

# A Historical View on Computer Aided Medical Procedures and Augmented Reality\*

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**Abstract**—Bringing innovation in medicine is commonly an act of perseverance and patience. Prof. Nassir Navab has proven however that such an endeavour can become a life full of success. By navigating in uncharted waters led by curiosity and creativity, Nassir has forged the future of hundreds of people and changed the face of Computer Aided Medical Procedures and Augmented Reality at a global level. This review, rather anecdotal and incomplete summarizes the journey of Nassir making out of his passion a path of innovative research and successful mentoring. His (ex) colleagues, (former) students, peers and friends take here the opportunity to thank him in his 60th birthday (Thomas Wendler).

**Index Terms**—the man, the legend

## I. INTRODUCTION

### A. Foreword (Daniel Roth)

Many research articles start with the words “In these days...”, “In current times...”, or “With the current technological development of [put AR, VR, and alike here] today, ...”. Many of us have done it, many are ashamed by now, even to a level that each time you review it a small piece of your academic soul dies. Yet, the present paper is an exemplary target for such phrases. Or is it not the current situation (and I mean CoViD, not your aging) that keeps us from experiencing social closeness and joy together, exchanging attention and hugs to beloved ones, family and friends? So...

In these (unusual) days, this paper is meant to spark joy (hopefully) and communicate gratitude from present, former, and past colleagues and collaborators. It is meant to transport the best wishes that the authors would like to communicate personally. Many of which you have been a colleague, collaborator, advisor, mentor, and friend. Several dozens have contributed to this review, and we hope you enjoy the read. We congratulate you to your 60th’s birthday and wish you all the best for your next missions.

### B. Early Days (Wolfgang Wein)



Fig. 1. While exploring the peaks of the science, he still feels like a first year school boy.

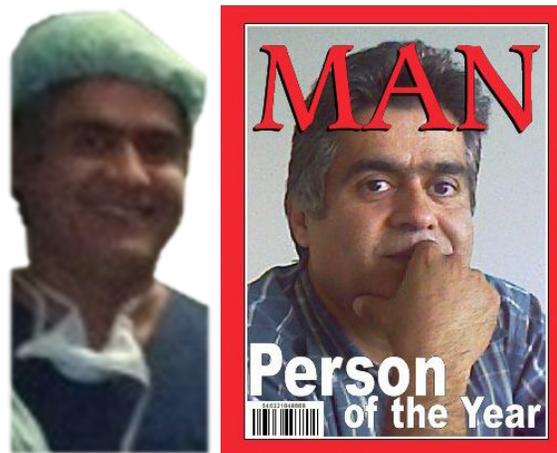


Fig. 2. Nassir never changing over time (left 2019, right 2007)

In spring 2003 at SCR in Princeton, Nassir asked me to join his new group after my internship. Never having thought about my future before, I was like “sounds good”. I had no idea how memorable, challenging and amazing that all would turn out to be. That fall, in the first pioneering months after founding I16, we pretty much had to arrange for our own toilet paper, and were parsing hundreds of applications for a secretary, among other duties. Nassir easily convinced collaborators to provide collaborative lab space, in all relevant Munich hospitals, not just the TUM ones. We loved our time in the tiny Trogerstraße office above MITI, being close to the patients whom this was all about (and saving plenty of commute time to Garching - the subway wasn’t finished yet). Nassir had a huge amount of time to hang out in our office (a privilege many later students obviously could not enjoy), and to talk about research and teach us, but also make us teach right away; including the first computer vision lecture in summer 2014 for which the room was always too small. He taught me how to manage expectations from industry partners, and that a good scientist not just develops algorithms, but also knows how to present and position a paper with care. My first MICCAI submission 2004 about 2D-3D registration was rejected, an adapted version made it to SPIE-MI, and with a change of topic to multi-modal ultrasound registration (with constant support from Nassir how to think outside the box) I got my first MICCAI paper accepted in 2005 [1]. It was also in summer 2005 that Nassir for the first time in decades traveled to Iran, while our still small group was sincerely afraid that our Prof might not be able to come back. I already left for the US in spring 2006, henceforth working permanently in industry. Nassir insisted I always keep an academic track record and give invited talks wherever applicable, which turned out to be extremely valuable advise. Both from overseas and once back in Munich, I observed how CAMP grew and flourished, and how Nassir created an ever-larger pool of new talented researchers who would make a change around the world, whether in big medtech, innovative startups, or less developed countries that never engaged in medical imaging

research before. Apart from his incredible drive to help create innovation, he deeply cares about the career of every single one of his students, and always gives the most careful advise he possibly can. With all this, Nassir has made CAMP a one-of-its kind environment, with truly global impact.

### C. General Leadership, Skillset, and Role-Model Performance

Amongst many of the skills you can have as a researcher and team leader, only few have the skill to provide outstanding leadership and role-model guidance, while keeping the focus on a positive attitude and the motivation of all team members. Some anecdotal evidence underlines the fact that Nassir is most capable of that, even to the degree to make everyone wear really badly designed CAMP group shirts at MICCAI, showing his pride for the team and its achievements. Further evidence is reported in the following.

**Inspiration.** People may now ask general questions about crossing frontiers in science at CAMPAR: 'Too inspiring'? Does 'too inspiring' exist? The following proof is available. The party depicted in Fig. 3 took place because the birth simulator [2] was obviously too inspiring... (Tobias Sielhorst).



Fig. 3. Birthday party of baby David. Nassir had to hold my talk at St. Malo (MICCAI 2004) about the AR birth simulator just few days before, because I had a better appointment than MICCAI :-)

**Titles do not apply, not even in Tirol.** During dinner on the first day of the CAMP summer school in South Tirol (probably in 2007), Nassir addressed the attendees - MSc/PhD students, asking them to call him - a professor - by his first name instead of using his title. His approachable and positive personality combined with his extensive knowledge made working with him fun and a great learning experience (Dzhoshkun Shakir).

**Collecting trophies.** Nassir is a professional treasure hunter. His uncountable number of personal awards extend over the hundreds of awards collected by his students. However, even if not granted by others, if he gets his eye on a shiny trophy he always gets it. A proof is a legend from 2010 when he was at a meeting in Siemens Erlangen. As usual his great optimization skills made him arrive to the meeting just in time



Fig. 4. Nassir frequently travelled to The Johns Hopkins University for academic research and teaching starting in 2015. The university's location requires a car for transportation (Contributed by Ben Fürst and Tobias Sielhorst).

to hear the important part (and avoid the boring introduction). On entrance he saw an opportunity and hanged his jacket on a shiny beautiful doorbell. Optimizing as always, he also left the meeting before the boring conclusions and voilà, without anyone noticing he took the shiny object home. This legend was never confirmed, but people claim that there is a meeting at Siemens that has been going on for almost 10 years. Others claim poor Martina had to steal the doorbell from Nassir and send it back to Siemens with an apology letter. No matter what truly happened, Nassir will keep collecting shiny prizes for long (Thomas Wendler based on a true story).

**Fast and worthy 5.** These exceptional skills and leadership do not remain unrecognized. For example, according to his deserved VIP benefits, Nassir has a special membership, and can pick whichever car is on the lot. So back in 2015 he wanted to try a convertible, and picked a Camaro Convertible. See figure 4 (Ben Fürst).

