Lifestyle understanding through the analysis of egocentric photo-streams

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Summary

Describing people's lives has become a hot topic in several disciplines. Lifelogging appeared in the 1960s as the process of recording and tracking personal activity data generated by the daily behaviour of a person. The development of new wearable technologies allows to automatically record data from our daily living. Wearable devices are light-ware and affordable, which shows potential for the increase of their use by our society. Egocentric images are recorded by wearable cameras and show a first-person view of the life of the camera wearer. These collected images show an objective view of the daily life of a person and thus are a rich source of information about her or his habits. However, there is lack of tools for the analysis of collections of egocentric photo-sequences and thus room for progress.

This thesis investigates the development of automatic tools for the analysis of egocentric images with the ultimate goal of getting understanding of the lifestyle of the camera wearer. This work addresses five main topics in the field of egocentric vision:

1. *Temporal photo-sequences segmentation:* We introduce an automatic model for the definition of temporal boundaries for the division of egocentric photo-sequences into moments, which are sequences of images describing the same environment. The model is based on global and semantic features and achieves a 66% F-score over the EDUB-Seg dataset.

2. *Routine discovery:* We propose an automatic tool for the discovery of routine-related days and the visualization of patterns of behaviour, based on the use of topic modelling over semantic concepts extracted from the photo-sequences. The introduction of the EgoRoutine dataset composed of a total of 104 days is part of this work. The model is able to classify days into routine and non-routine related with an accuracy of 80%.

3. *Food-related scenes recognition:* We introduce a hierarchical classifier for the recognition of visually highly similar food-related images into 15 different classes that describe

daily activities related to food consumption, acquisition, and preparation. We introduce the EgoFoodScenes dataset, which our model is able to classify into the 15 categories with an accuracy of 68%.

4. *Sentiment retrieval:* We explore the sentiment associated with images by classifying them into Positive, Neutral, and Negative. Our model is based on the analysis of global features and obtained semantic concepts with associated sentiment. We obtain an accuracy of 75%. Results show that positive images relate to outdoor environments or with social interactions, neutral to work-related environments, and negative to non-informative or visually not clear images .

5. *Social pattern characterization:* We propose a model that characterizes the social behaviour of the camera wearer based on the occurrence of people that the camera wearer meets throughout her/his data collection. The proposed social parameters allow the definition of a radar chart that shows its potential for the comparison of social patterns among individuals.

The introduced and made publicly available egocentric datasets and the obtained results in the different performed experiments indicate that behaviour can be identified and studied. We conclude that the developed automatic algorithms for the analysis of egocentric images allow a better understanding of the lifestyle of the camera wearer. Applications based on the analysis of this data can lead to the improvement of the quality of life of people and therefore, are worth to continue exploring.

Samenvatting

Het beschrijven van het leven van mensen is in verschillende disciplines een hot topic geworden. Lifelogging is ontstaan in de jaren zestig van de vorige eeuw als het proces van het vastleggen en volgen van het dagelijkse gedrag van een persoon. De ontwikkeling van nieuwe draagbare technologieën maakt het mogelijk om automatisch gegevens uit ons dagelijks leven vast te leggen. Draagbare apparaten zijn licht en betaalbaar en zijn dus zeer interessant voor gebruik in onze samenleving. Persoonlijke beelden vanuit een eerstepersoonsperspectief worden opgenomen door draagbare camera's en geven een objectief beeld van het dagelijks leven van een persoon. Daarmee is deze verzameling beelden een rijke bron van informatie over haar of zijn gewoonten. Er is echter een gebrek aan hulpmiddelen voor de analyse van verzamelingen egocentrische fotoreeksen en dus is er ruimte voor vooruitgang.

Dit proefschrift onderzoekt de ontwikkeling van automatische hulpmiddelen voor de analyse van egocentrische beelden met als uiteindelijk doel inzicht te verkrijgen in de levensstijl van de cameradrager. Dit werk behandelt vijf hoofdonderwerpen op het gebied van egocentrische visie:

1. *Tijdelijke fotoreekssegmentatie:* We introduceren een automatisch model voor het definiëren van tijdsgrenzen om egocentrische foto-sequenties in momenten te verdelen die dezelfde omgeving beschrijven. Het model is gebaseerd op globale en semantische functies en behaalt een 66 % F-score met de EDUB-Seg dataset.

2. *Routine-ontdekking:* We stellen een automatische tool voor die routine-gerelateerde dagen en de visualisatie van gedragspatronen ontdekt en die is gebaseerd op het gebruik van topic modelling over semantische concepten uit de fotoreeksen. De introductie van de EgoRoutine-dataset bestaande uit een totaal van 104 dagen maakt deel uit van dit werk. Het model is in staat om dagen in te delen in routine- en niet-routine-gerelateerde dagen met een nauwkeurigheid van 80%.

