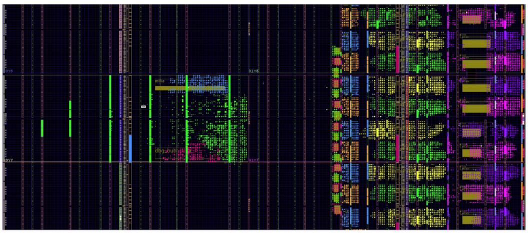
Hochschule Konstanz
Technik, Wirtschaft und Gestaltung

INSTITUT FÜR OPTISCHE SYSTEME



Institute for optical systems

annual report 2018

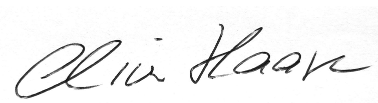
Foreword

Hochschule Konstanz University of Applied Sciences (HTWG) has been one of the first Universities of Applied Sciences that has clearly committed itself to applied research. Today, HTWG has positioned itself in the growing group of research active Universities of Applied Sciences, and is continuously striving for even greater excellence, visibility, and leadership.

The research institutes play an essential role in the overall research activities of HTWG. The Institute for Optical Systems (IOS) has been founded as one of three focus institutes in 2008, and has lived up to its mission and HTWG's expectation ever since.

Measuring the success of research is generally a difficult task. It becomes easy, however, for individuals and institutes alike that contribute to the scientific community in many different ways. The IOS clearly is such an institute. Its members have published their work in numerous high quality publications, they have acquired substantial amounts of external funding, and they have successfully led several doctoral candidates to their advanced degree, to name only the most obvious contributions. The institute's success has only been possible because of the enthusiasm of its members, and its tight integration with HTWG. Students have contributed to the research work on various levels, and the results have been fed into the members' teaching. In this sense, the IOS has demonstrated the importance of excellent applied research also as a means for high quality teaching, in particular on the graduate level.

I am proud to write these few lines of thanks and congratulations for the IOS and cordially wish the institute, but first and foremost its members, ongoing enthusiasm, thirst for knowledge, and success for the future.



Prof. Dr. Oliver Haase
Vice-President for Research, University of Applied Sciences Konstanz

Preface

The present report gives an overview over the research and development activities of the Institute for Optical Systems (IOS) Konstanz in the year 2016. Our main fields of interest are cognitive systems, geometric modelling, image processing, optical metrology and light engineering, thus representing the fundamental disciplines of current optical technology. The focus on optical systems as a whole allows us to offer competent partnership to the local industry in all relevant aspects. The IOS was founded in April 2008 by four professors from three different faculties of the University of Applied Sciences at Konstanz and is led by Prof. Dr. Umlauf (director) and Prof. Dr. Franz (associate director).

The following project descriptions present ongoing activities mainly on a status report level. Most of the reports are written by students working on their diploma, bachelor, master or Ph.D. theses. They reflect the largely varying levels of content, practice and insight that are characteristic for an institution involved in academic education. Due to its interdisciplinary nature, research at the IOS combines approaches from optics, computer graphics, image and signal processing, metrology, light engineering and sensor technology typically resulting in optical systems on a prototype level, either in pre-phase research or in cooperation with local industry.

On the occasion of our annual report, we would like to thank all of our students and co-workers for their enthusiasm and dedication which makes our institute a great place to be. Special thanks go to our institute officers, Pascal Laube, Martin Schall and Michael Grunwald for smoothly managing our day-to-day activities. We are also indebted to the administration and staff of the HTWG Konstanz for their help, especially president Dr. Carsten Manz and Prof. Dr. Oliver Haase, for their support and for continuing the start-up funding, and the faculties of Mechanical Engineering, Electrical and Information Engineering, and Computer Science with the deans Prof.Dr.-Ing.Klaus Schreiner, Prof.Dr.Thomas Birkhölzer and Prof. Dr. Jürgen Neuschwander for their assistance. Furthermore we appreciate the support of the Institute for Applied Research (IAF) Konstanz, especially Prof. Dr. -Ing Horst Werkle and Dipl.-Ing. FH Andreas Burger.

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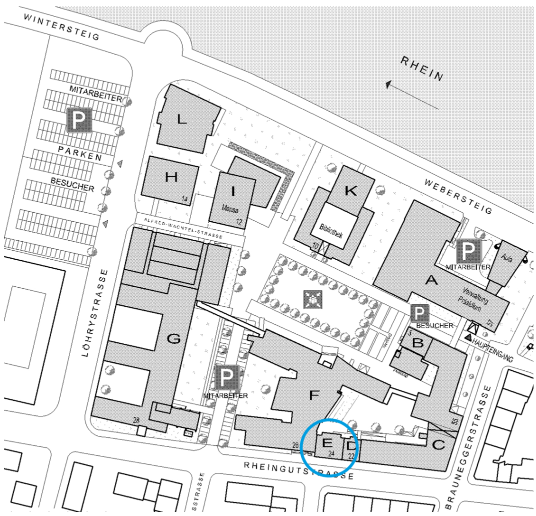
Institute Profile