**Forever young.** On IPCAI 2018 in Berlin, after Javier and Salvatore got two awards on the conference, Nassir decided to celebrate and he invited the team to a dinner in a super fancy restaurant. Already on the restaurant, some kids on the table beside started throwing stuff at CAMP's table, and at some point they threw a shrimp that landed very close to Nassir plate. Everyone shut up on an extremely tense situation, expecting such reputed professor to get mad. Quite the opposite happened, he took the shrimp, he threw it back to the kids table, and laugh out loud! (Javier Esteban)

**Talents and strength.** Aside from his general outstanding skillset in manifold disciplines that include arts, such as accordion playing (see Fig. 5), and martial arts, such as professional sumo wrestling (see Fig. 6), he is especially drawn to team disciplines. For example, during the 2017 annual dragon boat race on the Olympic Lake, Nassir spontaneously joined the TUM professor's team to race against the archenemy, the LMU. We are convinced that his strong contributions in the 17-person rowing team were decisive in securing the win (see Fig. 7). Furthermore, he somehow managed to steal the team trophy (see Fig.7), which likely still inhabits a special place in his home.

**Never ending list of contributions.** Despite Nassir time being finite, Nassir has proven that you can surprise people



Fig. 5. Nassir playing accordion during the dinner at ISMAR 2005 in Vienna.



Fig. 6. Nassir easily winning a professional Sumo fight at CAMPing 2014 in Innsbruck



Fig. 7. Nassir single-handedly secured the win against the LMU professor's team in the dragon boat race (top) and deservedly was awarded the trophy for first place (bottom).

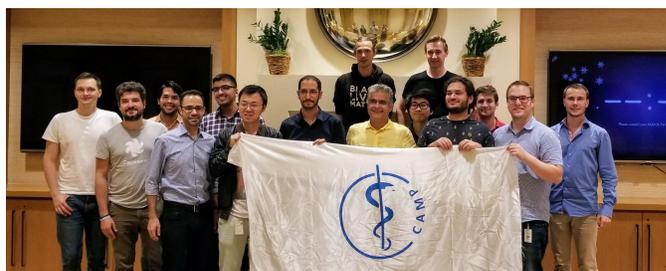


Fig. 8. Wherever Nassir travels, current and former CAMPers gather to welcome him and celebrate the team and culture that he builds. So happened in Silicon Valley in 2019.

and make changes everywhere. Some highlights of his contributions to humanity include :

- a successful implementation of the “alone we advance faster, together we go further” with a solid experimental validation over a database of > 100 junior researchers over several generations.
- a very deep long-memory network (VDLMNet) of people all around the world ready to collaborate, from whom Nassir remembers the conference (year and city) where he met them, as well as the name of the paper they presented.
- a unique and healthy research culture that takes humans into account.
- a method for convincing people to leave a meeting with more work but happy

- the concept of "on the go" meetings (hallway, stairs, between-lab commutes...)

(Javier Esteban)

**Continuity in collaboration.** In early 2002, being a fresh PhD student of Gudrun Klinker, I saw Nassir giving a presentation at TUM (while he was not yet a TUM prof!). I only first met him a few months earlier during the open house of SCR in Princeton during ISAR 2001. My first impression was that he "knew a few things" about computer vision. I could have never guessed that our research group would later merge with CAMP and that we would be collaborating to this day! (Christian Sandor).

## II. GENERAL MENTORSHIP

Aside from his achievements and skills in leadership, Nassir was mentor to many of us. Some exemplary descriptions demonstrate his impact on individuals. In the following a list of testimonials makes this clear.

*I know him since the first time I was invited for an interview at TUM with another professor. Since then, even though he was not my official supervisor, he became my influential supervisor till date and has played the most important role in my career life. Not only I have learned from him the science of translation in medical engineering, but I also learned from him lots of aspects in the science of life. Today he is an excellent mentor and a reliable friend (M. Ali Nasseri).*

*Nassir has been inspiring us not only in our research but also in the life attitude. Here are some inspiring words/phrases that I recall and have been useful for me and making me walk towards the right path: "Let's forget about the funding; just do the crazy research that we like"; "During your Ph.D., you should enjoy what you are doing, and be able to sell them for funding."; "We should also have a maximum wage-right. People don't need that much money to live, but society needs it. Money should be reinvested into society but not be kept by the rich." Nassir also taught us the importance of work-life balance. When he is at JHU, he invites people from different fields to his game/wine/pasta party, in which everyone is relaxed and also gets the chance to mingle. It is a great platform to know people and explore cooperation opportunities. Many research ideas have been generated at the house party. For instance, 3D-3D CAMC [3] came from one of these house parties (Sing Chun Lee).*

*Looking back to the days when I started my PhD, I am really glad that Nassir convinced me to start the scientific journey, which I would have never dared to do just by myself. I was inspired by his serious and at the same time enthusiastic and very kind attitude to his students. This helped me to be bold with my scientific goals and easily handle failure and rejection which is common in the research world. As Nassir greatly fosters collaboration between his students and other scientists, I was able to come up with better ideas and find a lot of unexpected applications of my research to other*



Fig. 9. Nassir invited Dr. Osgood (left-most), Chief of Orthopaedic Trauma, JHMI, to the house party, mingling with CAMPers, discussing CAMC future direction, and playing party games together.

*domains (Daniil Pakhomov).*

*I became part of the CAMP chair during my master's in biomedical computing. Shortly after the successful defense of my thesis, I was offered a PhD position with the vision to revive an area of research that was inactive at the Chair, namely catheter tracking. Nassir's extraordinary perspective opened a lot of opportunities for my research, with main contributions in the EDEN2020 European project with Imperial College London (ICL). With the project approaching an end, the collaboration between the Chair and ICL, respectively with the group of Prof. Ferdinando Rodriguez y Baena, was extended for another four years through a successful grant written for TUM – ICL JADS program, led by Nassir's visionary idea of Bioelectric Navigation. Nassir's incredible skill of creating new connections opened another path of collaboration between the Chair and the German Heart Center in Munich (DHM – Deutsches Herzzentrum München). Through this collaboration, Nassir managed to create another already growing research group in one of the leading Heart hospitals in Germany, with Prof. Peter Ewert and Prof. Heribert Schunkert as new medical supervisors. It is fascinating to work in such a dynamic field, let alone to work closely with such a beautiful mind as Nassir's (Ardit Ramadani).*

*I was able to meet many people who were at the same time fascinating and had a lot of wisdom. After these exchanges, I was most often inspired and convinced that with the greater depth of knowledge of the subject, the road to the destination has become longer. This renewable experience has taught me to distinguish among all the STARS of SCIENCE those ones who can truly move things, giving hope and faith in the future. I was seldom to meet them in my path of scientific development, but with the special ones I am bound*

by a holy memory and a deep gracious gratitude from my heart for the opportunity to meet them personally. Prof. Nassir Navab is a person who has given me and my team hope, a particular target and the possibility of achieving it. Through his decision to work together, not only my professional life has changed, my whole team has started a new chapter in considering medical and surgical engineering. His attitude of listening, analyzing and helping is legendary and example of characteristics who every humanist should follow. Dear Professor Navab, I wish you, together with all my wide-ranging Team for the Birthday Jubilee lots of Health, fulfillment of your Dreams and God Blessing. Thank You for your Help. Your admirers, Konrad Karcz with all Members of the Team and associated Persons (Konrad Karcz).