3. *Voedselgerelateerde scèneherkenning:* We gebruiken een hiërarchische classificeerder voor de herkenning van visueel zeer gelijkwaardige voedsel-gerelateerde beelden in 15 verschillende klassen die de dagelijkse activiteiten met betrekking tot voedselconsumptie, -verwerving en -bereiding beschrijven. We gebruiken de EgoFoodScenes-dataset die ons model kan indelen in 15 categorieën met een nauwkeurigheid van 68%.

4. *Sentiment retrieval:* We onderzoeken het sentiment dat gepaard gaat met beelden door ze te classificeren in Positief, Neutraal en Negatief. Ons model is gebaseerd op de analyse van globale kenmerken en verkregen semantische concepten met bijbehorend sentiment. Met het model wordt een nauwkeurigheid van 75 % verkregen. De resultaten tonen aan dat positieve beelden betrekking hebben op buitenomgevingen of op sociale interacties, neutraal op werkgerelateerde omgevingen, en negatief op niet-informatieve of visueel onduidelijke beelden.

5. *Karakterisering van sociale patronen:* We stellen een model voor dat het sociale gedrag van de cameradrager karakteriseert op basis van het aantal mensen dat de cameradrager ontmoet tijdens haar of zijn gegevensverzameling. De voorgestelde sociale parameters maken het mogelijk om een radarkaart te definiëren die potentieel mogelijk maakt om sociale patronen tussen individuen te vergelijken.

De geïntroduceerde en openbaar gemaakte egocentrische datasets en de verkregen resultaten in de verschillende uitgevoerde experimenten geven aan dat gedrag kan worden geïdentificeerd en onderzocht. We concluderen dat de ontwikkelde automatische algoritmen voor de analyse van egocentrische beelden een beter begrip mogelijk maken van de levensstijl van de cameradrager. Toepassingen gebaseerd op de analyse van deze gegevens kunnen leiden tot verbetering van de levenskwaliteit van personen en zijn daarom de moeite waard om verder te verkennen.

Resumen

Describir la vida de las personas se ha convertido en un tema candente en varias disciplinas. Lifelogging apareció en la década de los 60 como el proceso de registrar y rastrear datos de actividad personal generados por el comportamiento diario de una persona. El desarrollo de nuevas tecnologías portátiles permite almacenar automáticamente datos de nuestra vida diaria. Dichos dispositivos son livianos y asequibles, lo que muestra potencial para su uso por parte de nuestra sociedad. Las imágenes egocéntricas son grabadas por cámaras portátiles y muestran una vista en primera persona de la vida del usuario. Esta recopilación de imágenes muestra una visión objetiva de la vida diaria de una persona y, por lo tanto, son una rica fuente de información sobre sus hábitos. Sin embargo, faltan herramientas hoy en día no hay herraminetas para el análisis de colecciones de fotosecuencias egocéntricas y, por lo que hay espacio para el progreso.

Esta tesis investiga el desarrollo de herramientas automáticas para el análisis de imágenes egocéntricas con el objetivo final de comprender el estilo de vida del usuario de la cámara. Este trabajo aborda cinco temas principales en el campo de la visión egocéntrica:

1. *Segmentación temporal de secuencias de imágenes:* Introducimos un modelo automático para la definición de límites temporales con el objetivo de dividir secuencias de imágenes egocéntricas en momentos. Entendemos como momentos secuencias de imágenes que describen el mismo entorno. El modelo se basa en características globales y semánticas y logra un F-score del 66% sobre el conjunto de datos EDUB-Seg.

2. *Descubrimiento de la rutina:* Proponemos una herramienta automática para el descubrimiento de días relacionados con la rutina y la visualizacion de patrones de comportamiento. La introducción del conjunto de datos EgoRoutine compuesto por un total de 104 días es parte de este trabajo. El modelo puede clasificar los días en rutinarios y no rutinarios con una precisión del 80%.

3. *Reconocimiento de escenas relacionadas con la comida:* Presentamos un clasificador jerárquico para el reconocimiento de 15 clases diferentes de escenas relacionadas con los alimentos, que son visualmente muy similares y que describen actividades diarias relacionadas con el consumo, la adquisición y la preparación de alimentos. Además, presentamos el conjunto de datos EgoFoodScenes, el cual nuestro modelo puede clasificar en las 15 categorías con una precisión del 68%.

4. *Entender el sentimiento evocado:* Exploramos el sentimiento asociado con las imágenes clasificándolas en Positivo, Neutro y Negativo. Nuestro modelo se basa en el análisis de características globales y conceptos semánticos obtenidos con sentimientos asociados. Obtenemos una precisión del 75%. Los resultados muestran que las imágenes positivas se relacionan con ambientes al aire libre o con interacciones sociales, las neutrales con ambientes laborales y las negativas con imágenes no informativas o visualmente no claras.

