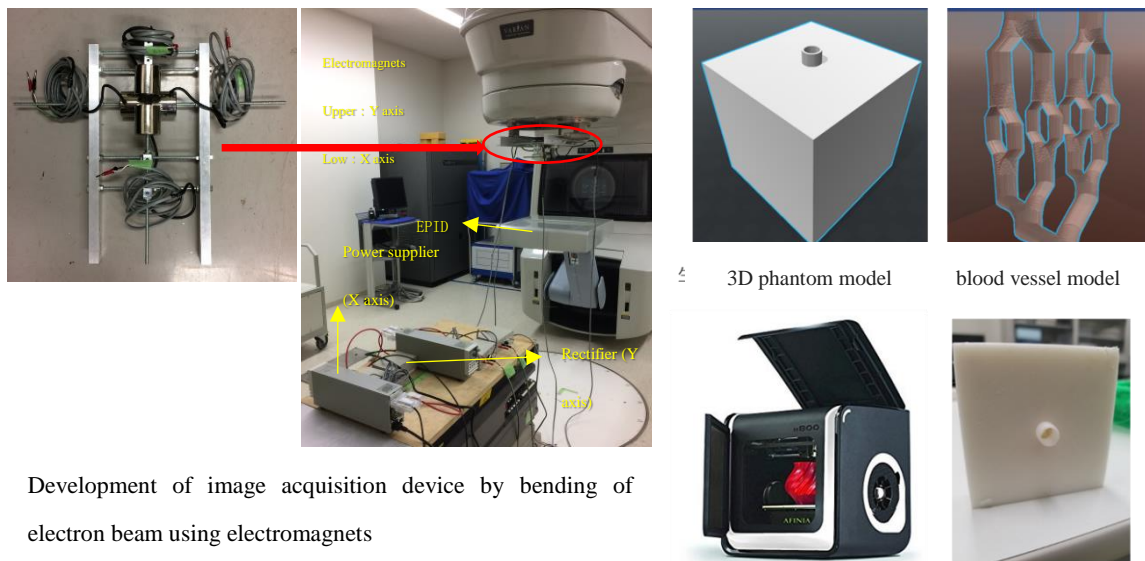
Development of image acquisition device by bending of electron beam using electromagnets
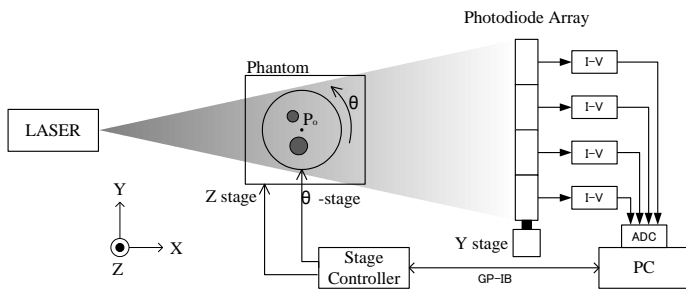
Development of new blood vessel phantom
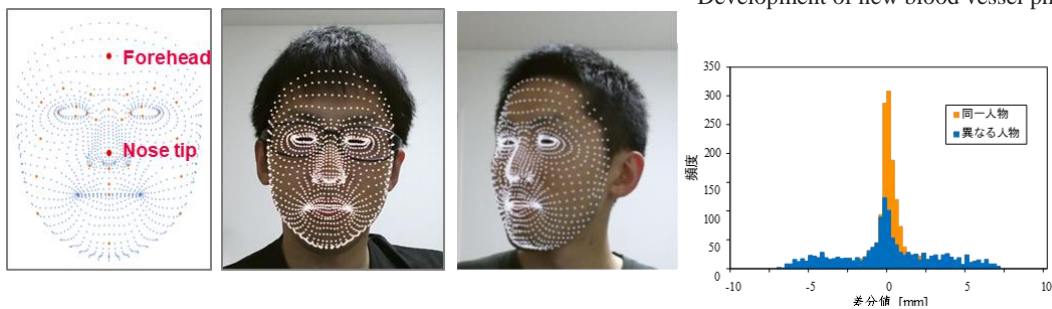
Automated patient authentication by face authentication using Kinect

医用計測システム学分野

小倉　泉

[研究]

1. レーザー光を用いた教育用模擬X線CT装置システムの検討

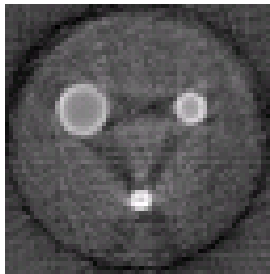　レーザー光を用いた光CT装置システムを構築し、X線CT装置の動作原理および画像再構成について理解を深めるための教育用模擬装置システムについて検討する。現在、シングルヘリカル模擬ＣＴ装置が完成し、マルチスライス方式への移行を検討する。
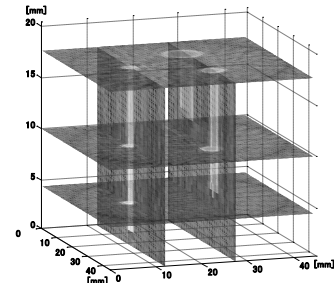

模擬CT装置の構成

シングルヘリカル模擬CT装置の外観

ファントムの模擬CT画像

ファントムの3D再構成画像

2. X線装置の日常管理に用いる

簡易形測定器の開発

　X線装置の日常管理普及のため、材料費が安価で必要な性能を満足するＸ線出力計や管電流計などの簡易形測定器を開発し、最適な日常管理方法について検討する。

日常管理用簡易形測定器システム

[教育]

