Application

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Information about application

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Descriptive data

Project info

Project title (Swedish)*

Analys- och realtidsigenkänning för att stödja naturlig interaktion med 3D hand-rörelser

Project title (English)*

Real-time 3D hand-gesture analysis and recognition to support natural interaction

Abstract (English)*

The rapid development and wide adoption of mobile devices in recent years have been greatly driven by the introduction of new interaction technologies. Although touchscreens have significantly enhanced the human device interaction, clearly for next generation of smart devices users will demand more natural interactions performed by the bare hands in the 3D space to control and manipulate the digital content. Based on our comprehensive studies, it has been clearly verified that today's 3D gesture technology is limited and cannot satisfy the users' needs in the near future.

Due to the complexity of the algorithms and hardware limitations computer vision solutions cannot successfully analyze the full Degrees of Freedom(DOF) of hand motions. In fact, articulation, diversity, and variations of hand gestures can be represented by 27 DOF. Analysis of this high dimension has been remained an extremely challenging problem in computer vision for a long time. Specifically for extending the gesture analysis to multiple hands and collaborative cases we need to handle more complex combination of gestures in real-time. In this project we plan to develop new concepts, methods, and algorithms to tackle these challenges. The following research questions and the corresponding actions will be undertaken:

RQ1(Month 1-6): How to enhance the current gesture analysis solutions (global hand tracking and gesture recognition) to full analysis of the hand gestures (full analysis of hands/fingers/joints)?
Tasks: Enabling technologies will be deeply investigated during this research. Different methods for gesture detection, recognition, tracking, and 3D motion analysis will be studied and new algorithms will be explored.
Outcomes: Comprehensive study of the field and state-of-the-art solutions will be provided. New methods and algorithms for gesture analysis will be provided for further development.

RQ2(Month 6-24): How to develop and employ new frameworks such as Big Data or Search methods for gesture analysis? Moreover, how to integrate them with existing computer vision solutions to tackle the high degrees of freedom 3D gesture analysis?
Tasks: Search framework will be employed for gesture analysis. Gesture Search Engine for recognition, tracking, and analysis of 27 DOF hand gestures will be implemented.
Outcomes: Novel solutions for high accuracy gesture analysis will be developed and implemented. New frameworks will be integrated to the existing technologies to enhance the 3D gesture analysis.

RQ3(Month 12-36): How to develop new methodologies and algorithms to extend the gesture analysis to multiple hands in collaborative applications?
Tasks: Large-scale search framework and computer vision methods for gesture analysis will be integrated to extend the gesture analysis to multiple hands. Concept of collaborative 3D gestural interaction will be explored.
Outcomes: Collaborative 3D Interaction will be implemented. Effective application scenarios for 3D interaction will be selected and tested. Usability analysis will be conducted.

RQ4(Month 24-36): What type of design and usability issues should be considered to effectively employ the 3D gesture-based interaction in applications?
Tasks: Prototypes in different application scenarios will be evaluated. User studies will be conducted iteratively to improve the research results from user perspective.
Outcomes: Prototypes will be tested by users in different application scenarios. User studies will be analyzed.

Our preliminary research results enable large-scale and real-time 3D gesture analysis. This can be used for user-device interaction in real-time applications in smartphones, tablets, wearable devices, smart TVs etc., where 100% natural and fast 3D interaction is important. Medical Applications, Virtual Reality, Augmented Reality, E-learning and 3D gaming will be among the areas that directly benefit from the 3D interaction technology. The results of this research project can substantially contribute to the fields of computer vision and human computer interaction.

Popular scientific description (Swedish)*

De senaste årens snabba utveckling kring mobil teknik har till största delen drivits av framstegen kring nya interaktionsteknologier. Trots att bruket av enheter med pekskärmar anmärkningsvärt har ökat antalet HD-interaktioner är det uppenbart att det för nästa generation av smarta enheter kommer att krävas interaktionsteknologier som är mer naturliga för att kontrollera och hantera det digitala innehållet, oavsett medium. Baserat på hittills genomförda studier är det uppenbart att dagens 3D-teknologier vad gäller gester är starkt begränsade och därmed inte uppfyller de krav som användarna inom en snar framtid kommer att ställa.

Till följd av komplexiteten och begränsningarna av algoritmer och hårdvara kan computer vision solutions inte fullt uppfylla alla de DOF-krav (Degrees of Freedom) som finns vad gäller handrörelser. Enbart artikulation, mångfald och variationer kan representeras av 27 olika DOF:s. Att analysera detta område har över tid varit en extremt utmanande uppgift, och då särskilt kring att överföra utökade gestanalyser till att gälla för mer än enbart en hand, samt för samarbete. I just dessa fall behöver vi hantera mer komplexa kombinationer av handgester i realtid.

I detta projekt ämnar vi utveckla nya koncept, metoder och algoritmer för att hantera ovanstående utmaningar. Följande forskningsfrågor med därtill hörande insatser kommer att behandlas:

Forskningsfråga 1 (månad 1-6)
Hur förbättrar vi nuvarande lösningar för gestanalys (”global hand tracking” och ”gesture recognition”) till att omfatta en fullständig analys av handgester (full analysis of hands/fingers/joints)?
Uppgifter: Involverade teknologier kommer att djupstuderas i denna forskningsinsats. Varierande metoder för upptäckt, igenkänning, spårning och 3D-mönster kring gester kommer att studeras och analyseras, och nya algoritmer kommer att skapas för fortsatt utveckling.
Resultat: En uttömmande områdesstudie och state-of-the-art lösningar kommer att genomföras. Nya metoder och algoritmer för gestanalys kommer att tillhandahållas för vidareutveckling.

Forskningsfråga 2 (månad 6-24)
Hur utvecklar och implementerar vi nya metoder och ramverk likt ”BigData” eller ”Search-methods” för gestanalyser? Tillika, hur integrerar vi dessa med befintligt arbete och visioner som hanterar höga nivåer av frihet i 3D-gestanalys?
Uppgifter: ”Search framework” kommer att användas för gestanalysen och ”Gesture Search Engine” för igenkänning, spårning och analys av 27 DOF-handgester kommer att implementeras.
Resultat: Nya lösningar för precisionsgestanalys kommer att utvecklas och implementeras. Nya ramverk för att förbättra 3D-gestanalyser i befintliga teknologier kommer att integreras.

Forskningsfråga 3 (månad 12-36)
Hur utvecklar vi nya metoder och algoritmer för att utöka gestanalysen till att omfatta tvåhandsinformation i kollaborativa användarmiljöer?
Uppgifter: Storskaligt ramverk och computer-vision metoder för gestanalys kommer att integreras för att utöka analysen till mer än en hand. Koncept för konceptuell kollaborativ 3D-interaktion skall undersökas.
Resultat: Kollaborativ 3D interaktion kommer att implementeras. Tillämpning och test av 3D interaktionsscenarier kommer att utföras. Användaranalyser ska genomföras.

Forskningsfråga 4 (månad 24-36)
Vilka användarfrågor och vilken sorts användardesign bör övervägas för att så effektivt som möjligt sjösätta olika applikationers gestbaserade 3D-interaktioner?
Uppgifter: Prototyper i olika applikationsscenarier kommer att utvärderas. Användarstudier kommer att genomföras iterativt för att förbättra forskningsresultaten utifrån ett användarperspektiv.
Resultat: Prototyper kommer att testas av användare i olika sorters applikations-scenarier. Användarstudier kommer att analyseras

Våra preliminära resultat tillhandahåller storskaliga 3D-gestanalyser i realtid. Dessa kan användas för interaktion i realtidsapplikationer för smarta telefoner, surfplattor, smarta textilier, smart-TV etc. där hundraprocentig, snabb 3D-interaktion är avgörande. Medicinska applikationer, VR, AR, e-learning och 3D-spel är de områden som främst kommer att gynnas av 3D-interaktionsteknologi. Resultaten av detta forskningsprojekt kan vara av avgörande art vad gäller bidrag till utvecklingen av området och hur människor interagerar med datorer.

Project period

Number of project years*

3

Calculated project time*

2016-01-01 - 2018-12-31

Classifications

Select a minimum of one and a maximum of three SCB-codes in order of priority.

Select the SCB-code in three levels and then click the lower plus-button to save your selection.

SCB-codes*	2. Teknik > 202. Elektroteknik och elektronik > 20205. Signalbehandling
	2. Teknik > 211. Annan teknik > 21102. Mediateknik
	2. Teknik > 211. Annan teknik > 21103. Interaktionsteknik

Enter a minimum of three, and up to five, short keywords that describe your project.

Keyword 1*

3D Interaction Technology

Keyword 2*

Hand Gesture Analysis

Keyword 3*

Gesture Recognition and Tracking

Keyword 4

Collaborative Gestural Interaction

Keyword 5

Mobile Human-Computer Interaction (HCI)

Ethical considerations

Specify any ethical issues that the project (or equivalent) raises, and describe how they will be addressed in your research. Also indicate the specific considerations that might be relevant to your application.

Reporting of ethical considerations*

Studies carried out within the proposed project may, if determined by VR or desired by other parties, be examined by an ethical council. The project team will consider all recommendations from VR concerning any form of ethical review or consideration. Selection and participation in the user studies will be voluntary with an assurance that the participants can terminate their participation in any time if desired. Written consent to conduct the study at the schools will be acquired from the organization responsible. Guidelines and policies produced by and already existing in the schools will be followed.

The project includes handling of personal data

No

The project includes animal experiments

No

Account of experiments on humans

No

Research plan

Real-Time 3D Hand-Gesture Analysis and Recognition to Support Natural Interaction

I- Purpose and Goals of the Research Project

The rapid development and wide adoption of mobile devices in recent years have been mainly driven by the introduction of novel interaction and visualization technologies. Although touchscreens have significantly enhanced the human device interaction, clearly for next generation of smart devices (future smartphones/tablets, smart watches, virtual/augmented reality glasses, etc.), users will no longer be satisfied with just performing interaction over 2D touchscreen. They will demand more natural interactions performed by the bare hands in the free space in front or around the smart device [1]. Thus, next generation of smart devices such as augmented reality glasses and smart watches will require a gesture-based interface to facilitate the bare hands for manipulating digital content directly. Therefore, users will be able to interact, through the mobile device, with the physical space, objects and information in virtual/augmented environments, medical applications, robotics, 3D games etc.

In general, 3D hand gesture recognition, tracking and analysis have been considered as classical computer vision and pattern recognition problems. Although substantial research has been carried out in this area, the state-of-the-art research results are mainly limited to global hand tracking and low-resolution gesture analysis [2]. However, in order to facilitate the natural gesture-based interaction, full analysis of the hand and fingers will be required which in total incorporates 27 degrees of freedom (DOF) for each hand[3]. This process will be even more challenging considering the analysis of multiple hands in one scene in more complex scenarios such as collaborative applications among different users.

Our vision with the research ideas described in this proposal is to substantially enhance the way people interact with smart devices. We believe that 3D gestural interaction, through fingers and hands, is the next "new big thing" in user experience. 3D interaction has a direct connection with realistic experiences users have in real life. For instance, the same experience as they have when they grab and rotate an object in the physical world but instead through a smart device. Our goal is to re-produce the same realistic experience in the digital space with extremely high accuracy hand gesture analysis.