When I visited Nassir's chair as exchange student during my PhD, I was overwhelmed by the vast amount of research topics that Nassir covers, his creativity, and impressed by the annual group retreat CAMPing. At that time, I could not have imagined finding myself two years later to be managing one of Nassir's Hospital research labs, which resulted in a number of publications in the areas of Augmented Reality [4]–[6], Medical Education [7], Surgical Training [8], [9], Medical Visualization [10], and Sonification [11] (Ulrich Eck).

Nassir was always supportive for my decisions. I always enjoyed discussing with him about new ideas. I managed to get two internship with his support at Microsoft. I got the main idea from Nassir at my first paper which I was a first author [12] and He also contributed a lot to the rest of my papers. I'm very happy to work with Nassir (Huseyin Coskun).

I have never encountered such a genuinely supportive person in my entire life. Nassir's positivity is at such a too-good-to-be-true level that, one feels as if something must just be wrong. Recall those times where you felt like the knot is totally scrambled and would never be rearranged? That is where Nassir comes into play and re-introduces you to yourself. I must also mention that he is the reason why I am at Stanford University in the first place. (Tolga Birdal).

**"Sure Sure. Go ahead":** I still remember the moments when I first met Nassir back in May 2013. I was a newcomer with a DAAD scholarship working on Biological Imaging -that I'm not really interested in- and was looking for an official supervisor. I was almost lost! I traveled 1200 km Bonn-Munich-Bonn to meet Nassir and get his approval to supervise me! I was just astonished and surprised by his humble! "Yes! He did agree to supervise me", I said back then! Although the stipend, I received from DAAD, was barely surviving in such an expensive city, I didn't hesitate to take the decision to completely move to Munich. I must say it was the right decision I ever took! Although I met Nassir a few times during my PhD, I just enjoyed his fruitful discussions and ideas. I must admit that I always sought to extend these

meetings with him as much as I could. With his incredible and sometimes crazy ideas, I managed to publish a couple of works in high impacted journals and top-tier conferences. Not only this, but I fulfilled my passion and worked with Medical Imaging – the topic I love-. I finished my PhD with distinction and made my family in Gaza, and Munich proud of me! Thanks, Nassir! Nassir's endless support didn't stop here! He hired me as a postdoc and gave me a lot of responsibilities to lead and mentor a team of PhD students. I found myself in the driver's seat and struggled a little bit at the beginning! I must admit dealing with 10 PhD candidates coming from different backgrounds was just a challenge! However, with his continuous and constructive feedback, I managed to make this happen! I'm so proud that most of the PhDs I mentored are writing up their thesis, if not graduated already. "Sure Sure. Go ahead" – these words among others what I picked from Nassir. With his humble, ultimate support, and flexibility, which I liked most in Nassir, I managed to establish my own research group at Helmholtz AI. I am grateful to you, Nassir! (Shadi Albarqouni)

While these are only a few examples, that stand for uncountable more, and demonstrate the attributed passion with which Nassir supervises, supports, and mentors his academic senior and junior researchers and colleagues. Throughout and in line with these processes comes innovation and high quality research in manifold areas, most prominently, medical image computing and computer aided interventions. These result in outstanding presentations that usually gather the largest crowds, even larger ones than some presidential inaugurations (see Fig. 11). Some of these endeavours are documented in the following.

### III. MEDICAL IMAGE COMPUTING

In early times Nassir put significant efforts in establish a strong know-how in the Chair on Medical Image Computing. Independent if Image Reconstruction, Segmentation, Registration, or any type of manipulation, Nassir made it clear that without fundamental research in those fields the Chair would be standing on shaking legs.

Nassir had outstanding achievements in all fundamental fields of medical imaging, including reconstruction, segmentation, and registration. His comprehensive vision, along with his brilliant managing abilities, has made a joyful scientific environment that everyone has the great pleasure of being part of it. He also believes in international collaboration and team working. With Nassir's support and his fantastic team, Shahrooz Faghihroohi won the third title of the MRRec challenge in the MIDL conference and had this opportunity to continue this remarkable experience as the scientific coordinator of the ICL-TUM JADS program. This program consists of several multidisciplinary projects that merge medical imaging, machine learning, and robotics (Shahrooz Faghihroohi).

Before deep diving, Nassir and his team had surfed manifolds [13]–[16] and climbed trees [17], [18] (Diana Mateus).



Fig. 10. Nassir even has meme-potential, as proven by an anonymous artist. Photo credits: Ari Tran



Fig. 11. Millions come from all over the world to attend Nassir’s public appearances. This phenomenon was pictured at MICCAI 2019 in Shenzhen, China.

Under the supervision of Nassir, Benjamin Gutierrez-Becker introduced novel methods for machine learning based medical image registration [17], [19], and even managed to pull an underdog move and get a Young Scientist Award at MICCAI 2016 (Benjamin Gutierrez-Becker).

With support of Nassir, Tingying Peng developed a novel method based on low rank and spare decomposition, BaSiC, for illumination correction of microscopy images, which turns into a Nature Communication paper [20]. Now BaSiC has been used for microscopy image processing in both academia and industry (Tingying Peng).

With the advent of deep learning, especially in Computer Vision, Nassir came with an incredible idea of organizing a three days Deep Learning workshop<sup>1</sup> to i) introduce our industry partners to this technology, ii) engage with them in longer-term research collaboration, e.g. BMW, Rohde & Schwarz, among others, and finally iii) make use of this chance to strengthen the knowledge of his students. His idea went surprisingly well allowing his team to continue organizing this workshop for a couple of years.

As probably mentioned earlier, Nassir has given his team the flexibility to work on their interests. Shadi Albarqouni picked this up and started investigating Deep Learning with Medical Imaging. His contribution [21], among the first ones at the CAMP chair, on aggregating the knowledge from deep learning with the ones coming from human oracle was well received in the community achieving the top downloaded papers at IEEE TMI [22] (Shadi Albarqouni).

Nassir supported an off-beat path towards investigating a relatively new technology called Hashing for Content based Image Retrieval in Medical Images. Our work went on to win the prestigious Medical Image Analysis Best Paper Award in MICCAI 2016 [23] which was a major step in my career. Nassir helped nurture in me the confidence to bare the unknown and stay focused to develop a wide breadth and depth during my PhD. The best part of all was Nassir’s sense of humor and anecdotes that are both fun and motivating. He continues to be approachable for his students even after they graduate and I would deem him as a mentor for a lifetime (Sailesh Conjeti).

Nassir has always been fully supportive of his students, even if, at times, they want to jump off a cliff during research. As a direct result of this, Anees Kazi took a different direction of research by employing Graph Deep Learning for medical applications [24] into her Ph.D. She is still alive and healthy thanks to the life-saving parachute of guidance and support Nassir has provided her (Anees Kazi).