・特論では、微小電流の計測と信号ケーブルの特性等に関する講義を行う。
・演習では、マイクロプロセッサを用いた基本的な計測法等について演習する。

Medical Measurement Systems

<div align="right">Izumi Ogura</div>

[Research]

### 1. Consideration of simulated X-ray CT system for education using Laser Beam

We will construct an optical CT system using laser beam and consider the educational simulator system for deepening understanding of the operation principle and image reconstruction of X-ray CT system. Currently, a single helical simulation CT apparatus is completed and we will consider transition to multi slice method.
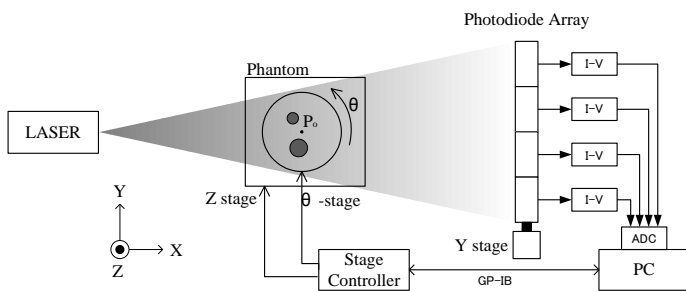
Construction of simulated CT apparatus

Appearance of single helical simulated CT device
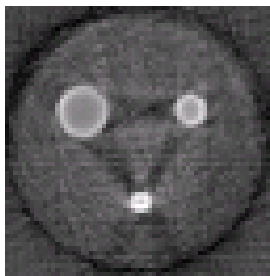
Simulated CT image of phantom
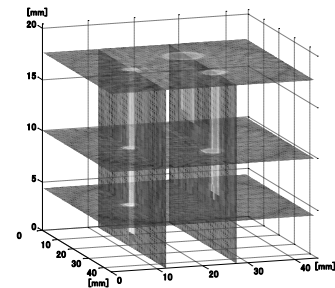
3D reconstruction image of phantom

2. Development of a simple measuring instrument for daily management of X-ray equipment

In order to disseminate the daily management of X-ray equipment, we develop simple measuring instruments such as X-ray power meters and tube ammeters that are inexpensive in material cost and satisfy the required performance.

Simple measuring instrument system for daily management

[Education]

In the special theory, we will give lectures on measurement of minute current and characteristics of signal cable. In exercise, we will exercise about basic measurement method using microprocessor.

Medical Measurement Systems

Faculty in charge: Kiyomitsu Shinsho

**Research laboratory policies:** We place importance on developing the ability to independently solve problems (individual problem-solving skills). You should try to tackle questions that no one can answer. In our research laboratory, you can gain experience in the synthesis of phosphors that are sensitive to radiation, chemical analysis, optical measurement, analysis, and even the development of measurement systems.
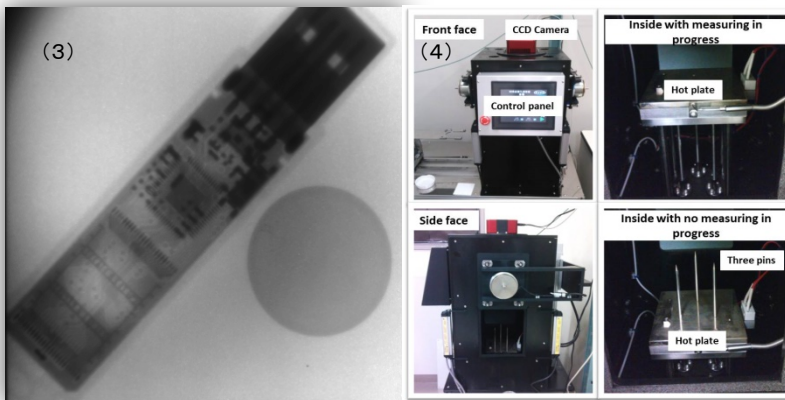
Research details: We develop new radiation measurement devices, making use of a classical phenomenon called "thermoluminescence," and conduct research on its mechanism.

Current major research projects

1. Studies on the development of imaging devices for charged particle radiation using thermoluminescent phosphors

(Research collaborator: National Institute of Radiological Sciences)

2. Research on the development of verification systems for high-precision radiation therapy plans

3. Studies on the development of neutron imaging devices using thermoluminescent phosphors

(Research collaborators: Kindai University and Kyoto University)

（1） X-ray irradiation （2） Heating
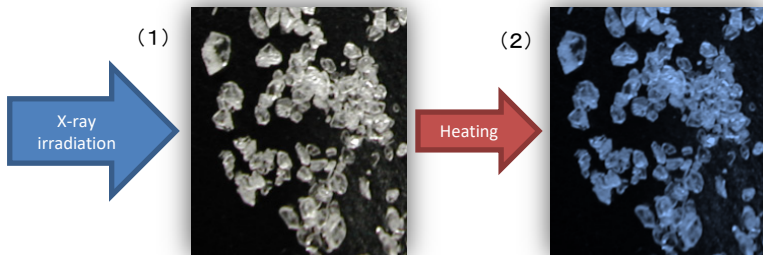
Thermoluminescence: When heat is applied to crystals irradiated with X-rays and so on (1), they can produce luminescence (2). This emission is called "thermoluminescence," and it is correlated with the radiation dose. Taking advantage of this property, thermoluminescence has been used for personal radiation dosimeters and so on.