The main objectives behind this research project are to develop new concepts and methods and to introduce emerging technologies for intuitive and realistic interaction with future smart devices. In order to fulfill these objectives, challenges from conceptual perspective, as well as design and technical aspects will be considered. Based on our comprehensive studies,[4]–[6], and feedback from top researchers in the field and major technology developers, it has been clearly verified that today's 3D gesture analysis methods are limited and will not satisfy the users' needs in the near future.

Our preliminary research results and findings enable large-scale and real-time 3D gesture tracking and analysis[37]. This can be used for user-device interaction in real-time applications in smartphones, tablets, wearable devices, smart TVs etc., where 100% natural and fast 3D interaction is important (see Fig.1). Medical Applications, Virtual Reality, Augmented Reality, E-learning and 3D gaming will be among the areas that directly benefit from the 3D interaction technology.

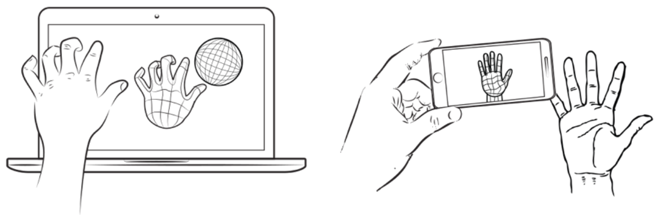

Fig.1: High-resolution gesture analysis enables users to manipulate the digital content in various application scenarios.

Specifically, during this research project we aim to investigate the following research questions:

RQ1- How to enhance the current gesture analysis solutions (6-10 DOF) to full analysis of the hand gestures (27 DOF)? What type of hardware and software-based solutions might be utilized to perform this significant change?

RQ2- How to develop and employ new frameworks such as Big Data or Search methods for gesture analysis? Moreover, how to integrate them with existing computer vision solutions to tackle the high degrees of freedom 3D gesture analysis?

RQ3- How to develop new methodologies and algorithms to extend the gesture detection, recognition and analysis to multiple hands and collaboration of multiple users in collaborative applications?

RQ4- What type of design and usability issues should be considered to effectively employ the 3D gesture-based interaction in applications?

The main strategies towards solving the mentioned research questions can be summarized in the following items:

- In order to support the concept of 3D gestural interaction, enabling media technologies will be deeply investigated during this research. Different methods for gesture recognition, tracking, and 3D motion analysis will be considered and new algorithms for supporting this concept will be developed.
- Based on the preliminary research findings, Gesture Search Engine, as an innovative framework, for 3D gesture detection, recognition, tracking, and analysis will be introduced.
- Concept of collaborative 3D interaction using hand gestures in mobile platforms, web-based applications and distributed systems will be explored and implemented.
- Prototypes and technical demos in different application scenarios will be considered in the research plan. User studies will be conducted iteratively to improve the research results from user perspective.
- Common supervision and collaboration between Linnaeus University (LNU) and KTH Royal Institute of Technology is considered in the project plan. Resources from both universities such as supervision from senior researchers and laboratory facilities will be used for the project.
- New findings and research results will be published in the highly ranked journals and conferences in the field. Top researchers in the field will be invited for joint workshops and seminars between LNU and KTH to deeply explore this topic from scientific perspective.

Our main goal after the completion of this research project is to introduce novel and intuitive ways in which people can interact with smart devices in order to significantly improve the current user experience. We strongly believe that the results of this research project will substantially contribute to the fields of computer vision, pattern recognition and human computer interaction. Moreover, the excepted outcomes of this research proposal are aligned with our overall research strategy plan to be recognized as a leading research group in 3D Interaction technologies in Europe after 4-5 years of intensive research and development on this particular field. We have formed a complementary team including two young, hard working and ambitious PhD researchers, two full professors, one PhD student and a small team of master students in media technology with the focus on interaction technologies.

II- Area Overview

One of the enabling technologies to build gesture-based interfaces is hand tracking and gesture recognition. The major technology bottleneck lies in the difficulty of capturing and analyzing the articulated hand motions. One of the existing solutions is to employ glove-based devices, which directly measure the finger joint angles and spatial positions of the hand by using a set of sensors (i.e. electromagnetic or fiber-optical sensors) [7]–[11]. Although there exits such applications in human computer interaction, the glove-based solutions are too intrusive and expensive for natural interaction with smart devices. To overcome these limitations, vision-based hand motion capturing and tracking solutions need to be developed.

Capturing hand and finger motions in video sequences is a highly challenging task due to the large number of DOF of the hand kinematics. Tracking articulated objects through sequences of images is one of the grand challenges in computer vision. Recently, Microsoft demonstrated how to capture full body motions by means of their newly developed depth cameras, Kinect [12]–[14]. Substantial development of hand tracking and gesture recognition are based on using depth sensors or integration of depth and RGB cameras. Sridhar et al., [15] use RGB and depth data for tracking of articulated hand motion based on color information and part-based hand model. Oikonomidis et al., [16] and Taylor et al., [17] track the articulated hand motion using RGBD information from Kinect. Papoutsakis et al., [18] analyze limited number of hand gestures using RGBD sensor. Model-based hand tracking using depth sensor is among the common proposed solutions [17], [19]. Oikonomidis et al., [16] also introduce articulated hand tracking using calibrated multi-camera system and optimization methods. [20] propose a model-based solution to estimate the pose of two hands using discriminative salient points. Here, the question is whether using 3D depth cameras can potentially solve the problem of 3D hand tracking and gesture recognition. Of course, this problem has been greatly simplified by the introduction of real-time depth cameras. However, the technologies based on 3D depth information for hand tracking and gesture recognition still face major challenges for mobile applications. In fact, mobile applications have at least two critical requirements: computational efficiency and robustness. For mobile applications, feedback and interaction in a timely fashion is assumed. Any latency should not be perceived as unnatural to the human participant. Therefore, the maximum time between the completion of a gestural action from a person and response from the device must be no longer than 100 ms (at least 10 frames per second should be processed in real-time vision-based systems). This requires an extremely fast solution for hand tracking and gesture recognition. It is doubtful if most existing technical approaches, including the one used in Kinect body tracking system would be the direction leading to the technical development for future smart devices due to their inherent resource-intensive nature. Another issue is the robustness. The solutions for mobile applications should always work no matter indoor or outdoor. This may somehow exclude the possibility of using Kinect-type depth sensors in the next generation of mobile devices. Therefore, we come back to our original problem again, how to solve the problem of hand tracking and gesture recognition with video cameras. A critical question is whether we could develop alternative video-based solutions to hand tracking and gesture recognition that may fit future mobile applications better. Obviously, this question is of significance to address, since it is not only one of the fundamental problems in computer vision, but also it would have a potential impact on the mobile industry, and above all on the interaction with mobile devices in the future.

Bare-hand Gesture Recognition and Tracking

Existing algorithms of hand tracking [18] and gesture recognition can be grouped into two categories: appearance-based approaches and 3D hand model-based approaches [3], [21]–[24]. Appearance-based approaches are based on a direct comparison of hand gestures with 2D image features. The popular image features used to detect human hands and recognize gestures include hand colors and shapes, local hand features, optical flow and so on. Our earlier proposed works on hand tracking belong to this type of approaches[4], [5], [25]–[27]. The gesture analysis step usually includes feature extraction, gesture detection, motion analysis and tracking parts. Pattern recognition methods for detecting and analyzing the hand gestures are mainly based on local or global image features. Simple features such as edges, corners, lines, and more complex features such as Symmetry patterns, SIFT(Scale-invariant feature transform), SURF(Speeded Up Robust Features), and FAST(Features from accelerated segment test) features are widely used in the computer vision applications [28], [29]. If the desired goal is to detect a specific pattern, a combination of image features might be used. For dynamic hand gestures, it is quite challenging to define a single pattern for detection due to the complex combination of the hand joints. Therefore, combination of local/global image features might be useful to detect and localize the hand gestures. Distinctive features are extremely useful for robust tracking and 3D motion analysis. If the hand gesture is correctly detected and localized, robust features such as SIFT or SURF might be used to analyze the 3D motion parameters in a sequence of image frames. If the main goal is to track the gesture in consecutive frames, the detection algorithm might be conducted on single frames in a sequence. Another way to track the gesture is to detect and localize the gesture in a single frame and follow the detected pattern in the coming frames using common tracking methods.

However, depending on the application scenario, if the recognition of different types of gestures is required, different gesture patterns should be analyzed. If the goal is to track a special gesture, the specific pattern might be detected in consecutive frames, and if the 3D motion of the hand gesture is required, gesture localization and 3D motion analysis from the sequence of frames should be performed.

In general, the drawback of the feature-based approaches is that clean image segmentation is generally required in order to extract the hand features. This is not a trivial task when the background is cluttered. Furthermore, human hands are highly articulated. It is often difficult to find local hand features due to the self-occlusion, and some kinds of heuristics are needed to handle the large variety of hand gestures.

Instead of employing 2D image features to represent the hand directly, 3D hand model-based approaches use a 3D kinematic hand model to render hand poses. An Analysis-By-Synthesis (ABS) strategy is employed to recover the hand motion parameters by aligning the appearance projected by the 3D hand model with the observed image from the camera, and minimizing the discrepancy between them.

Generally, it is easier to achieve real-time performance with appearance-based approaches due to the fact of simpler 2D image features. However, this type of approaches can only handle simple hand gestures, like detection and tracking of fingertips. In contrast, 3D hand model based approaches offer a rich description that potentially allows a wide class of hand gestures. The bad news is that the 3D hand model is a complex articulated deformable object with 27 DOF. To cover all the characteristic hand images under different views, a very large image database is required. Matching the query images from the video input with all hand images in the database is time-consuming and computationally expensive. This is why the most existing 3D hand model-based approaches focus on real-time tracking for global hand motions with restricted lighting and background conditions.

In general, we need to cover full range of hand gestures. 3D hand model-based approaches seem more promising. To handle the challenging search problem in a high dimensional space of human hands, the efficient index technologies used in information retrieval field, have been tested. Zhou et al. proposed an approach that integrates the powerful text retrieval tools with computer vision techniques in order to improve the efficiency for hand image retrieval [30]. An Okapi-Chamfer matching algorithm is used in their work based on the inverted index technique. Athitsos et al., proposed a method that can generate a ranked list of 3D hand configurations that best match an input image [31]. Hand pose estimation is achieved by searching for the closest matches for an input hand image from a large database of synthetic hand images. The novelty of their system is the ability to handle the presence of clutter. Imai et al. proposed a 2D appearance-based method to estimate 3D hand posture [32]. In their method, the variations of possible hand contours around the registered typical appearances are trained from a number of graphical images generated from a 3D hand model. A low-dimensional embedded manifold is created to overcome the high computation cost of the large number of appearance variations.

Although the methods based on retrieval are very promising, they are too few to be visible in the field. The reason might be that the approach is too primary, or the results are not impressive due to the tests just over very limited size of database. Moreover, it might be also a consequence of the success of 3D sensors such as Kinect in real-time human gesture recognition and tracking. The statistical approaches (random forest tree, for example) adopted in Kinect start dominating mainstream gesture recognition approaches. This effect is enhanced by the introduction of a new type of depth sensor from the Leap Motion company. This type of depth sensor can run at interactive rates (it should process at least 10 frames/second) on consumer hardware and interact with moving objects in real-time. Despite of its attractive demo, Leap Motion sensor cannot handle full range of human hand shapes and sizes. The main reason is that such sensors usually detect and track the presence of fingertips or points in free space when user's hands enter the sensor's field of view. In fact, they can be used for general hand motion tracking.