“Communication is the most important skill as a postdoc” This was the first advice Nassir gave Seong Tae Kim, who was a fresh Ph.D. His advice has inspired a young scientist to start thinking about the importance of collaboration and networking for research. [25] was one of the studies that Seong Tae presented with collaborators under Nassir’s support, where his research team proposed an efficient ensemble model framework for epistemic uncertainty estimation which will

<sup>1</sup><http://campar.in.tum.de/DeepLearning2016/Program>



Fig. 12. CAMPing 2005: The one person that can still be recognized is Nassir.

be the key technique to make human-centered deep learning (Seong Tae Kim).

For Nassir, it has always been very important that research has an impact and motivates interesting applications that leave the walls of university and find their way into the clinic and industry. Therefore, he constituted a great supervisor when Hendrik Burwinkel joined the CAMP chair in a collaboration with the industrial partner Carl Zeiss Meditec AG. Inspired by Nassir's guidance and vision, Hendrik dove into the field of multimodal deep learning [26] and the incorporation of domain knowledge into the learning process [27]. While he had to balance between the industry and university role, he is most grateful to know Nassir and his invaluable support on his side (Hendrik Burwinkel).

Continuing with the motivation and flexibility that Nassir gives to his students, and in the context of medical image segmentation in CT, Nassir has provided valuable feedback and support to Roger during the development of an uncertainty-graph-based segmentation refinement method [28]. The author of this last work would like to express his gratitude and admiration for the commitment that Nassir has to his students (Roger Soberanis).

Nassir's unique vision gave Ari the opportunity to do something highly unconventional, entering a collaboration with the Irish meat industry, in the name of science and tissue classification. There she had the once in a lifetime experience of being tackle by a cattle carcass thrice her size and a significant multiple of her weight. She clearly understood the meaning of being at the wrong place at the wrong time after this. Again Nassir's excitement about the unconventional made her shift her focus on the less dangerous domain of OCT image reinterpretation as a language. A field she feels as passionate about as the revolution of steaks. Nassir's CAMPing dancing skills and insight into Iranian poems as well as his casual jump scares at the Garching office corridors serve as a further preparation for life (Ari Tran).

Thanks to Nassir's unconventional ideas, we made great progress in the field of X-ray to CT registration [29], which we could present in China last year. This work is also nominated for the German Medical Award 2020, whose winner is being decided soon. Without Nassir's great commitment, this would never have been possible (Matthias Grimm).

Stefano Gasperini joined CAMP in 2018 for his IDP, as

a Master student. Thanks to Nassir and the Chair support, this IDP led to Stefano's first contribution to the scientific community [30]. He will never forget the night of that MIC-CAI submission, spent at IFL, where Nassir represented a lighthouse in the surrounding storm, guiding everyone in need, dispatching tips and jokes, always on point on the most diverse topics, even very late at night, with remarkable dedication to his students and research. Stefano is really grateful for this project and Nassir's Chair support, which made him discover a passion for research, and motivated him towards pursuing a PhD, which is now ongoing (Stefano Gasperini).

With the wisdom of Nassir, Hasan was able to manage the collision between two worlds and get the best out of it. While Hasan was doing his research externally at Carl Zeiss, he was supported by Nassir's free spirit and innovative ideas to scratch the surface of fairness and disentanglement research [31] and apply it in medical applications. Hasan was also greatly supported in publishing a review on machine learning techniques for ophthalmic data analysis (Hasan Sarhan).

Collaborating with clinical experts to solve meaningful problems has always been a key driver for Nassir's research. Recently, a new collaboration has been established with the Poison Control Center at the Klinikum Rechts der Isar, which lead to a novel decision support system for intoxications based on graph convolutional networks [32]. One of the authors, Matthias Keicher, was inspired by Nassir to return to academia and is very grateful for his guidance and support as well as the freedom to explore ideas (Matthias Keicher).

As surely pointed out earlier, a key component of Nassir's approach to research is unshakable trust. An example for this is his student Christoph, whom Nassir enabled his Bachelors', Masters', the pursuit of his PhD and taking his career steps at the company of Rohde & Schwarz. Already early during Christoph's master studies, Nassir trusted his abilities and allowed him to explore his very own research ideas on Deep Learning driven catheter tip detection and depth prediction [33]. Nassir further trusted him with presenting his results at a conference, for which Christoph is still grateful today. Similarly, Nassir let Christoph explore his very own research ideas on unsupervised anomaly detection in brain MRI [34] in his PhD studies (Christoph Baur).

#### IV. COMPUTER AIDED INTERVENTIONS

One of Nassir's passion has been always to make contributions to surgery and intervention. There he has found a niche where few dare to go to and challenges are thrilling. This adventure in this field has made of his team the right address in intraoperative imaging, medical robotics, augmented reality and surgical workflow analysis.

##### A. Intraoperative Imaging

Nassir's wisdom and know-how extend to most directions of technology and Physics in particular is one of his strengths. And as Nassir usually claims "why make things it easy if you can make them hard", he devoted significant time in creating imaging solutions that underlie the hard constraints of surgery.



Fig. 13. MICCAI 2006, the conference that put CAMP at the top of the MICCAI society.

1) *Intraoperative Nuclear Imaging*: In 2004 Nassir had a yet another idea. Motivated by the fact that Prof. Markus Schwaiger, the head of Nuclear Medicine at Klinikum rechts der Isar at that time was instrumental in him getting his Chair, we started looking at potential projects using radioactivity. Yes... An Iranian wanting to play with radioactivity before the Iran Atomic deal...! Anyhow, in a brain storming session with the head of Physics at Nuclear Medicine, Prof. Sibylle Ziegler and his then PhD candidate Joerg Traub, they came out with the idea of combining tracking and beta-detecting probes to generate surface images of beta-emissions in the surgical room. This would enable visualizing tumors on the resection bed and potentially reduce re-operations or relapses. It took almost one year to recruit a volunteer and make it happen [35], but within only 3 years the developments in this area led to the Chair introducing the concept of freehand SPECT image reconstruction [36], [37] and later freehand PEEp [38]. This line of research was further enhanced by adding Augmented Reality and resulting in one of the very first deployments of AR in surgery [39]. Further, based on this concept Nassir, Joerg and his then Master student Thomas Wendler founded the Chair's first spin-off, SurgicEye GmbH 14. Over the years this resulted in several PhD thesis and almost hundred publications worldwide showing that Nassir's ideas can go beyond science and make it into medical products and solve real clinical problems [40] (Thomas Wendler).

In an inter-disciplinary PhD project jointly supervised by Prof. Sibylle Ziegler (Nuclear Medicine, Klinikum rechts der Isar), Dzhoshkun worked on an extension of the freehand SPECT technology using beta and high-energy gamma probes. Some of that research work could potentially benefit lymph node localization in head and neck cancer surgery [41]. It never ceased to amaze him how keen Nassir was on learning from his students' research work. This had the psychological effect of giving his team members confidence in their work.



Fig. 14. Nassir, Joerg Traub, Eric Soehngen and Thomas Wendler brainstorming for the first spin-off of CAMP in 2007.

In addition, despite his busy schedule, Nassir always managed to find time whenever his students needed his help. One day, while Dzhoshkun was struggling to draft his PhD thesis, Nassir encouraged him to think along the lines of "what the reader could learn from this PhD thesis", which was enlightening advice. To this day Dzhoshkun feels privileged to have been Nassir's PhD student and is grateful for all the support he received from Nassir, Sibylle and the CAMP research team, in particular Tobias Lasser and Thomas Wendler (Dzhoshkun I. Shakir).

