Enhancing prenatal care through deep learning

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Publication date
2024

Citation for published version (APA):


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In this thesis, we aimed to address the challenges in improving prenatal care through the development and evaluation of deep learning algorithms. Our focus was on enhancing the accuracy and precision of fetal ultrasound biometry, fetal birth weight estimation, and computer-assisted surgery, particularly for Twin-to-Twin Transfusion Syndrome fetoscopic laser photocoagulation. Our study aimed to demonstrate the effectiveness of deep learning algorithms in improving prenatal care, with the ultimate goal of reducing adverse outcomes and improving the quality of care for pregnant women and their babies.

In Chapter 2, we presented a method for fetal ultrasound video scan analysis and interpretation. Our method simultaneously localized standard planes in video sequences, classified and measured fetal biometric parameters, and estimated gestational age and fetal weight. We demonstrated that our method achieved human-level performance, comparable to inter-rater agreement, including experienced sonographers. Our method has the potential for use as a fetal biometry assistance tool that may save time when reading fetal ultrasounds.

In Chapter 3, we presented an end-to-end method that automatically performed fetal birth weight prediction on fetal ultrasound video scans acquired less than 24 hours before delivery without the need for finding standard planes. Our method has the potential to help clinicians select the safest type of delivery for the mother and the child.

In Chapter 4, we presented a method for fetal birth weight prediction using fetal multimodal data, an extension of Chapter 3. We used fetal ultrasound videos and clinical (tabular) data to develop a custom Transformer module that can efficiently embed clinical data into an image feature representation. Our experiments showed that our method outperformed existing state-of-the-art algorithm approaches and expert clinicians who applied available commercial tools. Furthermore, the use of standalone abdominal video
scans resulted in fetal birth weight prediction performance that was within clinical experts’ error margins.

In Chapter 5, we presented a novel framework and feasibility of using only the fetal abdominal ultrasound video scans and gestational age to estimate fetal weight using a deep learning algorithm. Our experiments showed that abdomen data may be sufficient for this task when artificial intelligence is used.

In Chapter 6, we presented a novel framework for real-time placental vessel segmentation in videos obtained during fetoscopic laser photocoagulation for Twin-to-Twin Transfusion Syndrome. We developed custom data augmentations specifically tailored for this task and showed that our method was accurate and robust, with superior performance compared to current state-of-the-art methods.

Finally, in Chapter 7, we provided a general discussion of our proposed approaches and findings, including their contributions, limitations, potential clinical applications, and suggestions for future research directions.
Samenvatting

In dit proefschrift beschrijven we oplossingen voor het verbeteren van prenatale zorg door het ontwikkelen en evalueren van deep-learningalgoritmen. Onze focus lag op het verbeteren van de nauwkeurigheid en precisie van foetale echografische biometrie, schatting van foetale geboortegewicht, en computergestuurde chirurgie, met name voor foetoscopische lasercoagulatie bij het tweelingtransfusiesyndroom. Onze studie had als doel om de effectiviteit van deep-learningalgoritmen aan te tonen in de prenatale zorg, daarmee ongunstige uitkomsten te verminderen, en de kwaliteit van de zorg voor zwangere vrouwen en hun baby’s te verbeteren.

In Hoofdstuk 2 presenteren we een methode voor de analyse en interpretatie van foetale echografische videoscans. Onze methode voert de volgende taken tegelijkertijd uit: hij lokaliseert de standaarddoorsneden in videosequenties, meet en classificeert foetale biometrische parameters, en schat de postmenstruele leeftijd en het gewicht van de foetus. We tonen aan dat onze methode een prestatieniveau behaalt, vergelijkbaar met menselijke beoordeling door ervaren echografisten. Onze methode kan in potentie worden gebruikt als hulpmiddel om tijd te besparen bij het beoordelen van foetale echografie.

In Hoofdstuk 3 presenteren we een end-to-end methode die zonder het lokaliseren van standaardvlakken automatisch voorspellingen doet van het foetale geboortegewicht op echoscans die verkregen zijn binnen 24 uur voor de bevalling. Onze methode kan in potentie clinici helpen bij het kiezen van de veiligste bevallingsmethode voor moeder en kind.

In Hoofdstuk 4 presenteren we, als uitbreiding van Hoofdstuk 3, een methode die het foetale geboortegewicht voorspelt met behulp van multimodale gegevens van de foetus. We gebruiken foetale echografische videos en (tabulaire) klinische gegevens om een aangepaste Transformer-module te ontwikkelen die klinische gegevens efficiënt in een beeldkenmerkrepresentatie kan transformeren. Onze experimenten tonen aan dat onze methode beter
presteert dan bestaande state-of-the-art algoritmen en klinische experts die beschikbare commerciële tools toepassen. Bovendien resulteert het gebruik van abdominale videoscans alleen al in schattingen van het foetale geboortegewicht die binnen de foutmarges van klinische experts vallen.