（3）

（4） Front face CCD Camera Control panel Side face Inside with measuring in progress Hot plate Inside with no measuring in progress Three pins Hot plate

Two-dimensional analyses: When crystals exhibiting thermoluminescence are distributed in two dimensions, they can be used as a radiation imaging device. Photo (3) is an X-ray image of a USB stick and a one-yen coin taken with a thermoluminescent dosimeter developed by our research laboratory, and (4) shows the measuring instrument. (Six patents applied for) Images with a very high resolution can be obtained. The instrument can be used as an imaging device for verification of high-precision radiation therapy plans, boron-neutron capture therapy, and the measurement of environmental radiation. This is anticipated to be a new dosimeter that can obtain different information from that provided by existing dosimeters, and it has also been featured in newspapers and journals.

（5）

（6）

（7）

（8）
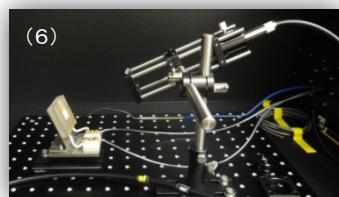
Increase in precision and three-dimensional analyses: In studies utilizing the heavy particle radiotherapy equipment for cancer at the National Institute of Radiological Sciences (5), the nuclear reactors at Kindai University and Kyoto University, work is underway to develop methods to measure radiation quality and dose distribution using thermoluminescence. In order to achieve this, it will be important to precisely measure thermoluminescence (6) and unravel its mechanism.
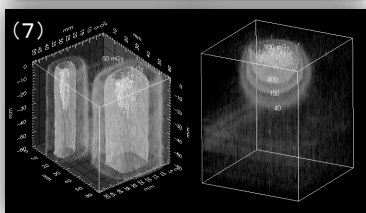
In addition, work is being done to measure three-dimensional dose distributions (7) and to develop a system that can measure the distribution of radiation in living trees over time without felling them (8). This is effective in identifying flow pathways and useful for decontamination measures and the like.

Diagnostic Medical Imaging

Akira Furukawa, MD, PhD, Takako Shirakawa, MD, PhD

In our research laboratory, we; diagnostic and interventional radiologist radiologists mainly conduct clinical studies on abdominal diagnostic imaging focusing on CT scans, MRI and ultrasound, and interventional radiology. Firstly, targeting the early detection of emergent diseases by advancement of diagnostic imaging that can lead to appropriate treatment options, we collect and analyze images of patients with various diseases causing acute abdominal conditions. We also disclose typical and characteristic imaging findings of these diseases, as well as, the diagnostic performance of various imaging tests for better understanding of values and limitations of each method. Secondary, we will develop morphofunctional imaging on gastrointestinal contractions, as well as related evaluation methods. Thirdly, diagnostic utility of ultrasonography using state-of-the-art machine for subcutaneous, joint, thyroid and breast diseases are investigated for further progress in diagnosis.

【Main Topics】

＃ Performance and indication of MDCT for GI bleeding and bowel ischemia

＃ Imaging Diagnosis for acute abdomen and various intestinal disorders

＃ Analysis of bowel contraction using MRI

＃ Morphological analysis of the liver in liver cirrhosis

＃ Ultrasound assessment of disorders of the superficial organs

【Diverticular hemorrhage】   【Crohn Disease】
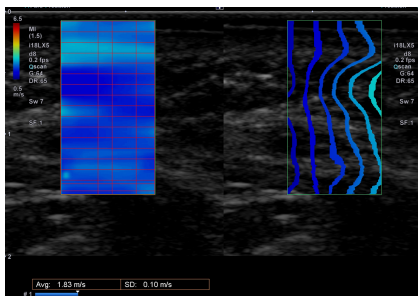

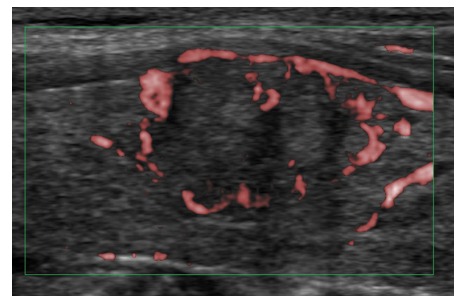Angiogram   Contrast –enhanced CT   Barium study   MR (SSFSE with fat saturation)   MR (SSFSE)

【Ultrasound elastography of buccinator】   【Power-Doppler ultrasonography of thyroid gland】

Radiation Dosimetry

Supervised by Yoh Katoh (Prof., Ph. D.)

We apply nuclear methods to analyze the concentration distributions of trace elements in living organisms for elemental analysis. We have applied nuclear methods including neutron activation analysis, particle-induced X-ray emission analysis, and so on, and quantity values of the order of ppm and ppb have been obtained.

We evaluate the physical properties, protection abilities, and so on of lead-free radiological protection materials against the energy in X-ray diagnosis. We employ effective energy as a benchmark in our evaluation, but we discuss this in depth, since variations in radiation quality, including the structures of X-ray sources, added filters, and the like, can produce different evaluation results.