5. *Caracterización del patrón social:* Proponemos un modelo que caracteriza el comportamiento social del usuario de la cámara basádose en la ocurrencia de personas que el usuario de la cámara se encuentra a lo largo de su recopilación de datos. Los parámetros sociales propuestos permiten la definición de un gráfico de radar que muestra su potencial para la comparación de patrones sociales entre individuos.

Los conjuntos de datos egocéntricos introducidos y puestos a disposición del público junto con los resultados obtenidos en los diferentes experimentos realizados indican que el comportamiento puede identificarse y estudiarse. Concluimos que los algoritmos automáticos desarrollados para el análisis de imágenes egocéntricas permiten una mejor comprensión del estilo de vida del usuario. Las aplicaciones basadas en el análisis de estos datos pueden conducir a la mejora de la calidad de vida de las personas y, por lo tanto, vale la pena continuar estudiándolas.

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Doing a PhD is not taking the easy path. However, I would choose this path all over again, not just because of all that I have learned - that is quite a lot - but the experiences that I have lived and the people I have met. I have introduced myself as a Sandwich PhD, most of the times causing some laughs. But yes, I used to say I was the 'ham and cheese' between the universities of Groningen and Barcelona. This type of position pushed me to grow fast, living in two different countries with very different cultures. I enjoyed it.

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Estefanía Talavera Martínez
Groningen
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Research Activities

Journal Papers

- **E. Talavera**, C. Wuerich, N. Petkov, P. Radeva, *"Topic Modelling for Routine Discovery from Egocentric Photo-streams"*, (Submitted - Under Review).
- **E. Talavera**, M. Leyva-Vallina, Md M. Sarker, D. Puig, N. Petkov, P. Radeva, *"Hierarchical approach to classify food scenes in egocentric photo-streams"* , Journal Biomedical and Health Informatics (JBHI), IF 4.217, Q1, 2019.
- Md. M. Kamal Sarker, H. A. Rashwan, F. Akram, **E. Talavera**, S. F. Banu, P. Radeva, D. Puig, *"Recognizing Food Places in Egocentric Photo-streams using Multi-scale Atrous Convolutional Networks and Self-Attention Mechanism"*, IEEE Access, Pages 39069-39082, Vol. 7, IF 4.098, Q1, 2019.
- M. Dimiccoli, M. Bolañnos, **E. Talavera**, M. Aghaei, G. Stavri, P. Radeva, *"SR-Clustering: Semantic Regularized Clustering for Egocentric Photo Streams Segmentation"*, International Journal Computer Vision and Image Understanding (CVIU), pp. 55-69, Vol. 155, IF 2.645, Q1, 2016.
- S. John, R. Butson, **E. Talavera**, R. Spronken-Smith, P. Radeva, *"Beyond perceptions: exploring Reality Mining to research student experience"*, (Submitted - Under Review).
- S. John, **E. Talavera**, A. Cartas, R. Butson, R. Spronken-Smith, P. Radeva, *"Re-framing our understanding of student experience: the use of photographs to capture activity"*, (Submitted), .

Book Chapters

- G. Oliveira-Barra, M. Bolaños, **E. Talavera**, O. Gelonch, M. Gardera, P. Radeva, *"Lifelog Retrieval for Memory Stimulation of People with Memory Impairments"*, Book Chapter *Multimodal behavior analysis in the wild*, 2017

- **E. Talavera**, N. Petkov, P. Radeva, *"Egocentric vision for behavioural understanding"*, Book Chapter *Wearable Sensors: Fundamentals, Implementation and Applications*, (Submitted)