Regarding the special requirements for mobile applications such as real-time processing, low-complexity and robustness, it seems that a promising approach to handle the problem of hand tracking and hand gesture recognition is to use retrieval technologies for search. In order to apply this technology to next generation of smart devices, a systematic study is needed regarding how retrieval tools should be applied to handle gesture recognition, particularly, how to integrate the advanced image search technologies [33]. Surely, there exist many powerful tools to overcome this problem. The key issue is how to relate the vision-based gesture analysis to the large-scale search framework and define a right problem. Once the right problem is defined, we can identify and integrate right tools to form a powerful solution.

III- Project Description

In addition to exploring computer vision methods for gesture analysis, this project aims to introduce and integrate new frameworks and methodologies for recognition and tracking of articulated hand motions based on search technologies and analysis of Big Data. The innovative proposed approach described here is to define the problem of hand tracking and gesture recognition as a general search problem. The idea is to build a database that represent extremely large set of hand gestures. Ideally, these images should emulate all possible hand gestures. Furthermore, these images will be tagged with 3D motion parameters including 3D position and orientation of the hand and finger joints. When the hand of a user is captured by the sensors connected to the smart device, the captured image will be used to retrieve the most similar hand gesture stored in the database. Then, the motion parameters tagged with the matched image are given to the captured hand image. Thus, effective 3D hand tracking and gesture recognition can be achieved. The key of this approach is how to quickly find the best match from the database. The

proposed solution is to treat each image as a document, convert shape features to a huge visual vocabulary table, and employ the inverted indexing as a powerful retrieval tool to perform the search. This framework might have a big impact on gesture analysis, where high-resolution gesture analysis is required. In fact, unlike the classical pattern recognition methods, in the search framework, entries of the database will not be analyzed from shape-based or model-based methods. The main idea is to include every possible hand gesture image regardless of its shape or model. The entries of the database might be real images of articulated hand gestures or computer generated graphics. Here, the important point is to annotate the database entries with the position and orientation information of the recorded hand gestures. The vocabulary of hand gestures integrates the information from visual features of the gesture images and their pose information in an extremely large table. On the other hand, the query frame, captured by the vision sensor, will be pre-processed and its visual features will be extracted for analysis in the gesture search block. The core of the system is the gesture search engine that analyzes the similarity of the query input with the database entries in several steps and retrieves the best match. The output of the system is the most similar gesture image to the query input and in the ideal case is identical to the query. Finally, the retrieved image and its annotated pose information will be employed in the application.
The goal is that the new framework and algorithms could lead to solutions with high tracking and recognition accuracy than current ones. The accuracy should be so high that the solution could be used as a stand-alone module for 3D hand tracking. Obviously, such solutions will also be useful in providing single frame estimate to a 3D hand tracker, consequently achieve automatic initialization and error recovery. Based on the fact that 27 DOF of hand/joints information are annotated to the database entries in the offline step, this new framework provides the most accurate and instant gesture analysis system comparing with the abovementioned state-of-the-art solutions.

Providing the Database of Articulated Hand Gestures

The core in the gesture search system is how to represent gesture contours. To enable the formulation of the gestural interaction problem into a search framework, two particular properties should be considered: first: shape sensitivity, which means that the matched hand gesture shape should be as close as possible to the one from input frame; second: position sensitivity, which means that the matched gesture should be at a similar position as the input gesture.
In general, for the database we have to consider two main issues: how large the database should be? How to build such a database? The human hand is a complex articulated structure consisting of many connected links and joints. Including 6 DOF for orientation and position, there are 27 DOF for the human hand in total [3]. To render all possible combinations of joints and poses huge numbers of hand images will be generated. The state space of the joints has substantially lower dimensions [34]. If we quantize each DOF and represent it with 3 bits, thus we will have a total combination of 8^7 approximately 2 millions states. Thus, we have a rough estimation of the size of the database of hand gesture images, around at least 2 millions [36], [37].
The second issue is about how to build such a database. One solution is to use a 3D hand model to render all possible hand postures with computer graphics technology, and convert the generated gesture images into binary shape images through edge and boundary detection. The major problem with this approach is that the extracted edges are not natural, which directly affects the search of the best-matched hand shape. Recording the hand gestures from real users for converting into binary hand shape images seems to be a reasonable approach. Moreover, motion sensors and video cameras can be attached to the hand for measuring the exact position/orientation of the hand and finger joints. Thus, the ground truth 3D motion parameters can be provided for the gesture database.

IV- Timetable and Research Plan:

Research question 1	How to enhance the current gesture analysis solutions (6-10 DOF) to full analysis of the hand gestures (27 DOF)? What type of hardware and software-based solutions might be employed to perform this significant change?
Tasks/ Approach	Enabling media technologies will be deeply studied and investigated during this period. Different methods for gesture detection, recognition, tracking, and 3D motion analysis will be studied and new algorithms for supporting this concept will be explored.
Timeline	During the first 6 months of the project

Expected outcomes	Comprehensive study of the field and state-of-the-art solutions will be provided. New methods for gesture analysis will be provided for further development. Survey of 3D Gesture Analysis will be submitted to International Journal of Computer Vision/IEEE Tran. On Multimedia.

Research question 2	How to develop and employ new frameworks such as Big Data or Search methods for gesture analysis? Moreover, how to integrate them with existing computer vision solutions to tackle the high degrees of freedom 3D gesture analysis?
Tasks/ Approach	Search framework will be employed for gesture analysis. Gesture Search Engine for recognition, tracking, and analysis of 27 DOF hand gestures will be implemented.
Timeline	From month 6 till the end of second year
Expected outcomes	Novel solutions for high DOF gesture analysis will be developed and implemented. New frameworks will be integrated to the existing technologies to enhance the 3D gesture analysis. Research results will be published in ACMMM/CVPR/ICCV/ECCV/ICME.

Research question 3	How to develop new methodologies and algorithms to extend the gesture detection, recognition and analysis to multiple hands and collaboration of multiple users in collaborative applications?
Tasks/ Approach	Large-scale search framework and computer vision methods for gesture analysis will be integrated to extend the gesture analysis to multiple hands. Concept of collaborative 3D interaction using hand gestures in mobile platforms, web-based applications and distributed systems will be explored. Integration of new sensors and sensory fusion for enhancing the interaction technology will be explored in the research.
Timeline	From the second year
Expected outcomes	Collaborative 3D Interaction will be implemented. Effective application scenarios for 3D interaction will be selected and the technology will be tested. Usability analysis will be considered. Research results will be published in relevant HCI and multimedia conferences (ACMMM/CHI).

Research question 4	What type of design and usability issues should be considered to effectively employ the 3D gesture-based interaction in applications?
Tasks/ Approach	Prototypes, technical demos, and showcases in different application scenarios will be evaluated at this stage. Usability analysis and user studies will be conducted iteratively to improve the research results from user perspective.
Timeline	Mainly in the third year and partly in the second year
Expected outcomes	Prototypes will be tested by users in different application domains. User studies will be conducted and evaluated. The research results will be published at relevant conferences (CHI/Mobile HCI) and journals (IEEE Tran. On Multimedia/IJCV/TPAMI).

V- Significance of the Project and Contributions to the Research Area

In order to bring the real-life intuitiveness into the digital space, smart devices should understand the intuitive and natural communication or manipulation skills of humans. In other words, they should be able to analyze and understand human hand gestures with high accuracy and resolution. Major research groups in media technology and computer vision have also identified this need. Introduction of 3D depth sensors such as Kinect from Microsoft, Leap Motion, RealSense from Intel, and early prototypes such as Tango Project from Google and inForm from MIT Media Lab, verifies the need for natural interaction using 3D hand gestures. However, due to the complexity of the algorithms, power and hardware limitations current computer vision and pattern recognition solutions cannot successfully analyze the full Degrees of Freedom (DOF) of hand motions. Even though new depth sensors have simplified this problem to some extent, current solutions on stationary systems can perform global hand tracking and finger detection (around 6-10 DOF motion retrieval). Due to the fact that articulation, diversity, and variations of hand gestures can be represented by 27 DOF, analysis and processing of this high dimension have been remained an extremely challenging problem in computer vision for a long time.

This is even more challenging when we target the mobile and wearable smart devices since we should also consider the hardware and power limitations. Therefore, with the classical computer vision solutions full DOF hand gesture analysis seems impossible on mobile platforms with the today's methodologies.

Integration of the Search-based methods and classical computer vision algorithms to tackle these issues seems to be an effective approach. Specifically for extending the gesture analysis to multiple hands and collaborative scenarios we need to handle more complex combination of gestures in real-time.

VII- Preliminary Research Results and Findings

This project proposal is formed based on our previous research findings carried out during the last 5 years. An intensive research on the topic of 3D gesture analysis have been done by Dr. Yousefi during his PhD studies under the supervision of Prof. Li at KTH [4], [5], [26], [35], [36], [27], [37]. They have developed, implemented, and published new methodologies for 3D gesture detection, recognition, and tracking. During the last two years they have collaborated with Prof. Milrad and his research group at LNU for further development of their research activities in this area. Currently, new frameworks for 27 DOF hand gesture analysis in real-time are developed. The innovative solution is based on forming a large-scale gesture search engine. Our estimation shows that with this system it will be possible to recognize around 2 Million different hand gestures in real-time on a smart device. With the search-based framework the complexity will be shifted to the offline step and performing an extremely fast 27 DOF hand gesture analysis will be possible.

In order to build this gesture search engine, the following steps should be accomplished: First, recording a large-scale database of hand gestures including all variations, deformations, scales, user diversities, etc. Second, measuring 27 DOF motion information of the hand (3D position and orientation parameters of the hand and all finger joints) and annotating each database entry with its corresponding parameters. Third, constructing the large-scale search table and the algorithms for instant search over this search table. Fourth, performing the real-time gesture analysis and applying that to HCI applications. Architecture of the gesture search framework has been designed and the concept has been proved on a sample gesture database with very limited number of entries. The preliminary results can clearly indicate that this technology can make a revolution in 3D gesture-based interaction and can be implemented on current and future mobile/smart devices.

With the idea of Gesture Search Engine (GesTech), we won the first prize in two competitions in Sweden: best research project in Uminova Academic Business Challenge 2012, and best idea in KTH Innovation and EIT ICT Lab Idea Competition 2013. The gesture search framework has been compared with all the state-of-the-art research methodologies and has successfully gone through a novelty search and patentability analysis by Forskarpatent AB and KTH Innovation’s patent attorney. Therefore, a provisional US patent application was filed on 5 January 2014. The PCT application was thereafter filed 22 December 2014, with the support of Brann and KTH Innovation’s patent attorney.

Clearly, further development of this framework, including the investigation of theoretical aspects, methodology, algorithm, system development, implementation of large-scale gesture database and development of the gesture search engine will be explored in this research project. Gesture-based interaction has become a trend in the recent few years while we have investigated and published on this topic since 2009. With more than 5 years of intensive research activities and experience, we are planning to form and lead a research group on this topic. Further development of this technology has been systematically defined in the research plan. Supervision of PhD student, involving master students in this project through their master theses, course projects, and teaching related subjects such as interactive multimedia, gesture-based interaction, future interaction technologies etc. will be the top priorities in our plan. Our background knowledge, experience, and achievements will be a strong basis to form a leading research group in this area. In addition to the mentioned activities, we are planning to collaborate with high-profile researchers and research groups to expand the dimensions of this research project.