Example of research theme
- Actual measurement and calculation method of air kerma rate of diagnostic X-ray apparatus
- Application of MC Simulation to photon attenuation ratio of radiation protective material
- Verification of shielding ability of lead-free board and estimation by calculation
- Development of a filter dosimeter not accompanied by change of line quality
- Simple calculation method of intrinsic filtration of X-ray tube device
- Dose intensity distribution by target / filter combination
- Lead concentration in hair of X-ray laboratory workers
- Enrichment of tritium in environmental sample water
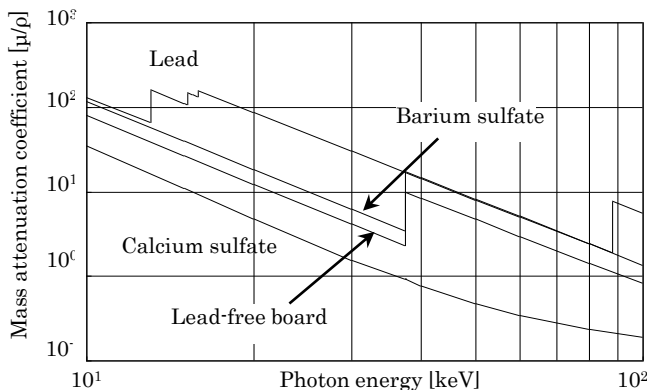- Implementation of breast fluoroscopy, etc.

Fig.1 Mass energy attenuation coefficient of lead-free board

Fig.2 Industrial X-ray equipment

放射線計測学分野

担当教員　加藤　洋 (Prof., Ph. D.)

生体中の微量元素濃度分布を核的方法で分析しています。核的方法として中性子放射化分析法，荷電粒子励起X線分析法などを適用し，ppm，ppbオーダの定量値を得ています。

X線診断領域エネルギーに対する鉛フリー放射線防護材の物理的特性，防護能力などの評価を行っています。その際に，実効エネルギーを基準としますが，X線源の構造，付加フィルタなどによる線質変化により評価が異なるため，細部まで議論していきます。

研究テーマの例
- 診断用X線装置の空気カーマ率の実測と計算方法
- X線管装置の固有ろ過の簡易的算出方法の検討
- 線質変化を伴わないフィルタ線量計の開発
- 乳房透視の具現化
- ターゲット/フィルタの組合わせによる線量強度分布
- 環境試料水中のトリチウム濃縮
- 無鉛ボードの遮へい能力の検証および計算による推定
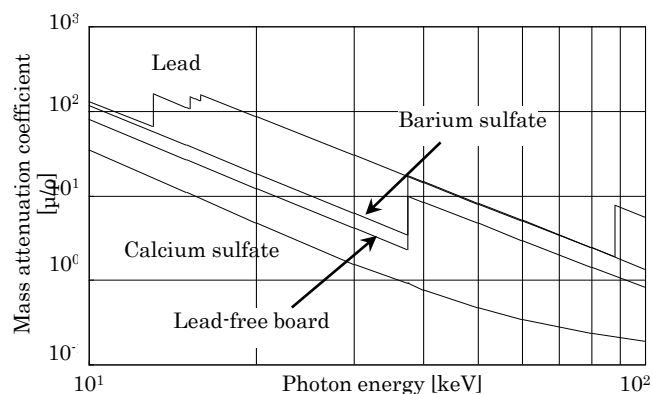- 放射線防護材の光子減弱比に対するMCシミュレーションの適用
- X線診療室従事者の頭髪中鉛濃度，など

図1　無鉛ボードの質量エネルギー吸収係数

図2　工業用X線装置

Diagnostic Imaging Systems Engineering

Faculty in charge: Atsushi Senoo

1. Research: My research projects are useful for medical technicians working in clinical settings, as well as patients or people suffering from diseases or disabilities and their family members.

1. Analysis of brain functions using MRI (functional MRI and diffusion tensor analysis)

We clarify the process of recovery from brain diseases and develop new diagnostic methods by using an MRI system to identify activated sites in the brain and detecting anomalies of the cranial nerve fibers. In addition, we also work on new image processing techniques for analyses and programming of MR imaging procedures (fMRI and diffusion).

2. Development of new MRI imaging procedures

In this research laboratory, we are developing various new imaging sequences and image reconstruction methods for clinical MR devices. We use PHILIPS GOLC for programing imaging sequences, and the C language, ITT Corporation's IDL and Mathwoks Corporation's MATLAB to develop image reconstruction methods.

3. Computer assisted diagnosis (CAD) with time-varying image processing

We are studying medical applications of a time-varying image processing method that can track objects in an image, and developing computer diagnostics such as gastroenterological diagnosis with X-ray fluoroscopic images of the stomach, three-dimensional analysis of myocardial dynamics based on gated myocardial SPECT images, and so on.

4. Risk management and patient care

What are the most common mistakes health care staff make in medical practice? We also conduct a survey on how they deal with patients and so on.

Functional MRI	Diffusion tensor analysis
Is it true that language is processed only in the left brain?	Can mental disorders be diagnosed with diagnostic imaging?
Although it has been said for about the last 100 years that the repetition of words ─ (1) understanding words by listening (sensory language), and (2) repetition of words aloud (motor speech) ─ involves the left brain, it had not been possible to visualize this. Last year, we succeeded in visualizing these conditions for the first time in the world, and made it clear that the right brain as well as the left brain is also involved in speaking words. This research can clarify the process of recovery from speech disorders, and will help evaluate the effectiveness of speech therapy.	Obsessive-compulsive disorder and schizophrenia are said to involve an abnormal arrangement of synapses, compared with the normal structure. Therefore, we developed a system to detect abnormal neural arrangements.