Institute for Optical Systems

Brauneggerstrasse 55
Building E
3rd and 4th floor
78462 Konstanz

Location Plan



Institute Members

Prof. Dr. Georg Umlauf:

Diploma in computer science from University of Karlsruhe, 1996. Doctoral degree in computer science from University of Karlsruhe, 1999. PostDoc at University of Karlsruhe and University of Florida, Gainesville, USA, 1999-2000. Software development and senior researcher at Tebis AG, Hamburg, 2000-2002. Assistant professor for geometric algorithms at University of Kaiserslautern, 2002-2009. Interim professor for computer graphics at University of Karlsruhe, 2009. Since 2009 professor for computer graphics at University of Applied Sciences Konstanz and head of the computer graphics lab. Since 2010 member of the 'Institute for Optical Systems (IOS)' and 'Institute for Applied Research (IAF)'. Main research interests: Computer graphics, geometric modeling (splines, subdivision), reverse engineering, physical simulations.

Prof. Dr. Matthias Franz:

M.Sc. in Atmospheric Sciences from SUNY at Stony Brook, Diploma in physics from the Eberhard-Karls-Universität, Tübingen and doctoral degree in 1998. Thesis research in visual insect and robot navigation at the MPI for Biological Cybernetics and as a PostDoc at the Australian National University in Canberra. In industry he worked on various aspects of autonomous vision systems. 2002, he returned to the MPI as a group leader in the area of machine learning and computer vision. Since 2007 professor at the University of Applied Sciences in Konstanz and head of cognitive systems lab. Member of 'Institut für Angewandte Forschung (IAF)'. Main research activities in the development of automatically generated vision systems, optimisation and probabilistic modeling, with applications in industrial machine vision, texture analysis and steganalysis.

Prof. Dr. Rebekka Axthelm:

Diploma in mathematics from University of Freiburg, 1998. Doctoral degree in applied mathematics from University of Freiburg, 2007. Software Engineer Video at Micronas GmbH in Freiburg, 2005-2008. Lecturer for mathematics and numerics at Zurich University of Applied Sciences (ZHAW) in Winterthur (Switzerland), 2009-20017. Since 2017 professor for mathematics at University of Applied Sciences Konstanz (HTWG). Since 2018 member of the 'Institute for Optical Systems (IOS)' and 'Institute for Science and Mathematics (INM)'.
Main research interests is in numerical mathematics that is in particular: Finite element methods to solve partial differential equations which describe different physical processes. My strong interest is currently focused on the calculation of pedestrian flow, based on a macroscopic modeling and mathematical methods of image processing.

Prof. Dr. Oliver Dürr:

Diploma in physics and doctoral degree at University Konstanz 2003 in the fields of theoretical and computational physics. From 2003 - 2012 senior algorithm developer/scientific consultant at Genedata AG (Basel). From 2012 assistant professor in statistical data analytics at Zurich University of Applied Sciences (ZHAW) in Winterthur (Switzerland). Since 2018 professor for data science at University of Applied Sciences Konstanz (HTWG). Since 2018 member of the 'Institute for Optical Systems (IOS). Main research interests in statistical/machine/deep learning, currently focusing on probabilistic aspects.

Prof. Dr. Claus Braxmaier:

Diploma in precision engineering at University of Applied Sciences Furtwangen. Diploma in physics and doctoral degree at the University of Konstanz in the field of fundamental tests of physics. Post-Doc at University of Konstanz. At EADS Astrium GmbH, system responsible for scientific and Earth observation missions for ESA and head of group 'Mission Metrology'. 2005-2013 professor for physics and control theory at the University of Applied Sciences Konstanz. Since 2013 ZARM Deputy Executive Director, Director Space Technology, and department lead "System Enabling Technologies" at the DLR-Institute of Space Systems, Bremen. Main research: high resolution optical metrology for industrial and space applications, tests of fundamental physics.

Prof. Dr. Bernd Jödicke:

Study of physics at the University of Kalrsruhe. Doctoral degree at Technical University Hamburg and University Karlsruhe in the field of high frequency technology. After that, industrial work at ABB Baden, Switzerland, as executive director for R&D. Since 1992 professor for applied physics at University of Applied Sciences Konstanz. Member of 'Institute for Applied Research (IAF)', 'Institut für Naturwissenschaften und Mathematik (INM)', 'Institute for Optical Systems (IOS) Konstanz' and 'Deutsche Lichttechnische Gesellschaft'. Head of laboratory for light engineering at HTWG. Main research activities in color and light measurements and color camera systems.

Prof. Dr. Burkhard Lehner:

Diploma in computer science from University of Kaiserslautern, 2004. Doctoral degree in computer science from University of Kaiserslautern, 2008. Software development at Sirona Dental System GmbH, Bensheim, 2008-2013. Since 2013 professor for computer science at University of Applied Sciences Konstanz. Since 2014 member of the 'Institute for Optical Systems (IOS)'. Main interests: software development, computational geometry, optical 3D measurement (especially in dental CAD/CAM).