VIII- Relevance of the Research Project to Societal and Industrial Needs

The need and interest for high-accuracy 3D gesture analysis has been verified by major industrial actors such as Samsung, Microsoft, Apple, Qualcomm, and Intel through a technical overview of the field and our contacts with these companies. These companies have recently shown their interest for further discussions and possible research collaboration. Two examples are:

> ***Qualcomm*** *(Dr. Michael Gervautz, Director of Product Management):*
> *“I do believe that the gesture-based interaction in 3D will be the solution for forthcoming AR glasses and wearable devices, the existing solutions in the market can not satisfy the need for natural interaction since they are limited to very basic motion detection. We would like to explore the possibility of integrating the gesture analysis system in our products”*

__Intel__ (Jonas Kollberg, Consumer Client Portfolio Alliances):
"We believe very strongly in this area. We are ourselves developing SDKs for gesture. We would also like to provide our new hardware to see the applicability of your solution to that".

The unique advantages and benefits that 3D gesture analysis offers can be summarized as follows:
• Resolves the limitations of 2D interaction approaches used on current touch screens.
• Is applicable to any type of mobile device and stationary systems such as PCs, laptops, virtual reality headsets and smart TVs.
• Is useful in many applications such as 3D gaming, virtual reality, augmented reality, medical applications, education, robotics etc.
• Is useful in single or multi-user applications and for collaborative sharing in virtual environments.

IX- Equipment
Members of this research project have access to a wide variety of hardware and software infrastructure at the Department of Media Technology at LNU and at the Department of Media Technology and Interaction Design at KTH. Mobile devices including smart phones, Tablets, portable computers, 2D and 3D sensors such as optical cameras, depth sensors etc. will be used for research and educational-related activities during the project. For practical experiments and lab works, Media Lab at LNU, Usability Lab at KTH, Visualization Studio at KTH and other facilities at both universities will be used. We also aim to establish a new lab at LNU (3D Interaction Lab) with the focus on design and implementation of the interactive applications by employing 3D interaction technology.

X- Ethical Considerations
Studies carried out within the proposed project may, if determined by VR or desired by other parties, be examined by an ethical council. The project team will consider all recommendations from VR concerning any form of ethical review or consideration. Selection and participation in the user studies will be voluntary with an assurance that the participants can terminate their participation in any time if desired. Written consent to conduct the study at the schools will be acquired from the organization responsible. Guidelines and policies produced by and already existing in the schools will be followed.

XI- Cooperation between Partners
The proposed research project brings together two groups from LNU and KTH that have been actively working in the field of Media Technology and Media Signal Processing for more than one decade. The combination of the research perspectives that these two groups encompass offers a unique expertise in development of new frameworks and technologies in the field of human-computer interaction. Their cooperation will strengthen the participants' theoretical and methodological understanding of the abovementioned research problems. It is expected that this collaboration will promote the scientific activities of research partners and leads to forming a leading research group in this area. It is also expected that besides the common research activities, both universities benefit from the scientific outcomes of the projects in form of new master theses, courses and course projects in masters and PhD level education.

XII- Project Staff and Division of the Activities:
1- Dr. Shahrouz Yousefi (LNU): PhD in Media Technology from KTH, Stockholm. He is currently employed as a Senior Lecturer at the Media Technology department at LNU. He will lead this research project with 60% activity for the first year, and 65% for second and third year including the technical development and supervision of the PhD and master students involved in the project. Shahrouz has intensively worked with design and implementation of the gesture-based interactive systems during and after his PhD studies at KTH. He is one of the pioneers in design and development of 3D gestural interaction around the smartphones from 2010 and introduced innovative ways for handling the recognition and tracking of complex hand gestures in 3D space. He has won two innovation competitions in Sweden for his novel solutions in this area.
2- Prof. Marcelo Milrad (LNU), He currently works as a Professor at the department of media technology, Linnaeus University. During this project Prof. Milrad will be responsible for the design and

analysis of the empirical studies and development of new methodologies for effective interaction from user perspective as well as supervision of the project as a senior member and management of the resources at LNU. His work commitment in the project will be 20% including the supervision of students.

3- Prof. Haibo Li (KTH), PhD in Signal Processing. He currently works as a Professor at the department of Media Technology, KTH. His role at this project is as a senior advisor, supervision and technical development conducted in Stockholm. His commitment will be 25% including the supervision of students. He is the main responsible person for management of the project resources from KTH.

4- Dr. Didac Gil de La Iglesia (LNU), PhD in Computer Science**.** Currently Didac is a research fellow at the Department of Media Technology at LNU. He received his PhD at LNU. His research focus is on aspects related to mobile collaborative systems by the share of resources between mobile devices. With the work commitment of 20% for the first and second year and 25% in the third year, Didac will be mainly responsible for technical development and design of collaborative gesture-based interaction and sharing the hardware/software related resources (RQ3, RQ4).

5- Bin Zhu (Tina) (KTH/MobileLife)

Tina is a PhD-student in Human-Machine Interaction with specialization in Mobile Interaction Design at KTH Royal Institute of Technology, Stockholm. She is also a member of MobileLife research group at Kista. Her research area is about affective interaction involving users bodily and somatically in communication. She will be involved in the evaluation and user study during the project (RQ4).

6- New PhD student: With the allocated budget in the project we plan to announce a PhD position and involve a new PhD student with 80% activity for the period of three years. The PhD student position will be based at LNU and will be supervised by both partners and having access to all technical resources from LNU and KTH. Our plan is to employ a student with relevant knowledge in computer vision and mobile multimedia processing at the latest 3 months after the start of the project.

XIII- National and International Collaboration

The project members have well-established relations and collaborations with academic partners in Europe, America and Asia as well as national relations to top research groups in Media Technology, Computer Vision, Signal Processing and Interaction Design at KTH, Linköping University & Umeå University. We plan to invite the following top researchers in the field for seminars and workshops during the project:

Dr. Shahram Izadi, Leader of the Interactive 3D Technologies (I3D), Microsoft Research, Cambridge.
http://research.microsoft.com/en-us/people/shahrami/

Prof. Touradj Ebrahimi, Head of the Multimedia Signal Processing group, EPFL, Switzerland.
http://people.epfl.ch/touradj.ebrahimi

Prof. Antonis Argyros , Computer Science, University of Crete, Greece / Researcher, FORTH-ICS.
http://www.ics.forth.gr/~argyros

Dr. Andrés Lucero, Associate Professor of Interaction Design, University of Southern Denmark.
http://findresearcher.sdu.dk:8080/portal/en/person/lucero

Moreover, R&D groups at Intel, Microsoft, Qualcomm and Samsung have shown their interest to collaborate and be involved in the project. Currently Intel has provided us with their new development kit for gesture-based interaction. We plan to evaluate the possibility of integrating our gesture analysis solutions to their products. Qualcomm has also shown their interest to provide their 3D sensors for the experiments we plan to run during the project.

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Interdisciplinarity

My application is interdisciplinary

☐

An interdisciplinary research project is defined in this call for proposals as a project that can not be completed without knowledge, methods, terminology, data and researchers from more than one of the Swedish Research Councils subject areas; Medicine and health, Natural and engineering sciences, Humanities and social sciences and Educational sciences. If your research project is interdisciplinary according to this definition, you indicate and explain this here.

Click here for more information

Scientific report

Scientific report/Account for scientific activities of previous project

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Budget and research resources

Project staff

Describe the staff that will be working in the project and the salary that is applied for in the project budget. Enter the full amount, not in thousands SEK.

Participating researchers that accept an invitation to participate in the application will be displayed automatically under Dedicated time for this project. Note that it will take a few minutes before the information is updated, and that it might be necessary for the project leader to close and reopen the form.

Dedicated time for this project

	Role in the project	Name	Percent of full time
1	Applicant	Dr. Shahrouz Yousefi	60
2	Participating researcher	Prof. Marcelo Milrad	20
3	Participating researcher	Prof. Haibo Li	25
4	Participating researcher	Dr. Didac Gil de la Iglesia	20
5	Participating researcher	New PhD Student	80
6	Participating researcher	Bin Zhu	25

Salaries including social fees

	Role in the project	Name	Percent of salary	2016	2017	2018	Total
1	Applicant	Shahrouz Yousefi	45	346,024	352,944	360,003	1,058,971
2	Participating researcher	Marcelo Milrad	10	121,718	124,152	126,625	372,495
3	Participating researcher	Haibo Li	10	121,905	124,343	126,830	373,078
4	Participating researcher	Didac Gil de la Iglesia	20	131,283	133,908	136,586	401,777
5	Participating researcher	PhD Student	80	360,090	367,291	374,637	1,102,018
	Total			1,081,020	1,102,638	1,124,681	3,308,339

Other costs

Describe the other project costs for which you apply from the Swedish Research Council. Enter the full amount, not in thousands SEK.

Premises

Type of premises	2016	2017	2018

Running Costs

	Running Cost	Description	2016	2017	2018	Total
1	Travel		40,000	60,000	90,000	190,000
2	Equipment		30,000	30,000	30,000	90,000
3	Computers/Peripheral Devices		40,000	30,000	30,000	100,000
	Total		110,000	120,000	150,000	380,000

Depreciation costs

Depreciation cost	Description	2016	2017	2018

Total project cost

Below you can see a summary of the costs in your budget, which are the costs that you apply for from the Swedish Research Council. Indirect costs are entered separately into the table.

Under Other costs you can enter which costs, aside from the ones you apply for from the Swedish Research Council, that the project includes. Add the full amounts, not in thousands of SEK.

The subtotal plus indirect costs are the total per year that you apply for.

Total budget

Specified costs	2016	2017	2018	Total, applied	Other costs	Total cost
Salaries including social fees	1,081,020	1,102,638	1,124,681	3,308,339	0	3,308,339
Running costs	110,000	120,000	150,000	380,000	45,000	425,000
Depreciation costs				0		0
Premises				0	0	0
Subtotal	1,191,020	1,222,638	1,274,681	3,688,339	45,000	3,733,339
Indirect costs	540,509	551,320	562,346	1,654,175		1,654,175
Total project cost	1,731,529	1,773,958	1,837,027	5,342,514	45,000	5,387,514

Explanation of the proposed budget

Briefly justify each proposed cost in the stated budget.

Explanation of the proposed budget*

This section briefly provides some explanations about aspects related to the budget according to the following:

- With regard to the costs of premises, offices and labs that will be used to carry out the proposed activities, these costs are contemplated in the indirect costs indicated in the described budget. With regard to depreciation costs, they will not be applicable to this project. The cost of the computers and mobile devices to be purchased and used in the project are under the required amount for calculation of the depreciation costs.
- It is also important to emphasize that all the efforts that the researchers involved in the project will put not only will be funded by VR but also with faculty funding coming from LNU and KTH. In the particular case of PhD student, Bin Zhu, her research efforts connected to this project will be covered solely by KTH.
- The specific traveling costs, equipment and materials are aligned with those efforts described in section IV of the proposal, namely Timetable and research plan.

Other funding

Describe your other project funding for the project period (applied for or granted) aside from that which you apply for from the Swedish Research Council. Write the whole sum, not thousands of SEK.