Development of new MRI imaging procedures	CAD with time-varying image processing
Development of MR imaging procedures with no noise	Computer recreation of gastroenterological diagnosis procedures by experienced doctors
Although MR devices have the advantage of obtaining cross-sectional images without using radiation, they produce a lot of noise during imaging. If this research can be put to practical use, it will be possible to greatly change the environment of laboratories. For example, examinations could be performed with music in the background in an MR room. In addition, an analysis of stimuli such as voices or sounds would be possible in imaging brain functions, which could make a significant contribution to the advancement of cerebrophysiology.	X-ray fluoroscopy is performed by doctors, and the accuracy of diagnosis is considered to vary greatly depending on the proficiency of the doctor making a diagnosis. In this research, we develop a diagnosis support system aiming to make computer recreations of diagnoses by experienced doctors. So far, we have made it possible to identify sites of stenosis with time-varying image processing.

2. Education

By following a curriculum of language acquisition specially created by the research laboratory, students can learn more about medical image processing and MR imaging sequences, and everyone will be able to perform programming. We are putting our efforts into developing human resources who can play active roles as core staff members at hospitals, research institutes, and businesses.

画像診断システム学分野

根岸　徹

研究について

　　主として画像診断機器システムの画質向上，および医療被ばくの最適化について検討を行うため，各医用画像機器の測定，解析を行う．

✓ 乳がん画像に関する研究

　　現在，乳がん検診に推奨されている検査方法は**マンモグラフィ**であり、画像の乳腺濃度は，がん発見に影響を及ぼす．特に高濃度乳房は発がんリスクの高い所見の一つとされている．

そこで、画像と被ばくの両面から装置の特性解析を行い、乳房用X線装置の最適化を検討する．

PMMA(mm)		
Breast Thickness(mm)	1	40
Air Karma(mGy)	7.667	
Breast Thickness(mm)	40	
HVL(mmAl)	0.338	
Spectrum	Mo/Mo	
Breast Glandularity(%)	50	
Average Glandular Dose(mGy)	1.747	
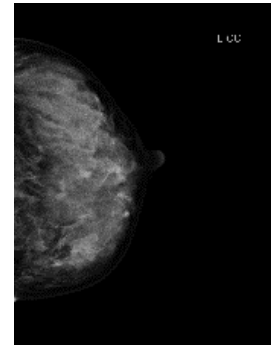
✓ 医療被ばくの最適化に関する研究

　　2015年に我が国の医療被ばくにおける**診断参考レベル**が策定された．そこで、医療現場における画質と被ばく線量の最適化について検討する．

✓ 診断用放射線機器の精度管理に関する研究

　　近年ではIEC規格として画像診断機器の日常試験方法として，**受入試験，不変性試験**等の品質保証に関して審議，発行が進んでおり，随時JIS化されている．これらの規格を基に診断用X線装置の精度管理について検討する．

（Ion chamber）
（Semiconductor）
（General）（Mammography）

教育について

　　X線診断機器学を中心として，医用画像診断装置の最近の動向や安全，および品質保証について最新のIECや論文など取り込んだ教育を行うとともに，X線測定技術の習得方法などを実践的に行う．

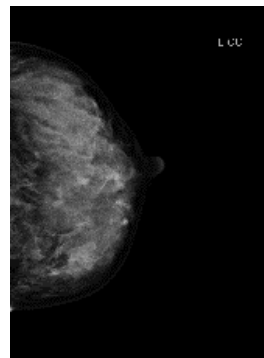# Diagnostic Imaging systems Engineering

Toru Negishi

Research

We perform the measurement of each medical imaging equipment, and we examine optimization of the medical radiation exposure.

✓ Mammography

PMMA(mm)		
Breast Thickness(mm)	1	40
Air Karma(mGy)	7.667	
Breast Thickness(mm)	40	
HVL(mmAl)	0.338	
Spectrum	Mo/Mo	
Breast Glandularity(%)	50	
Average Glandular Dose(mGy)	1.747	

Currently, the examination method recommended for breast cancer screening is mammography, the breast density of the image affects cancer detection. Especially high concentration breast is considered as one of findings with high risk of carcinogenesis. Therefore, we analyze the characteristics of the device from both aspects of image quality and exposure, and consider optimization of mammography.

✓ Optimization of the medical radiation exposure (Diagnostic Reference Levels)

A diagnostic reference level of medical exposure in our country was formulated in 2015. Therefore, we examine the optimization of image quality and exposure dose.

✓ Quality Control of X-ray equipment

（Ionization chamber）

（Semiconductor）

（General）（Mammography）
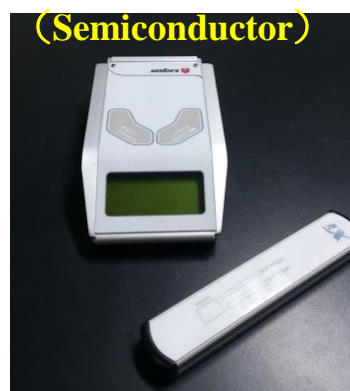
Based on the IEC standards, we examine the accuracy control of the diagnostic X-ray equipment's.

Education

We will lectures on X-rays diagnostic Imaging equipment, and we educate latest IEC or paper. We practice it about a measurement technology of the X-ray diagnostic equipment.

Medical Imaging and Informatics

Faculty in charge: Norio Sekine

We are working on medical image analyses and educational technology.

1. Evaluation of the quality of ultrasound images

○ Development of an automated screening system for breast cancer.

○ Development of a screening system for potential patients with osteoarthritis of the knee.

