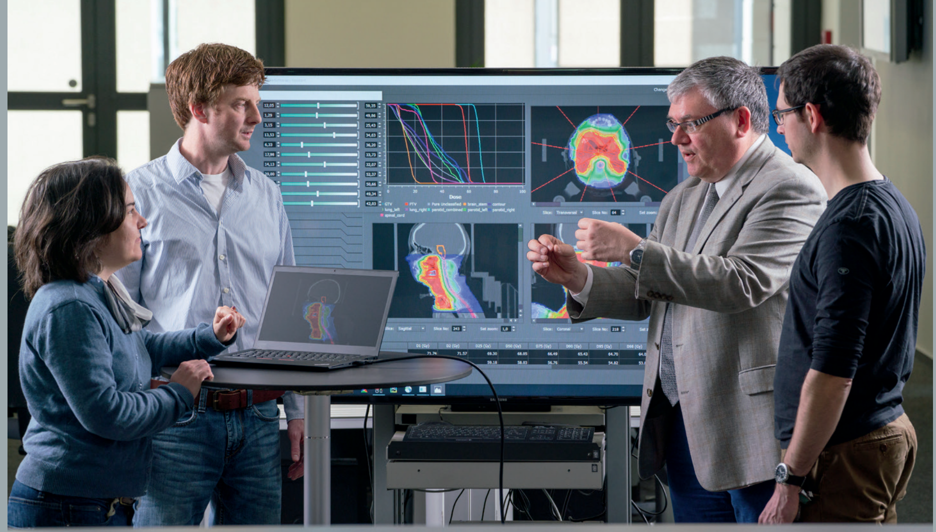

Research Directions

The team of the Fraunhofer ITWM already has several new ideas on how to further develop the software The team patented a histogram for adjusting the dose, which works similar to the brightness histogram in the image processing program used by many graphic artists. A further patent relates to the statistical dose distribution, i.e. which percent of an organ structure receives a specific dose. This spatial distribution of dose in an organ is valuable, but it also makes sense to think about the fourth dimension – time. Today, the patient is irradiated with a constant dose profile for weeks. It would be conceivable to vary the intensity of each treatment, sensitive areas are hit less frequently by the radiation.

The Optimization Department has a number of other areas of application for the multi-criteria optimization method in mind beyond medical physics - for example, for the planning of complex production processes. For more than ten years, they have been developing multi-criteria optimization software for the chemical industry to optimize energy input, quality, throughput and environmental properties in production – with significant success.

Feedback from Customers

"With the MCO tool, we are creating high-quality plans for very challenging cases that we could not have achieved in the past—in a fraction of the time."

Suzanne Currie, MSc, Beatson West of Scotland Cancer Centre Glasgow, U.K.

"MCO is a very powerful and clinically beneficial tool that will take many of the inefficiencies out of treatment planning and provide the required information to dosimetrists and clinicians at the time they need it most."

Trent Aland, national director of Physics at Icon Group

"Using MCO, we've been able to improve our optimization process, creating higher-quality plans in less time."

Tianyou Xue, Ph.D., St. Luke's University Health Network Pennsylvania

"We are finding great gains in speed and efficiency by utilizing MCO. This is especially true for more complicated cases, such as partial brain, head and neck, and lung."

Jennifer Jones, CMD, RT(R)(T), lead dosimetrist at St. Luke's University Health Network.

All quotes from the Varian Centerline article of February, 11 2019/www.varian.com