In Hoofdstuk 5 presenteren we een nieuw deep-learningframework voor het schatten van het foetale gewicht op basis van alleen foetale abdominale echografie en postmenstruele leeftijd. Onze experimenten tonen aan dat gegevens van alleen de buik mogelijk al voldoende zijn voor deze taak als kunstmatige intelligentie wordt toegepast.

In Hoofdstuk 6 presenteren we een nieuw framework voor realtime segmentatie van placenta- taven in video’s verkregen tijdens foetoscopische lasercoagulatie voor het tweelingtransfusiesyndroom. We hebben aangepaste data-augmentaties ontwikkeld die specifiek zijn afgestemd op deze taak en hebben aangetoond dat onze methode nauwkeurig en robuust is, met superieure prestaties vergeleken met huidige state-of-the-art-methoden.

Tot slot, in Hoofdstuk 7, geven we een algemene bespreking van onze voorgestelde benaderingen en bevindingen, inclusief hun beperkingen, potentiële klinische toepassingen en suggesties voor toekomstig onderzoek.
Complete List of Publications

Peer-reviewed journal publications


Conference proceedings


**Book chapters**


**Awards**

1. First place in the Instrument multi-class recognition of Workflow Recognition in Endoscopic Pituitary Surgery (PitVis) as part of the EndoVis challenge during the MICCAI 2023 conference,

2. First place in the Registration task of Fetoscopic Placental Vessel Segmentation and Registration (FetReg2021) as part of the EndoVis challenge during the MICCAI 2021 conference,

3. First place in the mini-projects during the Hamlyn Winter School on Surgical Imaging and Vision, Imperial College London, 2021.
Szymon Stefan Płatka was born on December 11, 1993, in Lębork, Poland. After high school, he moved to Gdańsk and began his bachelor’s studies in Biomedical Engineering with a specialization in Medical Informatics at the Gdańsk University of Technology. After obtaining his Bachelor of Engineering degree in 2017, Szymon moved to Warsaw for his Master of Engineering degree in Electronics and Computer Science in Medicine, which he earned in 2019 from the Warsaw University of Technology. His master’s thesis focused on applying machine learning and deep learning methods for transvaginal ultrasound image analysis for preterm birth prediction. In 2022, he joined the interfaculty Quantitative Analysis Group embedded in the Faculty of Medicine (Department of Biomedical Engineering and Physics) and Science (Institute of Informatics) of the University of Amsterdam to pursue his PhD. During his PhD studies, he was involved in medical image analysis projects aimed at enhancing prenatal care through deep learning. He was supervised by Prof. Dr. Ir. Clara I. Sánchez (UvA), Prof. Dr. Ivana Išgum (AMC-UvA), and Dr. Arkadiusz Sitek (Harvard Medical School). He is interested in applied computer vision and deep learning-based algorithms, especially in ultrasound medical image analysis and computer-assisted interventions. Since August 28, 2021, he has been the husband of Izabela and the proud father of his beloved daughter, Amelia, since February 2, 2023.
Acknowledgements

I am deeply grateful to everyone who has contributed to the completion of this thesis. This journey has been a significant undertaking, and I would not have reached this milestone without the support, guidance, and encouragement of numerous individuals.

First of all, I would like to express my sincere gratitude to my supervisors, Prof. Dr. Ir. Clara I. Sánchez, Prof. Dr. Ivana Išgum, and Dr. Arkadiusz Sitek, for their exceptional knowledge, unwavering dedication, and patience, which have profoundly influenced the development of this thesis. Their invaluable guidance, perceptive feedback, and consistent motivation have played a crucial role in shaping both the direction and methodology of my research. I am deeply grateful for their mentorship and the extensive amount of time they have devoted to nurturing my academic growth. Thanks to them, I have learned many new things and gained a different perspective on research. I understand that often the impossible is within our reach. The knowledge they have imparted to me will be utilized in my future career, so that one day, they can proudly say, ‘He was our student.’

Clarisa, first of all, thank you for giving me a chance after the interview. Thank you for your insightful support during the application process to the University and for helping me finish this thesis. Throughout my entire time here, I gained a lot of experience from you. I want to thank you for being a demanding supervisor who sets high standards and expects the same from the students. It has helped me a lot to improve my research skills and gain a different perspective on creating scientific papers. I am proud to be your first PhD graduate in Amsterdam.

Ivana, thank you for agreeing to be my supervisor. Your insightful and invaluable help in writing our manuscripts has been instrumental in shaping the quality and impact of our work. Thank you for your valuable time and help, even late at night. Your great optimism during our discussions calmed me, making me more confident. It is a great thing that will allow me to further develop both personally and in my career. Thank you! It is worth noting that I may be the only one supervised by both of our group directors.
ACKNOWLEDGEMENTS

Arek, thank you for everything! You have been not only my official supervisor but now I can also say a kindred spirit. You have inspired me to continue with hard work. When we met 'by chance' in 2019, I did not realize that our research adventure would unfold this way and that I would now be able to write about it in my doctoral thesis. Since then, you have helped me enter the world of science and medical imaging, where, in retrospect, I consider it my greatest intellectual and personal development. Every conversation with you motivated me to work and added courage and confidence to aim high, with the world’s elite. Thank you for your selfless commitment, and for knowing how to work with me. Haha, you knew what kind of character I have, how to talk to me to not discourage me. For showing me that failure and setbacks in academic work are part of it, a springboard to achieve something more. Thank you, Arek, for your unwavering support, boundless wisdom, and steadfast belief in my potential. Your mentorship has forever altered the course of my academic and life journey, and for that, I am eternally grateful.