2. Radiation imaging for medical applications

○ Development of a reconstruction algorithm for tomosynthesis images with a refraction contrast technique.
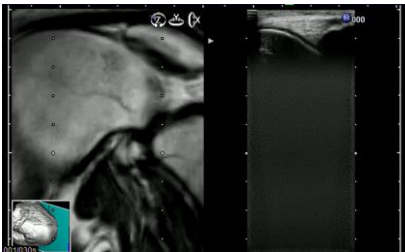
Simultaneous display of MRI
and ultrasound images
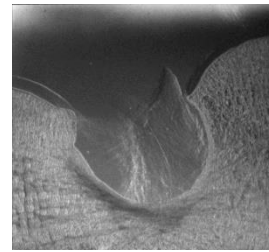
Depiction of ligaments and
cartilage in a monochromatic X-ray

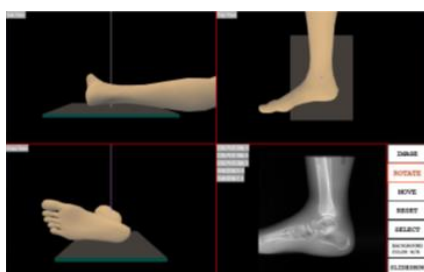## 3. Development of an education support system for radiological technology

○ Research on positioning support for augmented reality (AR) technology and its applications.

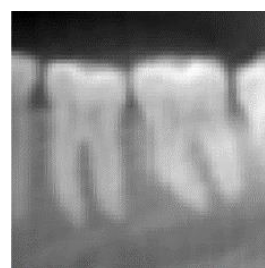○ Simulations of X-ray images for education using CT data.
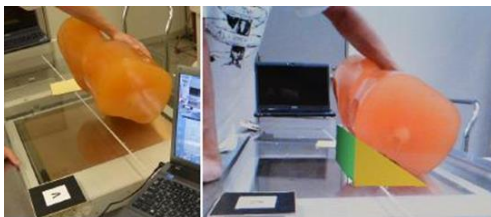
Virtual goniometer with real imaging and
augmented reality

Imaging simulation consistent with
information about posture

3D-CG display examples
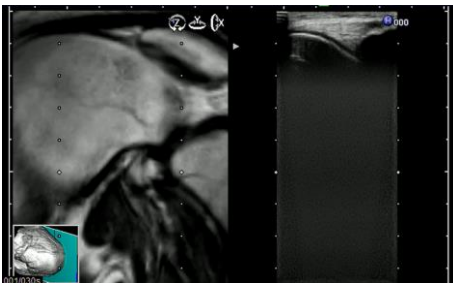

Dental X-ray simulation

医用画像情報学分野

関根 紀夫

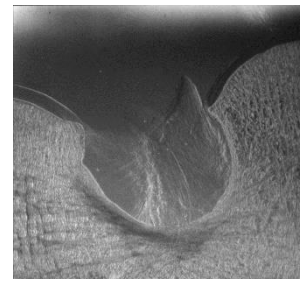## 医用画像解析や教育工学に取り組んでいます。

１．超音波画像の画質評価
○乳がん自動検診システム開発。
○変形性膝関節症予備群を対象とした検診システム開発。

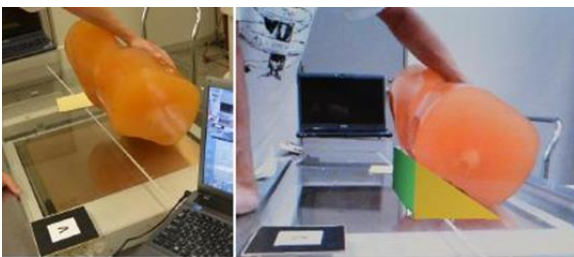## ２．医学応用のための放射光イメージング
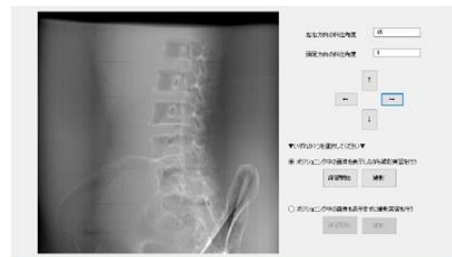○屈折コントラスト法における**トモシンセシス画像再構成**の開発。

MRIと超音波画像の同時表示

単色X線による靭帯と軟骨描写

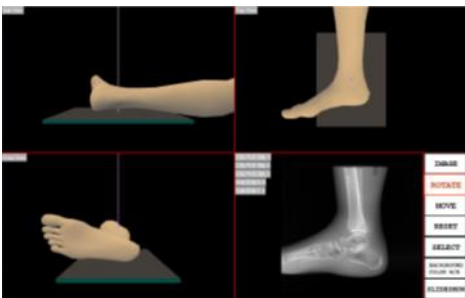## ３．放射線技術学教育支援システムの開発
○**拡張現実 (AR)技術**にポジショニング支援の研究と応用。
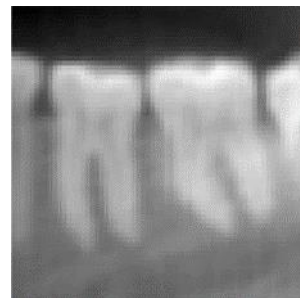○**CTデータを用いたX線撮影画像**の教育用**シミュレーション**。