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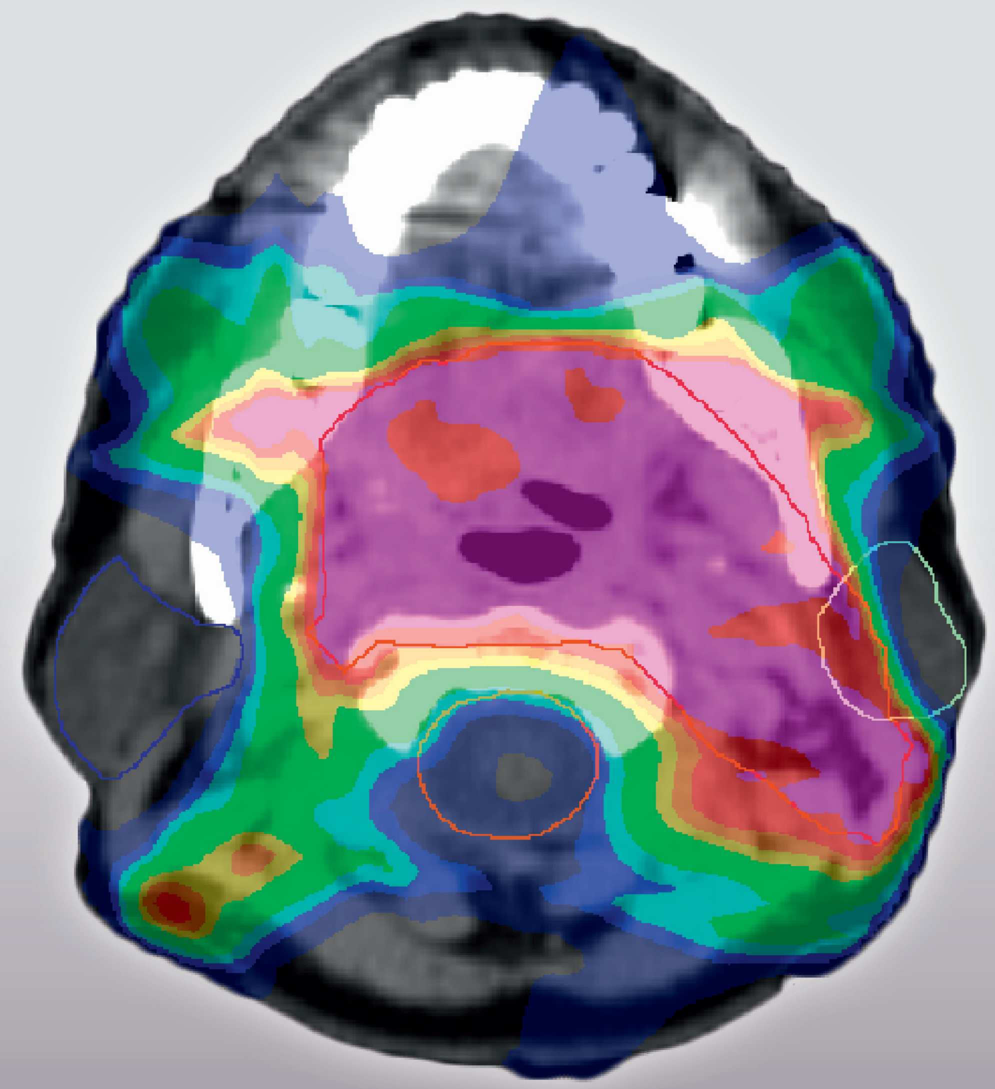
FRAUNHOFER INSTITUTE FOR INDUSTRIAL MATHEMATICS ITWM

FRAUNHOFER-SOFTWARE OPTIMIZES RADIATION THERAPY



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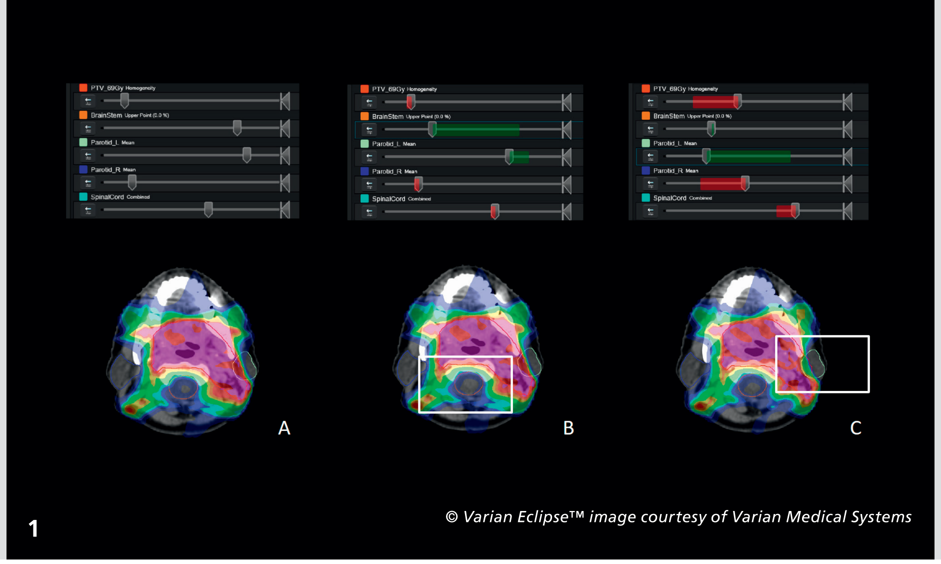

1 *Illustration of a typical planning session. Beginning at a starting plan (A), the planner first lowers the dose to the brainstem (B) and then additionally lowers the dose to the left parotid (C) to arrive at a good compromise between all objectives.*

Fraunhofer-Software Optimizes Radiation Therapy

When planning a therapy, different competing quality criteria like prospects of treatment success, risk of side effects and costs have to be considered. Thereby, chances and risks must be individually balanced for every patient. Using a real-time decision support tool the most appropriate treatment for a patient can be interactively selected.