In 2008, Asli joined CAMP for a student project under the supervision of Thomas Wendler and continued her journey there until 2017. Throughout this time she was first a student HiWi assisting surgeons with freehand SPECT system, then she completed her diploma thesis at SurgicEye GmbH in collaboration with CAMP, and finally she decided to pursue her PhD degree in CAMP. During this time, she collaborated with numerous clinicians as well as colleagues from CAMP. Her PhD research was also focused on freehand SPECT technology, especially its combination with ultrasound imaging indicating a high potential for future non-surgical sentinel lymph node biopsies for breast cancer patients [42] (Asli Okur).

2) *Optic Coherence Tomography*: Through a long-standing collaboration with Carl Zeiss Meditec, Nassir continued to envision and advance visualization techniques for intraoperative OCT [10]. His creative and open-minded ideas inspired numerous concepts and he always enjoyed personally joining the wetlabs when these techniques were tested by surgeons butchering (ex vivo) pig eyes. His capacity to create a bigger vision were highly appreciated by Jakob Weiss, as well as his strong support in defending innovative ideas against corporate interests (Jakob Weiss).

Nassir offers his students the unique opportunity to spend time at Johns Hopkins University and to get involved in exciting research projects. Michael Sommersperger enjoys the opportunity to continue his work on OCT-guided robotic surgery for one year at JHU, while at the same time having the freedom to pursue crazy ideas such as sonification and

simulation of eye surgery (Michael Sommersperger).

3) *Interventional Ultrasound*: Jumping into a new field, Christoph joined CAMP almost by accident as external PhD with a small startup in vascular ultrasound in 2011. Fast forward 4 years, not only did Nassir's mentorship provide the foundation for multiple scientific contributions in the field of vascular ultrasound, ultrasound guidance as well as different applications in robotic ultrasound imaging; it also enabled focusing on many crazy ideas (e.g. Computational Sonography), new teaching formats (e.g. MedInnovate) and embracing that among the most important things in professional life is that you better enjoy what you do and with whom you do it with! A collaborative approach to research remains part of Nassir's spirit, providing a simply great environment for researchers, which led Christoph to re-join Nassir's chair from 2016 to 2018 (Christoph Hennersperger).

The fascinating field of Medical Ultrasound offers ample room for research which Nassir knew how to leverage best and generate numerous impactful publications. Furthermore, Nassir made sure to offer his PhD students the opportunity to gain valuable industry experience through close collaborations with his former employer Siemens Corporate Research. This enabled Christian to publish multiple papers in the domain of real-time Ultrasound Processing and Visualization specifically targeted at interventional applications [43] [44] [45] (Christian Schulte zu Berge).

4) *Bioelectric Navigation*: Nassir has contributed to the advancement of a new kind of catheter tracking using bioimpedance-based navigation [46]. This technology is now being further researched in a cooperative PhD project with the Imperial College London, which gave me the chance to pursue a PhD in this interesting topic. I have only worked with Nassir for four weeks now, but experienced him as an approachable, caring and enjoyable person (Heiko Maier).

## B. Medical Robotics

When the robots became affordable around 2010, Nassir did not doubt a minute to acquire a UR-5 and started yet another trip that ended in over a dozen PhD thesis. In particular, Nassir always has had a strong interest in various medical robots for better and easier diagnosis and intervention purposes. One alternative route is to improve acceptance by making them look cute (cf. Fig. 16) which provided a fun basis for many interactions with medical staff [47]–[49] (Benjamin Busam and Marco Esposito).

Nassir has inspired so many great ideas towards eye surgical robotics [50], [51]. He also brought Mingchuan Zhou into the diagnostic robotics field and show me many examples of how scientific and high-quality research are performed [52]. All those scientific help and guidance let us know how the robot can benefit human health (Mingchuan Zhou).

After Javier Esteban started his PhD under Nassir supervision, the close collaboration established with the department of Neurosurgery at Klinikum Rechts der Isar finally succeeded



Fig. 15. German Chancellor, Dr. Angela Merkel treating our colleague Fred with the robotic US system developed at IFL.

on the first Robotic ultrasound-guided facet joint insertion on real patients [53]. The system was so simple that even the Chancellor of Germany could operate it 15. Nassir's support, not only on the academic part but also on the personal, was always a key factor to bring this project into real testing (Javier Esteban).

Afterward, Nassir supported Maria Tirindelli on the continuation of the project, with the goal of developing a fully automatic robotic system for spine injections. During this time, he always found the time to discuss ideas and gave her full trust and support on every scientific path she decided to follow. He was an important reference point for her when with challenging situations and always demonstrated great support from both scientific and personal points of view (Maria Tirindelli).

Carefully tracking the recent developments in Reinforcement Learning, Nassir had the idea of automating medical robotic interventions. In [54], researchers trained an agent to automatically locate the sacrum on the back of volunteers solely using ultrasound images as input (Farid Azampour).

Nassir and his team have shown that robotics can improve medical diagnosis. But he did not stop there. To broadly introduce robots into the clinical environment he also worked on improving human-robot interactions. His creative and big visions helped Christine Eilers to realize innovative projects and to view them in their entirety (Christine Eilers).

After Zhongliang Jiang joined the team for developing an automatic robotic ultrasound system, Nassir has given tons of valuable and constructive feedback. With his support, Zhongliang integrated an external force sensor to the existing robotic ultrasound system and further develop the method to fine-tune the probe orientation toward accurate and repeatable US imaging [52]. Nassir's innovative ideas and amazing passion for research have inspired Zhongliang Jiang to continue going depth in the area of robotic ultrasound (Zhongliang Jiang).

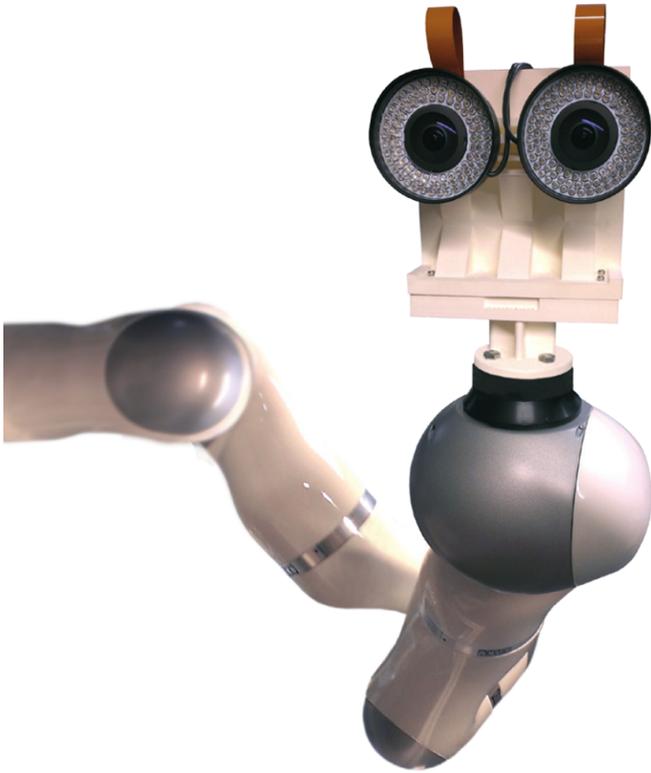


Fig. 16. Anthropomorphic stereo vision system.