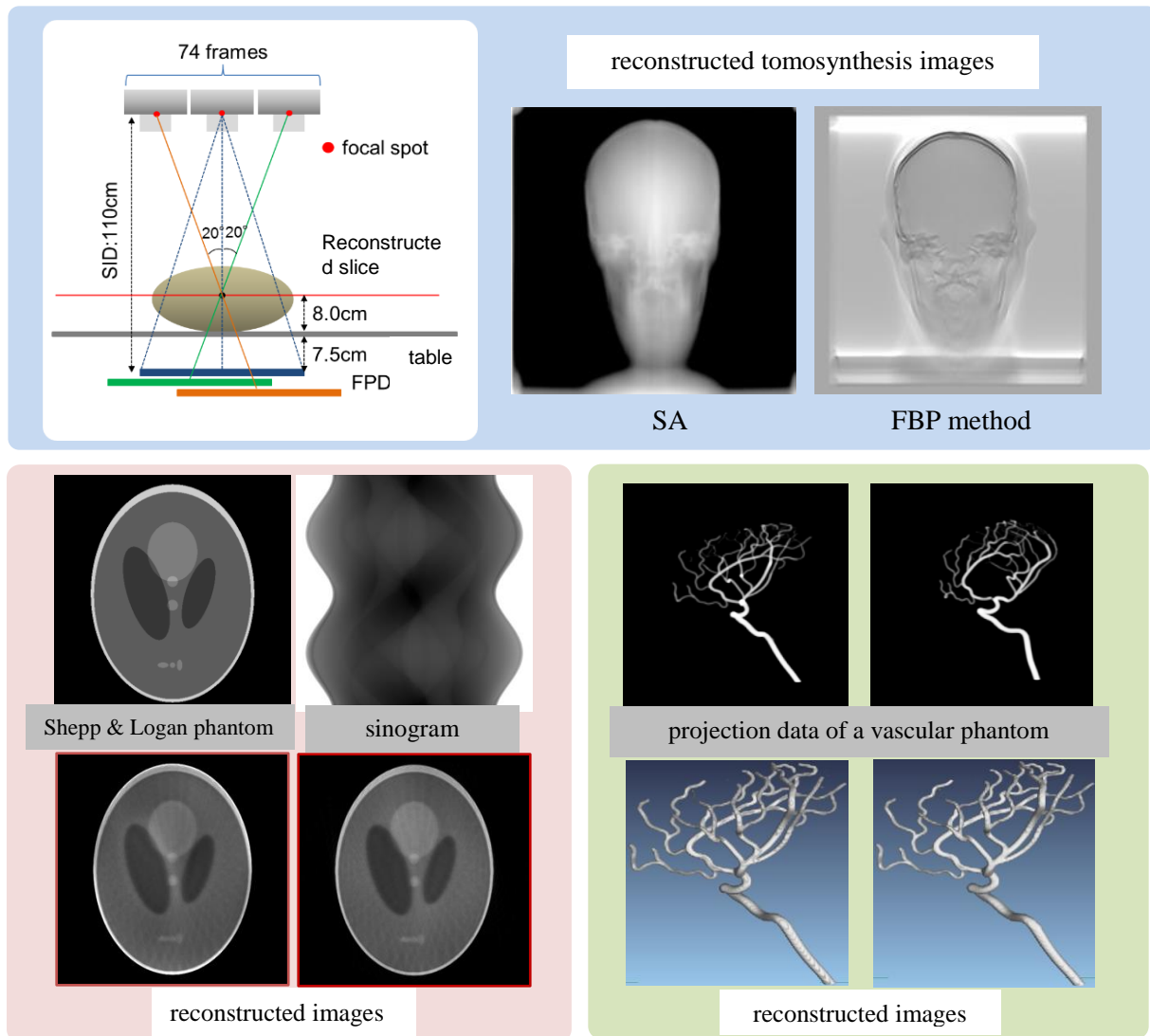リアル映像と拡張現実による仮想角度計

体位情報に合った撮影シミュレーション

3D-CG表示例

歯科X線シミュレーション

Medical Imaging and Informatics

Faculty in charge: Yoshiyuki Nyui

1. [Research]

We are conducting fundamental research on medical image concerned with image reconstruction techniques. We mainly study image reconstruction of tomosynthesis. And we also study to reconstruct images from a few projection data using iterative reconstruction techniques (algebraic reconstruction technique, a maximum likelihood expectation maximization method and so on).

reconstructed tomosynthesis images

SA FBP method

Shepp & Logan phantom sinogram

reconstructed images

projection data of a vascular phantom

reconstructed images

2. [Education]

In advanced courses on Medical Imaging and Informatics, we give lectures on the basic principles of image reconstruction methods. Furthermore, in the practical exercises of advanced courses on Medical Imaging and Informatics, students will actually create a simple image reconstruction program such as simple back-projection, filtered back-projection and iterative image reconstruction method. And further learn more about image reconstruction method by changing various parameters (such as projection angles, number of projections and so on).

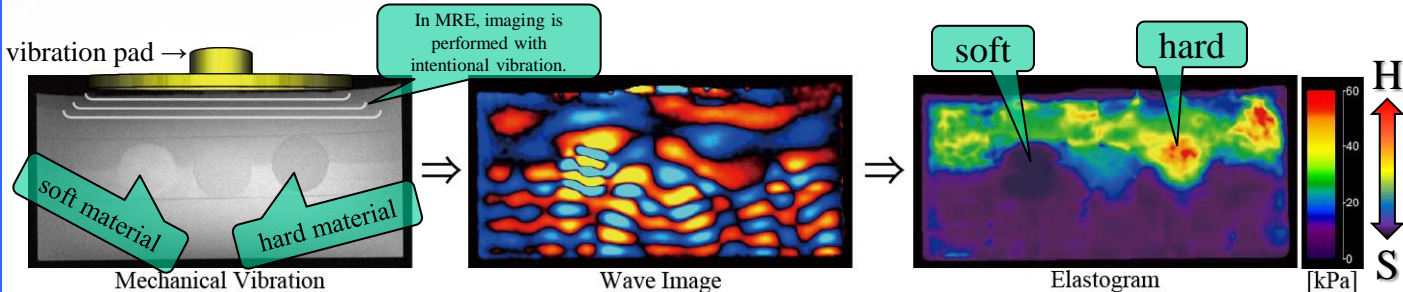# Details of research conducted in the Numano research laboratory

首都大学東京

Research project in Numano research laboratory: MRI

We make use of MRI to carry out research on techniques to visualize *in vivo* information that has been difficult to image.