Other funding for this project

Funder	Applicant/project leader	Type of grant	Reg no or equiv.	2016	2017	2018

CV

CURRICULUM VITAE
Shahrouz Yousefi, PhD

Senior Lecturer
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Shahrouz Yousefi is a Senior Lecturer in Media Technology at Linnaeus University, Sweden. Dr. Yousefi received his PhD degree in Media Technology from the department of Media Technology and Interaction Design, School of Computer Science and Communication, KTH Royal Institute of Technology, Stockholm, Sweden. His research interests include Computer Vision, Pattern Recognition, Media Technology, Media Signal Processing, 3D Gesture Analysis, 3D Rendering, Visualization, and Future Interaction Technologies.

1. Higher Education Qualifications

M.Sc. Master of Science in Robotics and Control, Umeå University, 2009
B.Sc. Bachelor of Science in Electrical Engineering (Electronics), Zanjan University, Iran, 2006

2. Doctoral Degree

Ph.D. Media Technology, KTH Royal Institute of Technology, Stockholm, 2014

Dissertation: *3D Gesture Recognition and Tracking for Next Generation of Smart Devices, Theories, Concepts, and Implementations*
Supervisor: Professor Haibo Li

3. Postdoctoral positions: Not applicable

4. Qualification required for appointments as a docent: Not applicable

5. Current Position
Senior Lecturer in Media Technology, Department of Media Technology, Linnaeus University, 50% research, 50% teaching & supervision

6. Previous positions and periods of appointment

2015 – now: Senior Lecturer in Media Technology, Linnaeus University, Sweden
2012 – 2015: Chief Scientist Officer, GesTech project, Stockholm, Sweden
2014: Research and Development, Centre for Biomedical Engineering (CMTF), Umeå, Sweden
2006: Control Engineer, Farasys Co., Tehran, Iran
2005: TV and Radio Lab Engineer, Pars Electric, Tehran, Iran

7. Interruption of Research: Not applicable

8. PhD Supervision and Examination Responsibilities: Not applicable

9. Other merits of relevance to the application

2015	Main inventor of the PCT Application for GesTech, Patent Pending
2014	Main inventor of the US patent application for GesTech technology
2013	First prize in KTH Innovation & EIT ICT Lab Idea Competition (GesTech)
2012	First prize in Uminova Academic Business Challenge for gPhone
2010-2015	Active reviewer of IEEE journals
2010-2015	Main author of more than 20 articles in top-ranked journals and conferences

Awarded Grants and Prizes:
VFT-0, VFT-1, KTHI, Uminova ABC, Wallenberg Foundation, Kempe Foundation

CURRICULUM VITAE
Haibo Li, PhD

1. Higher education degree(s) (year, subject area)

1987: Master's Degree in Electrical Engineering, Nanjing University, P. R. China.

2. Doctoral degree (year, discipline/subject area, dissertation title and supervisor)

1993: Ph.D in Information Theory from Linköpings Universitet, Dept. of Electrical Engineering (ISY), Sweden. Thesis title: Low Bitrate Image Sequence Coding (Supervisors: Prof. Ingemar Ingemarsson, Information Theory, and Prof. Robert Forchheimer, Image Coding)

3. Postdoctoral positions (year and placement) no

4. Docent (Senior Lecturer) level (year)

1997: Docent in Information Theory from Linköpings Universite

5. Present position, period of appointment, percentage of research in the position

2012 -, Full Professor in Media Technology, Program Director of Master of Science Program in Media technology, School of Computer Science and Communication, at KTH Royal Institute of Technology, 70% research, 30% education

6. Previous positions and periods of appointment (indicate the type of employment)

- *1999-2012, Full Professor in Signal Processing, Department of Applied Physics and Electronics (TFE), Umeå University*
- *1997 - 1998: Associate Professor, Division of Image Coding, ISY, Linköpings universitet.*
- *1993-1997: Assistant Professor in Division of Image Coding, ISY, Linköpings universitet.*
- *1990-1993: Research Assistant, Division of Information Theory, ISY, Linköpings universitet.*

7. Interruptions in research **n**o

8. PhD and Post-docs

PhD

- Astrid Lundmark, Linköping University, 2001 (as second supervisor)
- Jacob Ström, Linköping University, 2002 (as second supervisor)
- Jörgen Ahlberg, Linköping University, 2002 (as second supervisor)
- Lena Klasén, Linköping University, 2003 (as second supervisor)
- Apostolos Georgakis, Umeå University, 2004
- Zhengrong Yao, Umea University, 2005
- Jiong Sun, Umeå University, 2006

- Hungson Le, Umeå University, 2007
- Ulrik Söderström, Umeå University, 2008
- Shafiq Ur Rehman, Umeå University, 2009
- Johannes Karlsson, Umeå University, 2010
- Farid Abedan, Umeå University, 2014
- Shahrouz Yousefi, KTH, 2014

Post-docs

- Dr. Guangming Lu, Nanjing University, 2006-2007
- Dr. Dengyin Zhang, Nanjing University, 2007-2008
- Dr. Alaa Halawani, Albert-Ludwigs University of Freiburg, Germany, 2008-2010.
- Dr. Fei Li, Nanjing University, 2007-2008
- Dr. Fredric Lindström, Göteberg University, 2007-2008
- Dr. Danny Chen, CSIRO ICT Centre, Australia, 2010-2011
- Dr. Zhihan Lv, Université Denis Diderot (Paris VII), 2012-2013

9. VR Funding + EU Funding

- "Tactile Perception of Facial Expressions", Vetenskapsrådet(**VR**), Project Research Grant, 2005-2007, Co-Applicant

- "Vibrotactile Rendering of Facial Expressions", Vetenskapsrådet(**VR**), Project Research Grant VR, 2008-2010, Co-Applicant

- "Is Wyner-Ziv coding a core technique enabling next generation face recognition technology for large-scale face image retrieval?", Vetenskapsrådet(**VR**), Project Research Grant, 2010, Principal Applicant

- ”Distributed Wyner-Ziv Video Coding for SWE – Share What I Experience", Vetenskapsrådet(**VR**), Industrial PhD Fellowship, 2007-2010, Principal University Applicant

- "Green Video Sharing", Vetenskapsrådet(**VR**), Research Link, 2009-2011, Principal Applicant

- "Automatic Assessment of Pain in Infants by Computer Facial Expression Analysis", Vetenskapsrådet(**VR**), Research Link, 2005, Principal Applicant

- **More than 6 EU projects**

SHORT CURRICULUM VITAE
Marcelo Milrad, PhD

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Marcelo Milrad is a Full Professor of Media Technology at Linnaeus University (LNU) in Sweden. His current research interests include the areas of Technology-Enhanced Learning (TEL), web and mobile development, human-computer interaction and social media analytics. Professor Milrad has published over 160 articles in international journals, refereed conferences, books and technical reports. He has also been presenting and giving lectures about his work in more than 40 countries worldwide.

1. Higher Education Qualifications

B.Sc. Bachelor of Science in Technology Education (Specialization Electronics and Computers), ORT Academic College, Jerusalem. Israel, 1992

M.Sc. Master of Science in Computing Science, Uppsala University, 1995

2. Doctoral Degree

Ph.D. System Dynamics Simulations, University of Bergen, Norway, 2006
Dissertation: *Designing Interactive Learning Environments to Support Learners' Understanding in Complex Domains, Supervisor: Professor Michael Spector*

3. Postdoctoral positions: Not applicable

4. Qualification required for appointments as a docent: 2007

5. Current Position

Full Professor in Media Technology & Head of Department, Department of Media Technology, Linnaeus University, 40% research, 20% teaching & supervision and 40 % administration.

6. Previous positions and periods of appointment

2006 - 2008:	Senior Lecturer (Docent: 2007), Växjö University, SE
2002 – 2006:	Researcher, Department of Media Technology, Växjö University, SE.
2000 – 2002:	Senior Researcher, Research Corporation for Media and Communication Technology, SE
1995 – 2000:	Researcher, The Institute for Media Technology, Department of Applied Multimedia, SE

1993 – 1994: Research Assistant, Centre for Human-Computer Studies (CMD), Uppsala University, SE

7. Interruption of Research: Not applicable

8. PhD Supervision and Examination Responsibilities

1) PhD degree awarded to 5 PhD students since 2009. Licentiate degrees awarded to 8 PhD students. Currently main supervisor of 5 PhD students.
2) External Member of Jury of 14 PhD students at Pontifical Catholic University, Chile, 1 at University of Oulu, Finland, 1 at the University of Bergen, Norway, 1 at Trinity College Dublin, Ireland, 1 at Umeå University, 3 at KTH, Sweden, 1 at Linnaeus University, Sweden, 1 at Sydney University, Australia, 1 at University of Buenos Aires, Argentina and 1 at The Open University, Netherlands)

9. Other merits of relevance to the application

9.1. Selected Performance Indicators

Last five years external funding: 26 Million Swedish Crowns (3 million US dollars) coming from the EU commission, Swedish funding agencies such as VR, KK, Vinnova, Wallenberg, and industrial partners.

Publication data from Google Scholar (http://scholar.google.com), March 27th, 2015, Citations: 2200, h-index: 22, i10-index: 37

9.2 Selected Grants and Honours

2006 Fellowship from the "Tore Danielsson" research fund of Växjö University, SE
2006 "Cesar Milstein" Fellowship awarded by the Argentinian Government, ARG
2009 Fellowship from the "Japanese Society for the Promotion of Science", JP
2011 Best Technical Design Paper Award at the 19th ICCE Conference, Thailand
2012 "Weston Visiting Professorship Award", The Weizmann Institute of Science, IL
2013 "Linnaeus University Medal of Honour" for being an outstanding research scholar
2014 Best paper award at the 7th International Conference on Collaboration Technologies (*CollabTech 2014*)

9.3 Recent Professional Activities

1) Initiator and General Chair of the IEEE WMUTE Conference (2002 & 2012)
2) Editorial Board member of the Journal of *Educational Technology & Society, 2003-present*
3) Editorial Board Member of *the Journal IEEE Transactions on Learning Technologies,* 2011-present
4) Program Committee member for more than 50 scientific international conferences in the last eight years
5) Deputy member of the Committee for Internationalization, Linnaeus University, Sweden, January 2010-present
6) Keynote speaker at several conferences in Asia, Europe and South America.

SHORT CURRICULUM VITAE
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Didac Gil de la Iglesia is a Research Associate of Media Technology at Linnaeus University (LNU) in Sweden since June 2014. His research focuses on technical aspects related to mobile collaborative systems by the share of resources between mobile devices and Tangible User Interfaces. Currently, Didac is using Agent-based approaches for resource and service share between mobile devices and self-adaptive mechanisms to provide quality assurances and researching on the use of sensors and actuators to enhance user interactions in collaborative systems.

1. Higher Education Qualification

B. Sc.	Bachelor of Science in Computer, Autonomous University of Barcelona, Barcelona, Spain, 2004
M.Sc.	Master of Science in Telecommunications (Specialization Mobile Telecommunications in collaboration with Vodafone). Polytechnic University of Catalonia, Barcelona, Spain, 2005.

2. Doctoral Degree

Ph.D.	Computer Science (Specialization Media Technology), Linnaeus University, Sweden, 2014 Dissertation: *A Formal Approach for Designing Distributed Self-Adaptive Systems, Supervisor: Professor Danny Weyns*

3. Postdoctoral positions: Not applicable.

4. Qualification required for appointments as a docent: Not applicable.

5. Current Position
Research Associate in Media Technology, Department of Media Technology, Linnaeus University, 50% research, 40% teaching & supervision and 10% administration.