Fig. 17. Non-corona-compliant party at IFL in 2008.

### C. Surgical Workflow Analysis

Besides the rather recent work [55] between Nassir, Matthias and Daniel, there is a long history of a strong collaboration between Nassir and the Research Group MITI at Klinikum rechts der Isar. Together Nassir and Prof. Feussner were one of the pioneers of surgical workflow analysis and have substantially influence this field, not least by their work with Nicolas Padoy. [56] [57] [58] [59]. Nassir has always been a great inspiration with his visionary approach. And MITI hopes that we'll keep up the fruitful cooperation between MITI and CAMP (MITI - Prof. Feussner, Daniel Ostler).

Little known is the fact that the entire field of Surgical Data Science [60] emerged in a car ride from Garching to

NARVIS lab (dramatic exaggeration fully intended). Ahmad, a lost undergrad student unhappy with his ECE studies, was looking for a Bachelor thesis topic, and Nassir offered two topics. "I have one normal topic about [insert any segmentation/registration topic here], and a really exciting one, about a crazy idea that we call 'surgical workflow analysis'. Let me explain." (side note: many topic suggestions from Nassir start with such a juxtaposition. It is advisable, always, to follow the "exciting" topic). What followed was a rough topic outline for a Bachelor thesis, which resulted in one of the first papers on surgical workflow analysis [61], conducted with and in the surgery rooms of Prof. Feussner, under the supervision of Tobias Sielhorst and in close collaboration with Ralf Stauder. Tobias Blum and Tobias Sielhorst were giving augmented births to virtual babies using Dynamic Time Warping (DTW) at that time, and DTW turned out to be a nice tool to create average surgical workflows. Things professionalized when Tobias Blum started using HMMs [62], and then Nicolas Padoy joined... the rest is MedIA history [57]. What Ahmad couldn't expect was that the red pill he took during that sunny car ride would not only lead to a pioneering paper, but to the discovery of an exciting research rabbit hole so deep that it would keep him busy and excited for the next 16 years. Thanks Nassir, for inspiring and motivating young minds, and showing them what's out there, grand visions of what's still missing, and what an amazing feeling it can be to contribute (Seyed-Ahmad Ahmadi).

### D. Sonification and Acoustic Signal Analysis

In addition to the vast variety of topics mentioned in the sections above, Nassir never gets tired to explore new fields of research. In this regard, he is passionate about research topics including sound and acoustic signals in the medical domain. He continuously pushes forward the fields of conveying information with sound through *Sonification* [11], as well as using acoustic signals for information retrieval in diagnosis and surgery [55]. He motivates and supports his students and collaborators even if doctors and nurses called his PhD students Sasan Matinfar and Matthias Seibold crazy several times (Matthias Seibold and Sasan Matinfar).

### E. Augmented Reality

Amongst many true passions, Augmented Reality and Computer-Aided Surgery have certainly a prominent spot. Countless novel and high impact works have been demonstrated by Nassir and his Team that congratulates by heart to his birthday.

In 2004 Tobias Blum took part in the first lab course that was given at CAMP which was organized by CAMP's AR pioneer Tobias Sielhorst, and which contributed to the first augmented reality delivery simulator [2]. Although everything at Nassir's Chair at this time was really chaotic, this lab course was so interesting, that Tobias B. started his long year work at Nassir's Chair where he worked on numerous augmented reality and medical workflow projects, the most prominent being the AR magic mirror [63]. In particular Nassir's ability



Fig. 18. *Mirror, mirror on the wall, who's the fairest of them all?* The Magic Mirror reveals that Nassir also has a very feminine side.

to bring together medical doctors and computer scientists and his openness towards every idea, regardless of how crazy it is, made the work at his Chair so inspiring (Tobias Blum).

One of CAMP's longest lasting projects in the field of Medical Augmented Reality is the Magic Mirror (originally called *mirracle*). The concept is based on an idea by Christoph Bichlmeier, was presented in 2011 by Tobias Blum, and allows users to obtain a virtual view into their own body with the help of a Microsoft Kinect camera and a conventional TV screen [63]. Over the last decade, the Magic Mirror was featured in a number of TV shows, magazines, and was demonstrated at numerous international exhibitions. Under the guidance of Nassir, a number of PhD students have worked on the Magic Mirror. Tobias Blum was followed by Meng Ma who also made invaluable contributions to the system, all thanks to Nassir's great ideas and mentorship. The most recent PhD student to work with Nassir on the Magic Mirror was Felix Bork, who succeeded in integrating the system as an essential part of undergraduate anatomy education [64]. Thanks to Nassir's continuous support of this project, medical students across Munich today use the Magic Mirror to better understand the anatomy and physiology of the human body (Felix Bork).

Nassir once introduced a group of senior PhD students of NARVIS and Alexander Winkler, who was still a master-student, to new research partners. He finished with "...and this is Alex, also a senior, but not PhD." A few years later Alex is a PhD student, and Nassir is a continuous source of inspiration: Continuing his fondness for novel variations of mirror-like visualizations, Nassir envisioned a concept "Spatially-Aware Displays for Computer Assisted Interventions" [5], which registers the pose of a surgical display to both the patient and the surgeon. During the conception of the system and even more the paper writing Nassir was an indispensable help for Alex in finding the right formulations and not shying away

from working very long night shifts (Alexander Winkler).

His motivation for exploiting the physical properties of real mirrors paved the way to the development of the "Augmented Mirrors" [6]. A concept able to simultaneously reflect real and virtual content that can be used for alignment, exploration, and visualization in augmented reality applications. Nassir's innovative ideas and always positive way of looking both, research and everyday life, have inspired Alejandro Martin-Gomez to research alternative ways to improve depth perception in augmented reality (Alejandro Martin-Gomez).

Nassir commonly combines his knowledge from diverse domains to foster solutions in interventional medicine. Together with Javad Fotouhi and the team at Johns Hopkins University and Hospital, they employed imaging frustums in image-guided therapies, a concept that he had earlier suggested for industrial augmented reality at Siemens Corporate Research decades before. Interactive Flying Frustums [65] exploit the imaging geometries to their full extent and enable AR ecosystems within which communication between the stakeholders and the information, interaction with data, and visualization of intraoperative images take place. Javad learned from Nassir that innovation in digital medicine occurs at the intersection of the partnerships between clinicians and computational scientists. Therefore, they built strong clinical collaborations across the Atlantic and studied the usability of multiple AR concepts jointly at Johns Hopkins University, Technical University of Munich, and the University Hospital Balgrist (Javad Fotouhi).

Nassir Navab breathes life and joy into collaborative research. His creativity, humility, and affability give him the unique ability to bridge the gap between surgeons and the technical community, allowing him to guide the future of surgical procedures and ultimately improve the lives of countless patients. To hear Nassir say "This is reeeally coool!" is something that brings a smile to the face of anyone that has ever worked with him. His contributions to the orthopaedic surgery community are immense. His Johns Hopkins orthopaedic surgery colleagues are especially proud of the work recently published in IEEE-TMI, "Development and Pre-Clinical Analysis of Spatiotemporal-Aware Augmented Reality in Orthopedic Interventions" [65] as this a culmination of many years of fruitful collaboration between CAMP and the Johns Hopkins Department of Orthopaedic Surgery (Alex Johnson).