A technology to create an image of "hardness" *in vivo*: Elastography

We are advancing MR Elastography (MRE) that does not rely on the technology of MRI manufacturers, and have demonstrated MRE with our unique technology. MRE can create an image of "hardness" *in vivo* that had been impossible to image with traditional MRI technology. Thus, we can now obtain imaging data reflecting a distribution of hardness, which was not possible to image in the past.

vibration pad →

In MRE, imaging is performed with intentional vibration.

soft material   hard material

soft   hard

H   S

Mechanical Vibration ⇒ Wave Image ⇒ Elastogram [kPa]

A Simple Method for MR Elastography: A Gradient-Echo Type Multi-Echo Sequence. *Magn. Reson. Imaging* 2015 33:31-7

Development of a new MRE technology

We demonstrate a new technology which enable *shoulder* MRE and water/fat imaging simultaneously.

A   supraspinatus muscle   L

A   L

A   L

10   5   0

Water Image   Fat Image   Elastogram   [kPa]
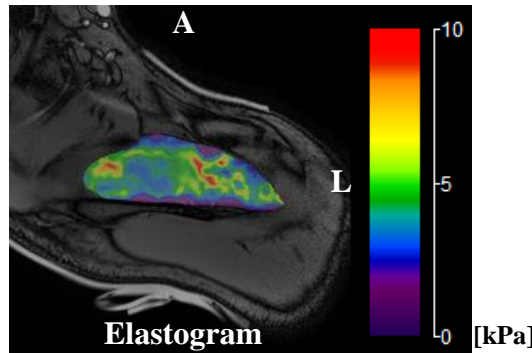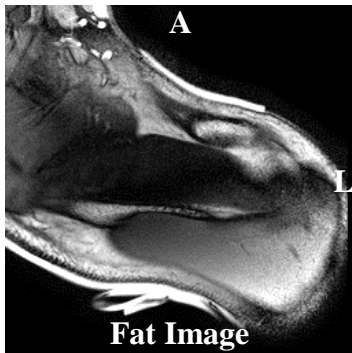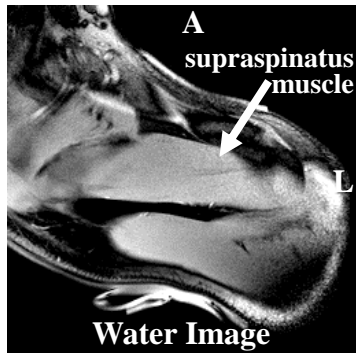
Fat is often a source of problems in MR imaging. It tends to have high signal intensity at all contrasts, which could mask image changes reflecting various tissue pathologies. We have developed a new method for simultaneous acquisition of MRE and two-point Dixon imaging (water/fat imaging) on a conventional MR imager.

Simultaneous Acquisition of MR Elastography and Two-point Dixon Imaging. *ECR 2018: ESR/EFRS Radiographer Awards*
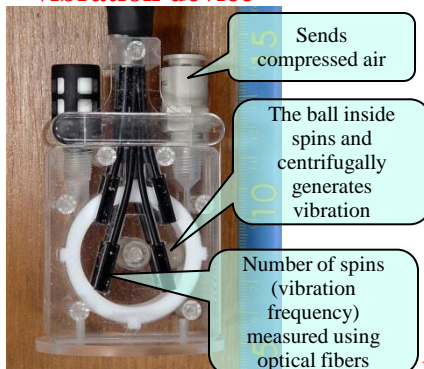
Development of a new vibration device for MRI

Japanese Patent No. 5376593

Current sound pressure-type vibration device

speaker   vibration pad

Uses the sound pressure generated by the speaker

→sound pressure

about 5 meters
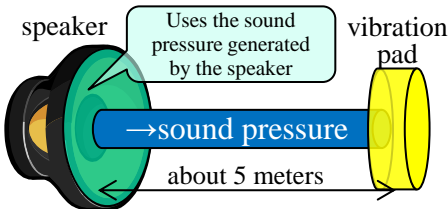
・Limited to a low vibration frequency range (the image resolution of MRE is low).
・The tube connecting the speaker to the vibration pad measures up to several meters (causing a great loss of vibrational energy)

Newly developed vibration device

Sends compressed air

The ball inside spins and centrifugally generates vibration

Number of spins (vibration frequency) measured using optical fibers

There are a number of advantages compared with a sound pressure-type vibration device.

- High vibration frequency range (the image resolution of MRE is higher).
- Directly vibrate the target (resulting in little loss of vibrational energy).
- Even a small device can generate strong vibration.
- As is the case with the sound pressure type, this new device does not influence MRI since it is made of non-magnetic materials.

In this research laboratory, we are also developing devices that will play a part in next-generation MRE technologies, together with MRE techniques with a relatively high feasibility.

Magnetic Resonance Elastography using an air ball-actuator. *Magn. Reson. Imaging* 2013 31:939-46