Not Science, but Art

Professor Karl-Heinz Küfer, head of Department "Optimization" from Fraunhofer ITWM was amazed when he saw for the first time how radiation therapy for cancer patients was planned: "Only long-serving specialists could find good solutions for difficult cases," says Küfer. A chief planner told him in 2001: "That's not science, it's an art". Today mathematics helps, to find a better balance between therapy opportunities and side effects.

In 1996, Karl-Heinz Küfer was approached by a doctoral student at a hospital, "I have a numerical problem, can you solve it?" In concrete terms, it was about the question of how to algorithmically plan radiation therapies. Küfer found the question interesting and thought about it with colleagues. In 1997, he approached Thomas Bortfeld, one of the fathers of intensity-modulated radiotherapy. During their meeting, Bortfeld sketched the outline of a horseshoe-shaped tumor, proliferating the spinal cord. "Show that you can calculate that a little better", he said. A year later, Küfer went to the DKFZ again: he brought with him the proof that Fraunhofer ITWM could do the math. "From then on, we were in business."

A Typical Planning Session

An exmplary use case of the software is illustrated in figure 2. The planner starts with a plan that has very good tumour coverage – as indicated by the slider position far to the left – but at the expense of the brainstem and the left parotid as indicated by the slider positions far to the right (A). Considering possible side effects to the patient, the planner decides to improve brainstem sparing by dragging the associated slider leftwards (B). This move also affects the other objectives. However, the trade-off is very favourable as there are only very minor costs in the tumour, the right parotid and the spinal cord (indicated red). Having improved the brainstem to a satisfactory level, the planner decides to lower the dose to the left parotid as well (C). He can do so, but now there is a substantial trade-off involved with respect to tumour coverage, right parotid and spinal cord (indicated red). The planner can drag the slider as far as he is still comfortable with the involved costs, and stop when he has reached the optimal balance beetween all objectives.

More than Ten Years of Start-up

Support for the project came from the German Cancer Aid (Deutsche Krebshilfe) and the Federal Ministry of Education and Research (BMBF). Since 2016, they are working in collaboration with Varian Medical Solutions, the market leader for intensity modulated radiotherapy equipment. Since November 2017, the software is on the market, selling well, and there is great feedback from customers. "Together with Varian, we can reach a huge market because the company sells in more than 150 countries", says Küfer.

The result of more than 20 years work is an interactive and easy to use software. It shortens the duration of radiotherapy planning. Previously, therapy planners sat in front of computers, examining Computed tomography (CT) sectional images for hours. Creating treatment plans required significant experience and patience, with planners spending hours tinkering the plan in order to design a three-dimensional radiation profile. The aim is to reliably destroy the tumour while minimizing the strain on sensitive tissues such as the optic nerve or spinal cord. Küfer: "We do not want to make the therapy planners obsolete, rather we want to make their work easier and safer for the patient." The principles of software operation are so simple that doctors will be able to carry out the final planning themselves using the software in the future. The prerequisite is that the model must have been prepared by a medical physicist, which takes only a quarter of the time previously required.

Interactive Multi-Criteria Radiation Therapy Planning Software

The time saving is possible because the software can overlay and recombine radiation therapy plans in real time. For example, the planner can use a slider to improve the dose level of the optic nerve and observe how the dose decreases in the tumour, reducing the safety margin by a few millimeters. At the same time, the radiation profiles are updated in the background using a mathematical algorithm which ensures that the desired dose is reached for the sliding objective but other relevant dose levels in the tumour and in healthy structures deteriorate as little as possible. The mathematical method is called multi-criteria optimization. It allows different, sometimes even contradictory goals to be brought into the best possible balance.

2 *In Radiation Therapy a good compromise between tumor control with sufficiently high doses and avoidance of complications by sparing the healthy tissue has to be found. In the planning process, the clinician searches for the compromise that best suits the patient.*