Intrinsically Interpretable Machine Learning In Computer Aided Diagnosis

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Acknowledgements

When I had come to Groningen in August 2014 for my Masters in Biomedical Engineering I was absolutely certain that I am not going to put myself through PhD. How could I make such a *mistake* after having watched the *PhDmovies*? But then Life happened: I got to know a friendly, funny and caring human named Prof. Dr. Michael Biehl, who taught the course *Modelling and Simulation*.

When I approached Michael about possible projects to learn Machine Learning (ML) he told me of a project which a former PhD student of his, Dr. Gert-Jan de Vries had for a Masters student, at Philips Research in Eindhoven. My master thesis project at Philips Research was when I first encountered Learning Vector Quantization and made a nerdy friend from Computing Science, Rick van Veen. It will sound cheesy but I fell for LVQ during this time. A few months after that I started my PhD journey with another of Michael's former PhD student, Dr. Kerstin Bunte as my daily supervisor, and Prof. Dr. Nicolai Petkov, along with Michael, as my promotors. Kerstin, you have not just been my daily supervisor in research, you have been an incredible emotional support at some of my worst moments during the last few years, and an inspiration.

During the very first week of PhD I got to know some of the people of the Intelligent Systems and the Distributed Systems, who influenced my life and personality in different ways and made me the current version of myself. They were Nicola, Estefania, Ahmad, Laura Fiorini, Xiaoxuan, Godliver, Jiapan and Astone, and Mohammad Babai. Also during that week I met Dr. Michael Wilkinson. When he told me that he made an extremely spicy sambal, I did not take him seriously. Being an Indian I used to take significant pride in my ability to *enjoy* spicy food and sauces. So I had thought to myself, *What does this European guy know about spicy food?* I took half a table spoon of his sambal and gulped it down. The rest was an episode of raging fire racing through my GI tract while I ran to get yoghurt. But then on the brighter

side, it was my first week of PhD and I was already on fire, thanks to Michael (W)'s sambal Satan. Michael (W) also introduced me to the Discworld series, and some other materials with dark humour.

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around in academia a bit longer after PhD. You've been my academic significant other, despite the physical distance, and the voice of sanity and strength every time I gave up on myself and PhD. Ahmad and Liz, you both have been my emotional support humans throughout this journey. During some of my bad days it was chats with you both which helped me get out of bed, and face the day.

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I see or talk to you I see the sweet Neville Longbottom from Harry Potter. You and Barbara (Hammer) explain complicated ideas so smoothly that it inspired me to try and become a science communicator. Your paintings and music inspire me to carry on my hobbies outside of academia. Wiebke, you are a power house of energy and enthusiasm. Thanks for being there for me whenever I reached out to you, for academic and non-academic reasons. Having strong female supervisors such as you and Kerstin, and such sweet male supervisors such as Michael and Peter shielded me from what I have heard some other female PhD students have had to tolerate. I aspire to become a human/scientist you will be proud to call your student. Kerstin, thank you for taking me for mud-walking back in 2017. It was the perfect analogy to what to expect from PhD. Also, thank you for teaching me kayaking at Mittweida, for being there for me when I needed support, and for pushing me to try harder. The four of you have made me a much better scientist, though I know there is still so much more to learn. Nicolai, thank you for arranging the Allersmaborg research retreats, the group dinners, and inviting us to bike trips around Groningen. Michael (B) you are the reason I got introduced to LVQ, Gert-Jan, Kerstin, Peter, Wiebke, Liz, the Intelligent Systems group, Villy and team, Barbara and team, and so many other wonderful people and started this PhD journey in the first place. I wish some day I can change the minds of young people towards research, the way you changed mine. Other amazing people I am grateful to have known over the last few years and will miss are Prof. Dr. Dimka Karastoyanova, Dr. Vasilios Andrikopoulos, Prof. Alexander Lazovik, Dr. George Azzopardi, and Dr. Charmaine Borg. Dimka, I miss our random chats in the corridor, and Vasilios I will miss your thundering laughter during post-exam times.

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Preface

A significant fraction of us, the so-called well-read intellectuals like to question the age-old beliefs, social, cultural, and theological *norms*, and try to find the logic behind not just rituals, but also natural phenomena. Since the paleolithic age, or even before maybe, pre-historic hominids observed natural phenomena, questioned the *hows*, *whens*, and most importantly the *whys* of them, even with their "simpler" minds, and survived, consequently leading to us, the modern hominids-*homo sapiens*. Now I will fast-forward to a slightly nearer historic time, from the part of the Indian subcontinent which is my birth place. Before the nineteenth century, education was withheld from women so as to prevent them from becoming widows[404], because that was what the *unquestionable* high priests of my parents and immediate ancestors' religion dictated. But things changed because social reformers such as Raja Rammohan Roy and Ishwar Chandra Vidyasagar questioned those social norm and fought to change it. Therefore here I am, a woman of Indian origin, having the privilege of boring you with this thesis of more than hundred pages. It seems very obvious to us *now* that those social norms had to be questioned. Back then it was just a handful of people though who thought to, and then dared to question. But as a Machine Learning PhD student why am I rambling on about questioning norms? In recent times of such technological advancements some of us might be trusting *the algorithm* just like our distant ancestors (or some parts of our family and/or friends we consider lesser intellectuals than us) trust(ed) the so-called divine machinations and high priests. Why should we then consider ourselves *better* when we too are trusting *that which is inscrutable*? While Googling "Ramification of trusting what you cannot understand" I was trying to find some examples of adverse

[404]Why was that such thing of concern you ask? A woman who outlived her husband was supposed to be unlucky and sometimes even a demon, back in those times. That was the norm until it was questioned and fought against.

effects of using some black-box methods. Guess what or who I found in the results! Really, try Googling that and you will understand why I took you on this journey. If you do not want to, then this is the main message: Are we not hypocrites if we are ready to question the logic behind just the non-technology related norms and rituals, and not what *Deep Thought* or its simpler cousins tell us? How is an algorithm whose working logic we do not understand, predicting our probable financial future different from believing in psychics? A bit far-fetched? Four winters ago a tech supermarket's *algorithm* deemed me unsuitable for buying a telephoto lens with the equated monthly installment (EMI) scheme. I did not question the decision, because an algorithm *computed* it in a fancy manner. So yes, I am a hypocrite as well, but I am trying to change.