Aside from intensive works on mirrors [6] and contributions to AR in general, Nassir was always open to support and guide trans-disciplinary endeavours, such as the AI and VR driven diagnoses of autism spectrum disorders [66]. In the context of this process in 2020, he can be described as the most incredible mentor and strategic career advisor, always having an open ear and valuable feedback to challenging decisions (Daniel Roth).

#### F. *Gluing all together*

Effective inter-disciplinary research in the domain of computer assisted interventions requires close collaboration between medical experts, computer scientists, and other dis-

ciplines. Nassir and colleagues published their insights on successful collaboration within this research area under the formative term "Surgineering" [67]. In order to establish this strong link, Nassir strives for close collaboration with medical experts by implanting computer science labs within hospitals. He is currently operating three scientific research labs at hospitals: Interdisciplinary Research Lab (IFL) at the Klinikum rechts der Isar, the NARVIS Lab at the LMU Klinikum Innenstadt, and the CAMP Lab at Johns Hopkins University (Ulrich Eck).

## V. COMPUTER VISION AND OTHER FUN STUFF

Going back to the roots, Nassir did his PhD in France at INRIA from 1988 to 1992 under supervision of the famous pioneer of projective geometry Prof. Olivier Faugeras. Indeed in his early career Nassir Navab was Computer Vision (CV) researcher and strongly marked the field of Augmented Reality during his time at Siemens Corporate Technology in Princeton. Being deeply connected to his computer vision roots Nassir always maintained Computer Vision group inside his lab. The aim of this group was, on one hand to strongly contribute to the vision community with the fundamental works, and on the other hand to be a strong support for the medical imaging research. In the past Computer Vision was important part of the entire CAMP's portfolio and Nassir himself was teaching 3D Computer Vision for many years. The first CV Group was led by Selim BenHimane, which was taken over by Slobodan Ilic and finally by Federico Tombari. There is a long history of successful CV research, but we would like to distinguish works on object detection and pose estimation like PPF [68] LineMOD [69] and SSD6D [70]. Successful continuation of high quality CV work was assured by Nassir's incredible sense for delegating right jobs to the right people. The leadership of the first groups was dedicated to a talented young researcher Selim from INRIA. Selim had the best PhD thesis award in France at the time for his template tracking approach based on second order approximation. For the recruiting the next CV group leader, Nassir was conveying the recruiting task to the current group leader. This kind of trust was clever and assured the continuity of good and influential research (Slobodan Ilic).

### A. Deep Learning: The Rise

Vasilis was part of the computer vision group from 2011 to 2015, working on human pose estimation. During the summer of 2014, he realized that deep learning was the next big research direction in the community. At the same period, Gustavo Carneiro visited CAMP for a sabbatical. Vasilis worked close with Gustavo and after a few months published the first deep learning paper of CAMP at ICCV 2015. Christian Rupprecht was actively involved in this paper and later established deep learning as main CAMP research direction. Also, Christian and Vasilis worked with Iro Laina to produce another deep learning paper on depth estimation in 2016. It has been one of the top papers for Nassir since then. From the very beginning, Nassir was very supportive on establishing a deep learning team at CAMP. In addition, he

was flexible and open to new research directions - never stuck with a specific topic. Not to forget to mention his generosity. He bought us all necessary hardware to burn kilowatt-hours (Vasilis Belagiannis).

Christian had been caught in CAMP's fangs early by Slobodan as a tutor for Tracking and Detection. One thing lead to another and he received a BSc, MSc, and Dr. title from Nassir. With Nassir and Greg Hager as advisors, Christian was never bored. Between visits to JHU (USA) and Mila (Montreal) to organizing workshops, CAMPings, lectures and courses, there was also time to do some research which lead to several interesting outcomes and collaborations. In his typical nature, Nassir was always open to adopt new ideas and directions even if there was no direct medical connection (Christian Rupprecht).

The election of President Trump in 2016 mark a special time for Nassir, Federico and the computer visionists at CAMP. At the time, with computer vision turning "deep", so had the contributions of Nassir, Federico and the CAMP CV team to the scientific field. This was, e.g., the case of the first ever proposed deep learning method for SLAM, renamed CNN-SLAM [71] in memoriam of the treatment that Mr. Donald J. Trump was giving at that time to the well-known US TV broadcaster. Another renowned tribute to Mr. President occurred with the publication of SSD-6D [70], "making 6D object pose estimation great again". The trend continued successfully until the end of Trump's mandate. Nassir not only always supported multi-disciplinary research in CAMP, but also continuously encouraged interaction across the different fields and disciplines, leading to an effective and steady flow of contributions and technology transfer from the fields of computer vision and machine learning to those of medical imaging, augmented reality and medical robotics, to name a few (Federico Tombari).

Iro first joined CAMP as a BMC student in 2013, but in a wild turn of events and with Nassir's unconditional support, she could pursue the dark arts of deep learning and computer vision during her PhD. Nassir has always encouraged and granted Iro research freedom, which allowed her to explore exciting uncharted territory, at the intersection of vision and language. Surprisingly, discussions with Nassir often include exclamations, such as "We should do this for medical!". To date, Nassir still wholeheartedly supports and advises Iro on her future steps (Iro Laina).

Nassir was leading another long lasting and successful collaboration between CAMP and Toyota, which drove the field of 6D pose estimation forward through important works such as LineMOD. Within this collaboration Nassir always provided valuable suggestions and helped developing new ideas. He particularly showed his expertise in research during the rebuttal of CPS in which he step by step reduced the word count to follow the ECCV guidelines. Further he always had an open ear for new PhD students and gave important advice such as "Go to Martina.. She can make things happen!" [editor's note: She did] - (Fabian Manhardt).

As part of a collaborative project between CAMP, Siemens



Fig. 19. Food for thoughts: during a “light” break, well sought after Pizzesco™ supplies support the spirit and morale of CAMP paper writers through the long and uncertain CVPR night. Garching b. München, circa November 2017.

and Stanford University a novel method for camera pose estimation solving for ambiguous viewpoints with continuous multimodal inference has been developed [72]. Having worked on the topic of cameras and geometry as part of his own PhD, Nassir has provided valuable and constructive feedback to Mai Bui. Beyond technical support Nassir is always open to provide helpful advice in all aspects of work and career, which is highly appreciated by his team and students (Mai Bui).

“Hello, my name is-a Fausto.” is how inconspicuous it can sound when a research hurricane hits the coasts of CAMP. Fausto joined the DFG project on transcranial ultrasound in 2013. In his insatiable thirst for discovering new techniques,

he quickly threw aside all (boring) plans for bilateral ultrasound reconstruction of the midbrain, carefully drafted by his supervisor Ahmad. Searching for a new way to handcraft features suitable to represent ultrasound image patches (pfh, handcraft...), Federico Tombari gave Fausto the innocuous tip: “Have you-a tried-a auto-encoders?” Never having heard of auto-encoders before, Fausto implemented them in one night in MATLAB (pfh, MATLAB...), and escalated the idea into Hough-Forests [73] and later Hough-CNN [74]. CAMP’s contributions to the world of Deep Learning would not be complete without V-Net and the Dice loss [75]. Virtually every deep segmentation network in MedIA research and industry now uses Dice loss or one of its derivatives, which will always be tied to CAMP and Nassir, and which is a real testimony to the innovative, open, and fun research spirit he managed to create (Fausto Milletari - by Seyed-Ahmad Ahmadi).