6. Previous positions and periods of appointment

2010 – 2014:	PhD Student, Linnaeus University, Sweden
2008 – 2009:	PhD Student, Växjö University, Sweden

2004 – 2012: Lecturer, Open University of Catalonia, Spain
2006 – 2008: Security Services Manager for “la Caixa”, SCC, Spain
2005 – 2006: Information Risk Management and Internet Security Services, KMPG, Spain
2004 – 2005: Information Technologies Manager, SET, Spain

7. Interruption of Research: Not applicable

8. PhD Supervision and Examination Responsibilities: Not applicable
2015 – FLUS. Supervision in Postgraduate Programmes, *Centre for Educational Development (UPE), Linnaeus University, Sweden.*

9. Other merits of relevance to the application
2011 – Nordic LEAF grant for PhD Exchange, Pontificia Universidad de Chile, Santiago de Chile, Chile.
2013 – Webbdagarna Växjö. Research speaker: “Wood, Glass and ICT: Towards Småland as Leader in Smart Homes”. Academy InternetWorld.
2014 – TEDxLinnaeus University organizer. Speakers Director. Media Distribution manager.
URL: http://tedxlinnaeusuniversity.com/
2014 – Think Tank Malmö. A World-changing step: Open Hardware. URL: https://natverk.dfs.se/think-tank-nr-8-world-changing-step-open-hardware
2015 – Technology Pilot Coordinator for BoConnect founded by *Kamprad Family Foundation,*
(Jan 2015 – Dec 2016)
2015 – VI Ubimus workshop. From Digital Arts to Ubiquitous Music. Local committee.
URL: http://ubimus.eu

Publication list

Shahrouz Yousefi – Publications (Google Scholar)

1. Peer-reviewed original articles

*"Yousefi, Shahrouz; Kondori, Farid Abedan; Li, Haibo; "Experiencing real 3D gestural interaction with mobile devices, Pattern Recognition Letters, 34,8,912-921, 2013,Elsevier, Number of citations: 4

*"Yousefi, Shahrouz; Kondori, Farid Abedan; Li, Haibo; "Camera-based gesture tracking for 3d interaction behind mobile devices, International journal of pattern recognition and artificial intelligence, 26,08,2012,World Scientific, Number of citations: 2

"Abedan Kondori, Farid; Yousefi, Shahrouz; Li, Haibo; "Direct Head Pose Estimation Using Kinect-type Sensors, Electronics Letters, ISSN 0013-5194, E-ISSN 1350-911X, 2014

"Yousefi, Shahrouz; Li, Haibo; ", 3D Hand Gesture Analysis through a Real-time Gesture Search Engine, International Journal of Advanced Robotic Systems, 2015

"Abedan Kondori, Farid; Yousefi, Shahrouz; Li, Haibo; "Direct hand pose estimation for immersive gestural interaction", Pattern Recognition Letters, 2015

2. Peer-reviewed conference papers

"Kondori, Farid Abedan; Yousefi, Shahrouz; Li, Haibo; Sonning, Samuel; "3D head pose estimation using the Kinect," IEEE International Conference on Wireless Communications and Signal Processing (WCSP)"1-4,2011, Number of citations: 35

"Yousefi, Shahrouz; Kondori, Farid Abedan; Li, Haibo; "3D gestural interaction for stereoscopic visualization on mobile devices, Computer Analysis of Images and Patterns, 555-562,2011, Springer, Number of citations: 10

"Kondori, Farid Abedan; Yousefi, Shahrouz; Li, Haibo; "Real 3D interaction behind mobile phones for augmented environments", 2011 IEEE International Conference on Multimedia and Expo (ICME)," 1-6,2011, Number of citations: 3

"Yousefi, Shahrouz; "3D photo browsing for future mobile devices, Proceedings of the 20th ACM international conference on Multimedia, 1401-1404,2012, ACM, Number of citations: 2

"Kondori, Farid Abedan; Yousefi, Shahrouz; "Smart Baggage in Aviation, "Internet of Things (iThings/CPSCom), 2011 IEEE International Conference on Cyber, Physical and Social Computing", 620-623,2011, Number of citations: 1

"Yousefi, Shahrouz; Kondori, Farid A; Li, Haibo; "Tracking Fingers in 3D Space for Mobile Interaction, The Second International Workshop on Mobile Multimedia Processing, 72,2010,Citeseer, Number of citations: 1

"Yousefi, Shahrouz; Abedan Kondori, Farid; Li, Haibo; "Bare-hand Gesture Recognition and Tracking through the Large-scale Image Retrieval, 9th International Conference on Computer Vision Theory and Applications (VISAPP), 2014

"Yousefi, Shahrouz; Kondori, Farid Abedan; Li, Haibo; "Robust correction of 3D geo-metadata in photo collections by forming a photo grid, "IEEE International Conference on Wireless Communications and Signal Processing (WCSP)", 1-5, 2011

"Yousefi, Shahrouz; Abedan Kondori, Farid; Li, Haibo; "Interactive 3D Visualization on a 4K Wall-Sized Display, Asia-Pacific Signal and Information Processing Association, 2014 Annual Summit and Conference (APSIPA), 1-4, 2014

"Abedan Kondori, Farid; Yousefi, Shahrouz; Ostovar, Ahmad; Liu, Li; Li, Haibo; "A Direct Method for 3D Hand Pose Recovery, 22nd International Conference on Pattern Recognition (ICPR2014), 2014

"Yousefi, Shahrouz; Kondori, Farid Abedan; Li, Haibo; "Stereoscopic visualization of monocular images in photo collections,", IEEE International Conference on Wireless Communications and Signal Processing (WCSP)",1-5,2011

"Yousefi, Shahrouz; Kondori, Farid Abedan; Li, Haibo; "3D visualization of single images using patch level depth, Signal Processing and Multimedia Applications (SIGMAP), 2011 Proceedings of the International Conference on, IEEE Press, 61-66, 2011

"Yousefi, Shahrouz; Li, Haibo; "3D Interaction through a Real-time Gesture Search Engine,"12th Asian Conference on Computer Vision (ACCV)", 2014

"Abedan Kondori, Farid; Yousefi, Shahrouz; Liu, Li; Li, Haibo; "Head operated electric wheelchair, "IEEE Southwest Symposium on Image Analysis and Interpretation (SSIAI)",53-56,2014

3. Monographs

*"Yousefi, Shahrouz","3D Gesture Recognition and Tracking for Next Generation of Smart Devices: Theories, Concepts, and Implementations, Doctoral Thesis in Media Technology, School of Computer Science and Communication, KTH Royal Institute of Technology, SE-100 44, Stockholm, Sweden, ISSN:1653-5723, ISBN: 978-91-7595-031-0, 2014.

"Yousefi, Shahrouz", "Enabling Media Technologies for Mobile Photo Browsing", Licentiate thesis in Media Signal Processing, Digital Media Lab (DML), Department of Applied Physics and Electronics, Umeå University, SE-901 87, Umea, Sweden, ISSN: 1652-6295:16, ISBN: 978-91-7459-426-3, 2012., Umeå University, 2012.

4. Research review articles

5. Books and book chapters

*"Yousefi, Shahrouz; Li, Haibo; Liu, Li; "3D Gesture Analysis Using a Large-Scale Gesture Database, Advances in Visual Computing, Lecture Notes in Computer Science, Volume 8887, pp 206-217, 2014

6. Patents

*"Yousefi, Shahrouz; Li, Haibo; Abedan Kondori, Farid; "Real-time 3D gesture recognition and tracking system for mobile devices, 2014, US patent application Jan. 2014, PCT application Dec.2014, Patent Pending

7. Open access computer programs or databases

8 Popular science articles/presentations

"Enabling Media Technologies for 3D Gestural Interaction with Future Mobile Devices", Collaborative Conference on 3D Research, Seoul, South Korea, 2014.

"Intuitive Gestural Interaction for Future Smart Environments", Seminar in Media Technology, Linnaeus University, Växjö, Sweden, 2014.

"Great Ideas in Signal Processing", Seminar in Mathematics and Mathematical Statistics, Umeå Univesrity, Umeå, Sweden, 2011.

Publication of Haibo Li (Google Scholar)

Most Cited IEEE Transaction Papers

Haibo Li, P. Roivainen, R. Forchheimer, 3-D motion estimation in model-based facial image coding, **IEEE Trans. Pattern Analysis and Machine Intelligence**, Vol. 15, Issue 6, June, 1993. **Citation: 418**.

Haibo Li, A. Lundmark, R. Forchheimer, Image sequence coding at very low bit rates: a review, **IEEE Trans. Image Processing**, Vol. 3, Issue 5, 1994. **Citation: 246**.

Haibo Li, R. Forchheimer, Two-view facial movement estimation, **IEEE Trans. Circuits and Systems for Video Technology**, Vol. 4, Issue 3, 1994. **Citation: 44**.

A. Lundmark, Haibo Li, Hierarchical subsampling giving fractal regions, **IEEE Trans. Image Processing**, Vol. 10, Issue 1, 2001. **Citation: 37**.

Haibo Li, R. Forchheimer, A transformed block-based motion compensation technique, **IEEE Trans. Communications**, Vol. 43, Issue 234, 1995. **Citation: 18.**

Book Chapter (2009-)

*Shahrouz Yousefi, Farid Kondori, Haibo Li, “3D Gesture Analysis Using a Large-Scale Gesture Database”, Book Chapter, **Advances in Visual Computing**, Lecture Notes in Computer Science, Volume 8887, pp 206-217, 2014

Ulrik Söderström, and Haibo Li. Side View Driven Facial Video Coding. Advanced Video Coding for Next-Generation Multimedia Services**. InTech, pp.139-154, 2013. Citation: 2.**

Ulrik Söderström and Haibo Li, Asymmetrical Principal Component Analysis Theory and Its Applications to Facial Video Coding, **Effective Video Coding for Multimedia Applications**,
p. 95-110, 2011

Jean-Paul Kouma and Haibo Li, Large-Scale Face Image Retrieval: A Wyner-Ziv Coding Approach, in Book of **New Approaches to Characterization and Recognition of Faces**, Editor: Peter Corcoran, Publisher: InTech, Aug, 2011, ISBN 978-953-307-515-0.