I would like to express my sincere gratitude to the members of my dissertation committee, Prof. Dr. Ir. Alfons Hoekstra, Dr. Wessel Ganzevoort, Prof. Dr. Henk Marquering, Prof. Dr. Asma Khalil, and Prof. Dr. Ir. Marius Staring, for their thoughtful feedback. Their expertise and insights have helped elevate the quality of my work. I am grateful for their time and examination of my research.

I want to thank Dr. Marian Bubak, whose support and guidance made it possible for me to pursue my PhD at the University of Amsterdam.

I am grateful to Dr. Tomasz Trzciński for introducing and inspiring me to the captivating realm of machine learning, deep learning, and medical imaging during my Master’s studies. His exceptional supervision and guidance not only captured my research interest but also paved the way for the development of this thesis.

I extend my heartfelt gratitude to the clinicians who generously dedicated their time, expertise, and support throughout my PhD research. Their invaluable contributions greatly enriched the quality and depth of my thesis. I especially want to thank Dr. Robert Brawura-Biskupski-Samaha, and Dr. Michal Lipa, for their collaboration and for granting me access to their clinical facilities, which were essential for data collection and gaining firsthand insights into the practical applications of my research.
Robert, thank you for your time and commitment. Thanks to you, the creation of this thesis was possible. You personally supervised the majority of the collected and annotated data used in this thesis to ensure high quality, enabling the creation of unique projects. Thank you for spending hundreds of hours of valuable time on this. Thank you for introducing me to the medical world, and for enabling a thorough understanding of the field, both theoretically and practically. It motivated me to continue working, knowing the purpose behind our efforts. This was very helpful during the most difficult moments, moments of weakness and fatigue. However, our acquaintance was not limited to research alone. You were the first person to show me my daughter on the ultrasound image. It was a very touching moment for me, one that I will remember forever. I am very grateful to you for taking care of my wife throughout the entire pregnancy, from beginning to end. I am proud and happy that the two most important people to me received care from a world-class specialist.

Additionally, I appreciate the numerous clinicians who participated in the data collection and annotation processes. Their willingness to share experiences and perspectives was crucial for comprehensively understanding the research subject. Special thanks to Dr. Beata Rebizant, Dr. Katarzyna Kosińska-Kaczyńska, Dr. Natalia Szymecka-Samaha, Dr. Małgorzata Siergiej, Prof. Dr. Asma Khalil, Dr. Jesús Rodríguez Calvo, Paula Szenejko, Kinga Żebrowska, Tomasz Łęgowik, Jan Klasa, Bogusław Marinković, Wojciech Górczewski, Norbert Majewski, and Anita Smal-Obarska.

To all my colleagues and co-authors not mentioned above, Michał Grzeszczyk, Tomasz Szczepański, Dr. Aneta Lisowska, Joanna Kaleta, Szymon Seliga, Dr. Diego Dall’Alba, and Dr. Przemysław Korzeniowski. Working with you was a pleasure!

Many thanks to Piotr Nowakowski for his assistance in proofreading. My appreciation goes to Gino Jansen for translating my summary into Dutch.

To my lovely wife, Iza. I want to thank you for everything, especially for your patience and years of sacrifice when I often had to work from early morning until late at night to meet important deadlines. Thank you for supporting me every step of the way, rejoicing in my successes, and comforting me in my failures. You have been, you are, and you will be my motivation, and thanks to the peace and love you have bestowed upon me, I have managed to achieve
so much.

To my beloved daughter, Amelia. You are my everything, my motivation. Thank you for beginning each day, even early in the morning, with your smile. I hope that in the near future, when you are ready to read this, you will be proud of your dad. I love you!

While it is impossible to mention everyone individually, I want to express my heartfelt gratitude to all those who have supported me in ways seen and unseen. Your contributions, whether big or small, have played a significant role in successfully completing this thesis. Thank you all for your unwavering support, belief in my abilities, and the countless ways you have enriched my academic journey.

Mamo i Tato, drodzy Rodzice. Chcę Wam serdecznie podziękować za Wasze wsparcie, które było dla mnie motywacją i siłą podczas całej mojej edukacji, aby uzyskać tytuł doktora. Wasza nieustająca obecność i wsparcie były dla mnie bezcenne, a Wasza cierpliwość i zrozumienie sprawiały, że nawet najtrudniejsze chwile stawały się łatwiejsze. Dziękuję Wam za wszystko, co dla mnie zrobiśliście. Jestem dumny, że mam takich wspaniałych Rodziców.