Conference Proceedings

- **E. Talavera**, N. Petkov, P. Radeva, *"Unsupervised routine discovery in egocentric photo-streams"*, 18th Conference on Computer Analysis of Images and Patterns, published in proceedings as Chapter Springer Verlag, 2019.
- M. Kamal, H. Rashwan, **E. Talavera**, S. Furruka, P. Radeva, D. Puig, *"MACNet: Multi-scale Atrous Convolution Networks for Food Places Classification in Egocentric Photo-streams"*, 3rd Workshop on Egocentric Perception, Interaction and Computing (EPIC), published in the proceedings, 2018.
- A. Cartas, M. Dimicolli, **E. Talavera**, P. Radeva, *"On the Role of Event Boundaries in Egocentric Activity Recognition from Photostreams"*, 3rd Workshop on Egocentric Perception, Interaction and Computing (EPIC), extended Abstract, 2018.
- **E. Talavera**, A. Cola, N. Petkov, P. Radeva, *"Towards Egocentric Person Re-identification and Social Pattern Analysis"*, 1st Applications of Intelligent Systems (APPIS), pp. 203-211, published in the proceedings in the series Frontiers in AI and Applications (IOS Press), 2018.
- G. Oliveira-Barra, M. Bolaños, **E. Talavera**, A. Dueñas, O. Gelonch, M. Gardera, *"Serious Games Application for Memory Training Using Egocentric Images"*, ICIAP, published in proceedings as Chapter Springer Verlag, 2017.
- **E. Talavera**, N. Strisciuglio, N. Petkov, P. Radeva, *"Sentiment Recognition in Egocentric Photostreams,"* 9th Iberian Conference on Pattern Recognition and Image Analysis (IBPRIA), pp. 471-479, Pattern Recognition and Image Analysis, published in proceedings as Chapter Springer Verlag, 2017
- **E. Talavera**, P. Radeva, N. Petkov, *"Towards Egocentric Sentiment Analysis,"* 6th International Conference on Computer Aided Systems Theory (EUROCAST), pp 297-305, published in proceedings as Chapter Springer Verlag, 2018.
- **E. Talavera**, N. Petkov, P. Radeva *"Towards Unsupervised Familiar Scene Recognition in Egocentric Videos,"* In 8th GI Conference on Autonomous Systems, pp. 80-91, published in proceedings as Chapter VDI Verlag, 2015.
- M. Bolaños, R. Mestre, **E. Talavera**, X. Giro-i-Nieto, P. Radeva, *"Visual Summary of Egocentric Photostreams by Representative Keyframes"*, In International Workshop on Wearable and Ego-vision Systems for Augmented Experience (WEsAX), pp. 1-6, published in the proceedings, 2015.
- **E. Talavera**, M. Dimiccoli, M. Bolañnos, M. Aghaei, P. Radeva, *"R-Clustering for Egocentric Video Segmentation,"* 7th Iberian Conference on Pattern Recognition and Image Analysis (IBPRIA), pp. 327-336, Pattern Recognition and Image Analysis, Chapter Springer Verlag, 2015.

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Summer Schools

- ICVSS, International Computer Vision Summer School, Siracusa, Sicily, 11-16th July 2015.

Talks

- "Deep Learning and applications to activity recognition from Egocentric Photostreams", Tutorial at the 1st International Conference on Applications of Intelligent Systems, APPIS 2018, together with Prof. Petia Radeva and MSc. Marc Bolaños (Las Palmas, Spain).
- Oral presentation in the 1st 3 Minutes Thesis Competition organized by the University of Groningen, March 2018.

Organized Seminars

- Member of the Program Committee for the PhD Day of 2016 at the University of Groningen.
- Organization member as volunteer at CAIP 2015, in Valletta, Malta.
- Organization member as volunteer at APPIS 2017, in Gran Canarias, Spain.

Followed Courses

- University Teaching Skills, duration of 70h, from the University of Groningen, 2019.
- Supervising thesis students/Begeleiden van thesisstudenten, from the University of Groningen, 2019.

Teaching duties

- Co-lecturer in the course Introduction to Intelligent Systems, in the bachelor of Computer Science, from the University of Groningen, Sept - Nov 2019.
- Main lecturer in the course Software Engineering, in the bachelor of Computer Science, from the University of Groningen, Feb - Jun 2019.
- Teacher Assistant in the course Artificial Vision, in the bachelor of Computer Science, from the University of Barcelona, fall semester 2017-2018 and 2018-2019

About the Author

Estefanía Talavera Martínez was born on September 21st, in Torreperogil, Jaén, within the region of Andalucía (Spain). When she was 9 she moved to Mallorca with her family.

For her undergraduate studies she joined the Degree in Industrial Engineering, specialized in Industrial Electronics, from the University of the Balearic Islands (UIB). The subject *Industrial Vision* dragged her attention to the computer vision world. In 2012, she moved to Barcelona and joined the M.Sc. in Biomedical Engineering, from Polytechnical University of Catalunya (UPC) and University of Barcelona (UB). It was there when she met Prof. Petia Radeva, with whom she made her first steps into the egocentric vision topic. She finished her master thesis "Towards unsupervised lifelogging video segmentation" with a qualification of 9.5/10.

In a hot summer day in Mallorca, August 2014, she received an email from Prof. Nicolai, her application for a 4 years joint PhD with the University of Groningen had been accepted. From February 2015 she started her PhD journey under the supervision of Prof. Nicolai Petkov (RUG) and Prof. Petia Radeva (UB), through the Ubbo Emmius program.

In 2016, she joined the Program Committee for the organization of the PhD Day 2016, a conference organized by and for PhD students of the University of Groningen. This experience allowed her to improve her organization skills.

Her research interests are in the field of image analysis, more specifically egocentric vision and medical imaging. In her studies she proposed several techniques for egocentric images analysis, such as inferred sentiment computation from visual and semantic features extracted form the images, and behavioral patterns analysis by describing routines, understood as the repetition of activities.

She balances her life by dancing salsa, hanging out with friends, visiting family in Majorca, and traveling around the world.