Johannes Karlsson, Tim Wark, Keni Ren, Karin Fahlquist and Haibo Li, "Applications of Wireless Visual Sensor Networks - the Digital Zoo", Book chapter in **Visual Information Processing in Wireless Sensor Networks**, 2010

Shafiq ur Réhman, Li Liu, "iFeeling: Vibrotactile Rendering of Human Emotions on Mobile Phones", In Springer in Mobile Multimedia Processing : Fundamentals, Methods, and Applications **(LNCS 5960: State-of-the-Art Surveys), pp. 1-20, 2010. Citation: 12.**

Ulrik Söderström and Haibo Li, HD Video Communication at Very Low Bitrates, **Mobile Multimedia Processing: Fundamentals, Methods, and Applications**, p. 295–314, 2009

Shafiq ur Réhman, Li Liu and Haibo Li, How to Use Manual Labelers in Evaluation of Lip Analysis Systems? **Visual Speech Recognition: Lip Segmentation and Mapping**, IGI Global LNCS 5960: State of the Art Survey, 239-258, 2009

Journal Papers (2007-)

Z. Yao and Haibo Li, Tracking a detected face with dynamic programming, **Image and Vision Computing**, Vol. 24, No.6, 2007, **Citation**: 23

H. Le and Haibo Li, Fused logarithmic transform for contrast enhancement, **Electronics Lettters**, 2008, **Citation**: 11

U. Söderström and Haibo Li, Asymmetrical principal component analysis for video coding, **Electronics Lettters**, 2008, **Citation**: 8

Shafiq ur Réhman, J. Sun, Li Liu and Haibo Li, Turn your mobile into the football: rendering live football game by vibration, **IEEE Trans. on Multimedia**, Vol. 10, Issue 6, 1022-1033, 2009, **Citation:** 11

F. Lindström, Keni Ren, Haibo Li, Comparison of two methods of voice activity detection in field studies, **Journal of Speech, Language, and Hearing Research**, Vol.52, Issue 6, 1658-1663 2009, **Citation: 10**

C. Schuldt, F. Lindström, Haibo Li, I. Claesson, Adaptive filter length selection for acoustic echo cancellation, **Signal Processing**, Vol. 89, Issue 6, 1185-1194, 2009, **Citation: 19**

Johannes Karlsson, Adi Anani, Haibo Li, Enabling real-time video services over ad-hoc networks opens the gates for e-learning in areas lacking infrastructure,

International Journal of Interactive Mobile Technologies, Vol.2, p17- 23, 2009, **Citation: 1**

Ulrik Söderström and Haibo Li, Representation bound for human facial mimic with the aid of principal, **International Journal of Image and Graphics**, Vol.10, Issue 3, 343-363, 2010, **Citation: 8**

Alaa Halawani, Haibo Li, Adi Anani, Building eye contact in e-learning through head-eye coordination, **International Journal of Social Robotics**, Vol.3, Issue 1, p95-106, 2011**, Citation: 3**

Alaa Halawani, Shafiq ur Réhman, Haibo Li, Adi Anani, Active vision for controlling an electric wheelchair, **Intelligent Service Robotics**, Volume 5, Issue 2, April 2012, Pages 89-98. 2012. **Citation: 3**

*Shahrouz Yousefi, Farid Abedan Kondori, Haibo Li, Camera-based Gesture Tracking For Real 3D Interaction Behind Mobile Devices, **The International Journal of Pattern Recognition and Artificial Intelligence (IJPRAI)**, Vol. 26, No. 8, 2012. **Citation: 2**

Farid Abedan Kondori, Shahrouz Yousefi, Haibo Li, Direct 3D head pose estimation from Kinect-type sensors. **Electronics Letters**, Vol. 50, No. 4, pp. 268-270. 2013, **Citation: 5**

*Shahrouz Yousefi, Farid Abedan Kondori, Haibo Li, Experiencing Real 3D Gestural Interaction with Mobile Devices, **Pattern Recognition Letters**, Vol. 34, No. 8, 2013, pp. 912-921 , 2013, **Citation: 4**

Bo Li, Söderström, U., Ur Réhman, S., Haibo Li, Restricted Hysteresis Reduce Redundancy in Edge Detection. **Journal of Signal and Information Processing**, 4(3B): 158-163, 2013, **Citation: 1**

W. Shao, Q. Ge, H. Deng, Z. Wei and Haibo Li. Motion Deblurring using Non-stationary Image Modelling. **Journal of Mathematical Imaging and Vision**, Sept. 2014. **Citation: 0**

W. Shao, Q. Ge, Z. Gan, H. Deng and Haibo Li. A Generalized Robust Minimization Framework for Low-rank Matrix Recovery. **Mathematical Problems in Engineering**, Volume 2014. **Citation: 0**

Zhihan Lu, A. Halawani, Haibo Li, "Hand and Foot Gesture Interaction for Handheld Devices", **ACM Transactions on Multimedia Computing Communications and Applications**. 10/2014; 11:1-19. **Citation: 0**

*Shahrouz Yousefi, Haibo Li, 3D Hand Gesture Analysis through a Real-time Gesture Search Engine, **International Journal of Advanced Robotic Systems**, 2015. **Citation: 0**

Qi Ge, C. Li, W. Shao and Haibo Li. A hybrid active contour model with structured feature for image segmentation. Vol. 108, **Signal Processing**, March 2015. **Citation: 1**

Conference Papers (2009-)

*Shahrouz Yousefi, Farid Abedan Kondori, Haibo Li, 3D Gestural Interaction for Stereoscopic Visualization on Mobile Devices, In Proceeding of The 14th International Conference on Computer Analysis of Images and Patterns (**CAIP**), Seville, Spain, CAIP (2), Vol. 6855 Springer (2011) , p. 555-562, 29-31 August 2011, **Citation: 10**

Johannes Karlsson, Shafiq Ur Rehman and Haibo Li, Augmented Reality to Enhance Vistors Experience in a Digital Zoo, The 9th International Conference on Mobile and Ubiquitous Multimedia (**ACM MUM 2010**), 1-3 December, 2010, Limassol, Cyprus. **Citation: 8**

Guanming Lu , Xiaonan Li ; Haibo Li Facial expression recognition for neonatal pain assessment , International Conference on **Neural Networks and Signal Processing**, 7-11 June 2008, **Citation: 10**

Johannes Karlsson, Keni Ren and Haibo Li, "P2P video multicast for wireless mobile clients", International Conference on **MobiSys**, 2006. **Citation: 7**

Johannes Karlsson, J. Eriksson and Haibo Li, "Tracking and Identification of Animals for a Digital Zoo", The 1st IEEE/ACM **Internet of Things** Symposium, 18-20 December 2010, Hangzhou, China. **Citation: 7**

Fei Li, Min Zhou, Haibo Li, "A Novel Neural Network Optimized by Quantum Genetic Algorithm for Signal Detection in MIMO-OFDM Systems", IEEE Symposium on Computational Intelligence in Control and Automation (**SSCI 2011**- CICA) Proceedings, Paris France, pp.170-177, 2011, **Citation: 6**

Fei Li, Dongpo Zhu, Feng Tian, Haibo Li. "Improved Quantum Genetic Algorithm for Competitive Spectrum Sharing in Cognitive Radios", Lecture Notes in Electrical Engineering (**LNEE**) (ISSN: 1876-1100, Book Series), Springer-Verlag, pp.1009-1014, 2011, **Citation: 3**

Fei Li, L Zhou, Li Liu, Haibo Li. “A Quantum Search Based Signal Detection for MIMO-OFDM Systems”, IEEE 18th International Conference on Telecommunications (**ICT 2011**) Proceedings, Ayia Napa Cyprus, pp.276-281, 2011, **Citation: 6**

Shafiq ur Réhman, Li Liu and Haibo Li, Lipless Tracking for Emotion Estimation, in Proc. of IEEE 3rd int'l Conf. on -Signal-Image Technology & Internet-based Systems (**SITIS' 2007**), pp.768-774, China, 2007, **Citation: 9**

Shafiq ur Réhman, Li Liu and Haibo Li , Manifold of Facial Expression for Tactile Perception, in Proc. of IEEE International Workshop on Multimedia Signal Processing (**MMSP07**), pp. 239-242, Greece, 2007. **Citation: 4**

Söderström, Ulrik and Li, Haibo, Anonymous video processing for live street view, IEEE International Conferences on **Internet of Things**, and Cyber, Physical and Social Computing, pp. 109-113, **Citation: 2**

Abedan Kondori, Li Liu, Shahrouz Yousefi, Haibo Li. Head operated electric wheelchair. In Proceeding of the IEEE Southwest Symposium on Image Analysis and Interpretation (**SSIAI2014**), April 6-8, 2014, San Diego, California, USA. 2014, **Citation: 1**

Shahrouz Youse, Farid Abedan Kondori, Haibo Li, Bare-hand Gesture Recognition and Tracking through the Large-scale Image Retrieval, in the 9th International Conference on Computer Vision Theory and Applications (**VISAPP**), January, 2014, **Citation: 1**

Z. Lv, S. Feng, S. Rehman and Haibo Li, Foot motion sensing: augmented game interface based on foot interaction for smartphone**, CHI’14** Exteneded Abstracts on Human Factors in Computing Systems, pages 293-296, 2014, **Citation**: 2

Shahrouz Youse and Haibo Li, 3D Interaction through a Real-time Gesture Search Engine, 12th Asian Conference on Computer Vision (**ACCV**), 2nd Workshop on User-Centred Computer Vision, 2014, **Citation: 2**

A. Darvish, Haibo Li, and U. Söderström, Super-resolution Facial Images from Single Input Images Based on Discrete Wavelet Transform, International Conference on **Pattern Recognition**, 2014. , **Citation:**

Bo Li, Aleksandar Jevtic, Ulrik Söderström, Haibo Li, Fast edge detection by center of mass, The 1st IEEE/IIAE International Conference on Intelligent Systems and Image Processing 2013 (**ICISIP2013**): 103-110, **Citation: 1**

Bo Li, Ulrik Söderström, Haibo Li, Independent thresholds on multi-scale gradient images , The 1st IEEE/IIAE International Conference on Intelligent Systems and Image Processing, 2013 (**ICISIP2013**): 124-131, 2013, **Citation:**

Farid Abedan Kondor, Shahrouz Yousefi, Li Liu, Haibo Li. Active human gesture capture for diagnosing and treating movement disorders. In Proceeding of The Swedish Symposium on Image Analysis (**SSBA2013**), Gothenburg, Sweden, March 2013, **Citation:**

Kallberg, D. ; Seleznjev, O. ; Leonenko, N. ; Haibo Li , Statistical Modeling for Image Matching in Large Image Databases, Internet of Things **(iThings/CPSCom)**, 2011 International Conference on Cyber, Physical and Social Computing , 2011, **Citation:**

Shahrouz Yousefi, Farid Abedan Kondori, Haibo Li, Stereoscopic Visualization of Monocular Images in Photo Collections, The 2011 IEEE International Conference on Wireless Communications and Signal Processing (**WCSP**), Nanjing, China, p 9-11 Nov. 2011. **Citation: 1**

Shahrouz Yousefi, Farid Abedan Kondori, Haibo Li, 3D Visualization of Single Images using Patch Level Depth, In Proceedings of the International Conference on Signal Processing and Multimedia Applications, **SIGMAP** 2011, Seville, Spain, 18-21 July, 2011. **Citation: 2**

Shahrouz Yousefi, Farid Abedan Kondori, Haibo Li, Robust correction of 3D geo-metadata in photo collections by forming a photo grid, The 2011 IEEE International Conference on Wireless Communications and Signal Processing (**WCSP)**, Nanjing, China, Nov. 2011. **Citation:**

Shahrouz Yousefi, Farid Abedan Kondori, Haibo Li, Tracking Fingers in 3D Space for Mobile Interaction, In Proceeding of The 20th International Conference on Pattern Recognition (ICPR), The Second International Workshop on Mobile Multimedia Processing (**WMMP**), Istanbul, Turkey, August 2010. **Citation:**

*Farid Abedan Kondori, Shahrouz Yousefi, Haibo Li, Real 3D Interaction Behind Mobile Phones for Augmented Environments, In Proceeding of The 2011 IEEE International Conference on Multimedia and Expo **(ICME),** International Workshop on Hot Topics In Multimedia, Barcelona, Spain, 15th July 2011. **Citation: 3**