### B. Scene Reconstruction and Semantic Scene Understanding

Apart from the numerous contribution of him in the area of the medical-related field, he also supports deeply in scene reconstruction and understanding.

He supports Shun-Cheng Wu to work under the DFG Project that is lead by Federico Tombari and the Applied Mechanics Chair to develop a visual perception system on the Humanoid Lola. We have developed a real-time semantic completion that helps Lola to grand a deeper understanding of the exploring stage [76](Sun-Cheng Wu).

Yida also explores widely in 3D reconstruction under Nassir’s kind support, so that he can try out interesting topics ranging from voxels to point cloud. Among all those works, Johanna, Helisa, Shun-Cheng and Yida contribute a lot for large scene understanding (Sun-Cheng Wu & Yida Wang).

In 2018, Nassir helped Yanyan get in touch with Federico for applying a Ph.D. position in the computer vision team. It is super nice to work with all CAMPer nowadays, but at the beginning of Yanyan’s project, the language was a huge gap between him and his colleagues, where Nassir’s signature sunny smile makes his tough time easier (Yanyan Li).

In the year 2019, Nassir started exploring scene graphs, which capture relationships between objects for a more dynamic scene understanding. The collaboration involved a large team composed of Helisa, Azade, Iro, Christian, Federico and Greg. The inspiring discussions led to a work [77] that showed that it is possible to understand and manipulate a scene through its scene graph, useful in image editing and robotics. Note: Nassir gives more emphasis on the useful robotic task, compared to the fun Photoshop game. Inspired by this success of scene graphs in 2D, Helisa and Johanna brought semantic scene graphs to 3D [78]. Rumors say that Nassir’s vision is to bring these findings to the medical world, for a holistic understanding of the surgery room. Helisa will never forget his words, which give special value to the work that the team has done - “We are making the scene graph dream come true.” (Helisa Dhamo).

Evin joined CAMP in 2019 for her Master’s thesis within the team of computer vision. The welcoming environment of

CAMP, with international researchers from all over the world and extremely high-quality research, is the perfect place to conduct research. Currently, Evin is pursuing a PhD, enjoying the full support of Nassir while working with great CAMP researchers (Evin Pınar Örnek).

Studying a masters of BMC, you have the privilege of sitting at Nassir's lecture from time to time. But after that if you start doing your thesis or working at the chair, Nassir is a gem. He is normally very hard to find. He is in the lab X? In the US? Sometimes no one knows. But as I was going to Persian festivals, cinema and concerts sometimes, I had the chance to find him there and talk to him about research and work. In a way going to Persian events paved my way to start doing my PhD with the computer vision group. Now I am stuck in the PhD and have almost no time to go to events (Mahdi Saleh).

Kalia M. joined CAMP as an exchange student for her master thesis. The great people at CAMP and her research project "Perceptual issues in Augmented Reality" helped her survive cultural shock and housing situation in Munich. Weiss beer also played a role. She got overconfident and decided to do a PhD. Nassir was very kind to land her the opportunity to do her PhD in the pretty city of Vancouver. She is still hanging in there. Apart from research, she admires the support and compassion Nassir has for his students. Personal story: Nassir's support helped her survive loss of a family member in the middle of her PhD. She considers herself fortunate enough to share Nassir's excitement about new (arguably crazy) ideas and some dance moves at occasion (Megha Kalia).

## VI. RESEARCH NETWORKS

No review of the path of Nassir in the fields of medical imaging, computer assisted procedures, and augmented reality could ignore his strong engagement in the community. Whether it is MICCAI, IPCAI, CARS, IPMI, ISMAR, or others, he is always there to push developments, get student scholarships assigned, guarantee high level research. Due to lack of space (yes, also this review is constrained), we will merely concentrate on the remarkable MICCAI 2015.

### A. MICCAI 2015 in Munich

In the year 2015, Nassir was the general chair of the MICCAI conference, which was held at the Gasteig Philharmonic Hall in Munich. The whole process of the conference application, the organization and planning as well as the execution of the conference, it was not only prestigious and exciting, but also an enormous effort for Nassir as well as many at the chair over many years prior the event. Between 2012 and 2015, Asli Okur, Ralf Stauder and Philipp Matthies were the Local Organization Chairs of the MICCAI 2015 and took the responsibility of the planning and organization of this major conference with many associated satellite events and over 1200 participants from all over the world. Today, Asli still considers MICCAI 2015 organization as her most valuable and most complex project management experience and is proud of what they achieved in year 2015 (Asli Okur).



Fig. 20. Nassir wearing Lederhosen at the gala dinner of MICCAI 2015 at Löwenbraukeller.

## VII. GENERAL ADMINISTRATION AND MANAGEMENT (SARA ERFANI, CHRISTIANE AUF, MARTINA HILLA)

In addition to the amazing team management comes the Chair administration, a duty many despise, but Nassir takes with ease. He continuously strives for process optimization together with Ulrich, not having any reservations in trying new tools and systems, which is why processes such as the inventory run amazingly smooth. The administrative team comments as follows: Leadership is not a skill it is a talent. We appreciate how you always give your best and inspire us to do the same. We're very glad to work with you. You are the best scientific manager!

## VIII. CONTRIBUTION TO OUR SOCIETY (THOMAS WENDLER)

To finalize, in this section we highlight the immense impact Nassir has on the community beyond science. If organizing conferences or lectures, Nassir is in first place a human with a huge heart. No wonder children love him! And he loves them too! You should simply see how babies enjoy his company!

Nassir has forged the future of hundreds of students and in some cases has been the pillar in hard times for them. He has never refused to organize a scholarship for a (former) student in financial danger or jump in as second father if students need guidance or simply some time off from the stress of life, no matter if due to bad luck, illness or any other reason. Nassir never brags about his efforts and rather prepares all such that the environment is proper for the student to find a new start and sometimes literally get back to his or her feet.

In the name of all of the ones who you reached your hand in moments of need, all those who you will help in future, THANKS.

## IX. CONCLUSION (DANIEL ROTH)

In this paper, we summarize the history of Computer Aided Medical Procedures and Augmented Reality by reporting



Fig. 21. Nassir always focuses on training and educating all age groups. Back in 2016, David joined the quickly growing CAMP group at Johns Hopkins.

anecdotal evidence of amazing innovation skills, leadership, guidance, mentoring, and friendship of Prof. Nassir Navab.

We elaborate on early day foundations, general mentorship, the focus areas of medical image computing and computer aided interventions, computer vision, general administration, and engagement.

In this regard, we do not show any novelty, whatsoever. All authors conclude and interpret unanimously, that the presented behavior observed for Prof. Navab has been present since the beginning and continuous to be present to date.

We therefore congratulate Nassir to his 60th birthday. Future work should not include any changes in personality, instead, Nassir should stay as he is.

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