Farid Abedan Kondori, Shahrouz Yousefi, Haibo Li, Samuel Sonning, Sabina Sonning, *3D head pose estimation using the Kinect*, The 2011 IEEE International Conference on Wireless Communications and Signal Processing **(WCSP),** Nanjing, China, Nov. 2011. **Citation: 1**

Farid Abedan Kondori, Shahrouz Yousefi, *Smart Baggage In Aviation*, In Proceeding of The 2011 IEEE International Conference on Internet of Things iThings-11, International Workshop on Cyber-Physical Systems and Applications **(CPSA-11),** 2011. **Citation: 1**

Shahrouz Yousefi, Farid Abedan Kondori, Haibo Li, *3D Visualization of Monocular Images in Photo Collections*, In Proceeding of The Swedish Symposium on Image Analysis **(SSBA**), Linkoping, Sweden, February 2011. **Citation: 1**

Farid Abedan Kondori, Shahrouz Yousefi, Haibo Li, *Gesture Tracking for 3D Interaction in Augmented Environments*, In Proceeding of The Swedish Symposium on Image Analysis **(SSBA)**, Linkoping, Sweden, February 2011. **Citation: 1**

Karin Fahlquist, Johannes Karlsson, Keni Ren, Li Liu, Haibo Li, Shafiq Ur Rehman and Tim Wark, " Human Animal Machine Interaction: Animal Behavior Awareness and Digital Experience", **ACM Multimedia 2010** , 25-29 October 2010, Firenze, Italy. **Citation: 3**

Johannes Karlsson and Adi Anani, "Ad hoc Networks as a tool for E-Learning", The International Workshop on New Achievements in the e-Learning's Domain **(WAEL'09),** 16-18 June 2009, Umeå, Sweden. **Citation: 1**

Johannes Karlsson, Jean-Paul Kouma, Haibo Li, Tim Wark and Peter Corke. "Demonstration of Wyner-Ziv Video Compression in a Wireless Camera Sensor Network". The 9th Scandinavian Workshop on Wireless Ad-hoc & Sensor Networks (**ADHOC'09).** 4-5 May 2009, Uppsala, Sweden. **Citation: 1**

Johannes Karlsson, Jean-Paul Kouma, Haibo Li, Tim Wark and Peter Corke. "Poster Abstract: Distributed Video Coding for a Low-Bandwidth Wireless Camera Network". The 5th European conference on Wireless Sensor Networks (**EWSN 2008**). 30 January - 1 February 2008, Bologna, Italy. **Citation: 1**
Tim Wark, Peter Corke, Johannes Karlsson, Pavan Sikka, Haibo Li and Philip Valencia. "Real-time Image Streaming over a Low-Bandwidth Wireless Camera Network". The Third International Conference on Intelligent Sensors, Sensor Networks and Information Processing **(ISSNIP 2007).** 3-6 December 2007, Melbourne, Australia. **Citation: 1**

Johannes Karlsson, Tim Wark, Philip Valencia, Michael Ung, Hiabo Li and Peter Corke. "Demonstration of Image Compression in a Low-Bandwidth Wireless Camera Network". The 6th International Conference on Information Processing in Sensor Networks (IPSN 2007). 24-27 April 2007, Cambridge (MIT Campus), Massachusetts, USA. **Citation: 1**

Al-Naser, Mohammad, Haibo Li and Söderström, Ulrik, Reconstruction of occluded facial images using asymmetrical principal component analysis, 18th IEEE International Conference on Systems, Signals and Image Processing (**IWSSIP)**, pp. 276-279, **Citation: 1**

Söderström, Ulrik and Li, Haibo, Anonymous video processing for live street view, IEEE International Conferences on Internet of Things, and Cyber, Physical and Social Computing, pp. 109-113, **Citation: 2**

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Marcelo Milrad

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Didac Gil de la Iglesia - Publications

1. Peer-reviewed original articles

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Gil de la Iglesia, D., Weyns, D. (2012). Enhancing Software Qualities in Multi-Agent Systems using Self-Adaptation. December. EUMAS'12. Number of citations: 0

Gil de la Iglesia, D., Weyns, D. (2013) Software Qualities in MAS using Self-Adaptation. In Proceedings of *12th International Conference on Autonomous*

Agents and Multiagent Systems (AAMAS 2013). p. 1159-1160. Number of citations: 0

Gil de la Iglesia, D., Weyns, D. (2013). Guaranteeing Robustness in a Mobile Learning Application Using Formally Verified MAPE-K Loops. In Proceedings of *8th International Symposium on Software Engineering for Adaptive and Self-Managing Systems (SEAMS 2013)*. p. 83-92. Number of citations: 3

*Real-Delgado, Y., Gil de la Iglesia, D., Otero, N (2014). Exploring the potential of mobile technology for creating music collaboratively. *5th Workshop in Ubiquitous Music (UbiMus).* Number of citations: 0

Sollervall, H., Gil de la Iglesia, D. (2015) Designing a didactical situation with mobile and web technologies. In Proc. of 9th Congress of European Research in Mathematics Education (CERME9). Number of citations: 0

3. Monographs

Gil de la Iglesia, D. (2012). Uncertainties in Mobile Learning applications: Software Architecture Challenges. Licentiate Thesis in Linnaeus University. Vol. 7493/2012, pages 120. Number of citations: 1

Gil de la Iglesia, D. (2014). A Formal Approach for Designing Distributed Self-Adaptive Systems. *Linnaeus University Dissertations.* ISBN: 978-91-87427-85-5, Linnaeus University Dissertations. 171/2014. pages 275. Number of citations: 0

4. Research review articles

Weyns, D., Iftikhar, U., Gil de la Iglesia, D., Ahmad, T. (2012). A survey of formal methods in self-adaptive systems. In Proceedings of the Fifth International C* Conference on Computer Science and Software Engineering (C3S2E '12). ACM, New York, NY, USA, 67-79. Number of citations: 25

5. Books and book chapters

Gil de la Iglesia, D., Berni Miller, P. (2010) Laboratori de PHP i MySQL. Edicions FUOC. ISBN: 978-84-692-9428-4

Gil de la Iglesia, D., Berni Miller, P. (2010) Laboratorio de PHP y MySQL. Edicions FUOC. ISBN: 978-84-692-9427-7

Berni Miller, P., Gil de la Iglesia, D. (2010) Disseny de bases de dades. Material docent de la UOC. Edicions FUOC. ISBN: 978-84-692-9423-9

Berni Miller, P., Gil de la Iglesia, D. (2010) Diseño de bases de datos. Material docente de la UOC. Edicions FUOC. ISBN:978-84-692-9430-7

6. Patents

7. Open access computer programs or databases you have developed

Gil de la Iglesia, D. (2013). 4ME103: Tangible User Interfaces. Laboratory Guide. *Creative Commons Attribution.* URL: http://194.47.95.238/~didac/4ME103/Materials/TUI_book_reduced.pdf

8 Popular science articles/presentations

Gil de la Iglesia, D. (2013). Wood, Glass and ICT: Towards Småland as Leader in Smart Homes. *Presentation at Webbdagarna, InternetWorld*. Växjö. URL: http://webbdagarna.se/vaxjo-2013/program

CV

Name: Shahrouz Yousefi	**Doctorial degree:** 2014-03-17
Birthdate: 19830207	**Academic title:** Doktor
Gender: Male	**Employer:** Linnéuniversitetet

Research education

Dissertation title (swe)

Dissertation title (en)

3D Gesture Recognition and Tracking for Next Generation of Smart Devices; Theories, Concepts, and Implementations

Organisation	Unit	Supervisor
Kungliga Tekniska Högskolan, Sweden Sweden - Higher education Institutes	MID, Medieteknik och interaktionsdesign	Haibo Li

Subject doctors degree	ISSN/ISBN-number	Date doctoral exam
21102. Mediateknik	978-91-7595-031-0	2014-03-17

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Name: Didac Gil de la Iglesia	**Doctorial degree:** 2014-05-12
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Gender: Male	**Employer:** Linnéuniversitetet

Research education

Dissertation title (swe)		
A Formal Approach for Designing Distributed Self-Adaptive Systems		

Dissertation title (en)

A Formal Approach for Designing Distributed Self-Adaptive Systems

Organisation	Unit	Supervisor
Linnéuniversitetet, Sweden Sweden - Higher education Institutes	Institutionen för medieteknik, ME	Danny Weyns

Subject doctors degree	ISSN/ISBN-number	Date doctoral exam
21102. Mediateknik	978-91-87427-85-5	2014-05-12

CV

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Research education

Dissertation title (swe)

Dissertation title (en)

earning Environments to Support Learners' Understanding in Complex Domains

Organisation	Unit	Supervisor
University of Bergen, Norway Not Sweden - Higher Education institutes	System Dynamics	Professor Michael Spector

Subject doctors degree	ISSN/ISBN-number	Date doctoral exam
10299. Annan data- och informationsvetenskap	82-308-0187-8	2006-06-16

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Name: Haibo Li	**Doctorial degree:** 1993-11-15
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Gender: Male	**Employer:** Kungliga Tekniska högskolan

Research education

Dissertation title (swe)		
låg bitrate video kodning		
Dissertation title (en)		
Low Bitrate Image Sequence Coding		
Organisation	**Unit**	**Supervisor**
Linköpings universitet, Sweden Sweden - Higher education Institutes	Institutionen för systemteknik (ISY)	Ingemar Ingemarsson
Subject doctors degree	**ISSN/ISBN-number**	**Date doctoral exam**
10209. Medieteknik	ISBN 91-7871-203-3	1993-11-15

Publications

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Yousefi, Shahrouz has not added any publications to the application.

Publications

Name: Didac Gil de la Iglesia	**Doctorial degree:** 2014-05-12
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Gil de la Iglesia, Didac has not added any publications to the application.

Publications

Name: Marcelo Milrad	**Doctorial degree:** 2006-06-16
Birthdate: 19650203	**Academic title:** Professor
Gender: Male	**Employer:** Linnéuniversitetet

Milrad, Marcelo has not added any publications to the application.

Publications

Name: Haibo Li	**Doctorial degree:** 1993-11-15
Birthdate: 19651008	**Academic title:** Professor
Gender: Male	**Employer:** Kungliga Tekniska högskolan

Li, Haibo has not added any publications to the application.

Register

Terms and conditions

The application must be signed by the applicant as well as the authorised representative of the administrating organisation. The representative is normally the department head of the institution where the research is to be conducted, but may in some instances be e.g. the vice-chancellor. This is specified in the call for proposals.

The signature*from the applicant*confirms that:

- the information in the application is correct and according to the instructions form the Swedish Research Council
- any additional professional activities or commercial ties have been reported to the administrating organisation, and that no conflicts have arisen that would conflict with good research practice
- that the necessary permits and approvals are in place at the start of the project e.g. regarding ethical review.

The signature *from the administrating organisation* confirms that:

- the research, employment and equipment indicated will be accommodated in the institution during the time, and to the extent, described in the application
- the institution approves the cost-estimate in the application
- the research is conducted according to Swedish legislation.

The above-mentioned points must have been discussed between the parties before the representative of the administrating organisation approves and signs the application.

Project out lines are not signed by the administrating organisation. The administrating organisation only sign the application if the project outline is accepted for step two.

Applications with an organisation as applicant is automatically signed when the application is registered.