Prof. Dr. Klaus-Dieter Durst:

Study of physics at the University of Stuttgart, 1986 doctoral degree in the field of magnetism at the Max-Planck-Institute of metal research. Thereafter research center Weissach of the Dr. Ing. h.c. F. Porsche AG, responsible for the central unit 'measurement technologies'. Since 1993 professor for measurement engineering and sensor technology at the University of Applied Sciences Konstanz. Member of 'Institut für Naturwissenschaften und Mathematik' and 'Institute for Optical Systems' Konstanz. Head of laboratories for measurement and sensor technology and production metrology. Currently director of 'Institut für Naturwissenschaften und Mathematik' Konstanz. Activities in the accreditation and surveillance of testing laboratories and inspection bodies.

Prof. Dr. Christian Hettich:

Diploma in physics and doctoral degree (2002) at the University of Konstanz in the fields of quantum-optics and nano-optics. Post-doc at the Eidgenössische Technische Hochschule (ETH) Zürich and at the Niels Bohr Institut in Kopenhagen. Systems engineer for illuminators of semiconductor lithography systems at Carl Zeiss SMT GmbH in Oberkochen. Systems engineer for time-of-flight cameras at ifm automotive GmbH in Kressbronn. Project leader for automated microscopes at Sensovation AG in Radolfzell. Since 2014 professor for physics, feedback control systems and metrology at the department of mechanical engineering of the University of Applied Sciences Konstanz. Member of the 'Institut für Naturwissenschaften und Mathematik' (INM) and the 'Institute for Optical Systems' (IOS). Main research interests: optical 3D measurements, spectroscopy, interferometry, holography, microscopy.

IOS Staff

Professors

Georg Umlauf, director IOS
Matthias Franz, associate director IOS
Bernd Jödicke
Burkhard Lehner
Klaus-Dieter Durst
Christian Hettich

Officer

Pascal Laube

Academic Staff

Matthias Hermann
Pascal Laube
Dennis Grießer
Fabian Freiberg
Tobias Birkle
Felix Schmidt
Martin Schall
Joey Rieg
Patrick Fiur
Daniel Dold

Postdoc

Thilo Schuldt

PhD Students

Matthias Hermann
Pascal Laube
Dennis Grießer
Fabian Freiberg
Tobias Birkle
Jürgen Keppler

External Fundings and Grants

- Baumer Inspection GmbH, Konstanz: "Farbtexturen in der industriellen Oberflächeninspektion", contract research.
- Baumer Inspection GmbH, Konstanz: "Inline - Inspektionstechnologie zum Farbabgleich für den digitalen Dekordruck", contract research.
- Australian Research Council, Pattern recognition in animals and machines: using machine learning to reveal cues central to the identification of individuals, Discovery Projects Grant.

Cooperations with Research Institutions and Industry

Academic and Institutional Cooperations

- Eberhard Karls Universität Tübingen
- Hochschule Aalen
- Universität Konstanz
- ZHAW datalab
- Universität Bremen
- Frauenhofer IPT
- Max-Planck-Gesellschaft

Industry Cooperations

- Siemens Postal, Parcel & Airport Logistics GmbH, Konstanz
- Zeiss AG, Oberkochen
- ZF Friedrichshafen AG
- Silicon Software GmbH, Mannheim
- Sirona GmbH, Bensheim
- Chromasens GmbH, Konstanz
- Sto SE & Co, Stühlingen
- Bosch GmbH, Gerlingen
- Der Katamaran, Konstanz
- Baumer Inspection GmbH, Konstanz
- arivis AG, München
- ACSYS Lasertechnik GmbH, Kornwestheim
- Genedata, Basel, Schweiz
- GIANTS software, Schlieren, Schweiz

Theses and Student Projects

Master Theses

- David Simon , Bestimmung des querregelungsrelevanten Objekts beim Staufolgegefahren über Deep Learning, 2018.
- Fabian Freiberg, Novelty Detection with Neural Networks on Texture Model based Features, 2018.
- Felix Peter, Erforschung und Evaluation von U-Networks aus dem Bereich des Deep Learning zur segmentierungsfreien Handschrifterkennung, 2018.
- Dennis Grießer,Personendetektion für mobile Roboter in RGB-D unter Verwendung von künstlichen neuronalen Netzen,2018.

Bachelor Theses

- Fabian Gendusa , Digitale Realzeit-Videostabilisierung (Sperrvermerk), 2018.
- Bastian Schöttle, Klassifikation von Bild-Regionen im postalischen Umfeld auf Basis von maschinellem Lernen, 2018.
- Thomas Gnädig, Signaltrennung: Ein Vergleich von neuronalen Netzen mit Transformations-Codes, 2018.
- Etienne Gramlich, Validierung der Bildsuche im B2B-Umfeld mit mobilem Frontend, 2018.
- Patrick Fiur , Klassifikation geometrischer Primitive unter Einsatz neuronaler Netze, 2018.

Student Projects

- Zarife Altikulac, Nico Brügel, Simulation von 3D-Druck auf elastischen Textilien , 2018.
- Daniel Dold, Marcel Arpogaus, Dennis Restle, Hardware acceleration of Neural Networks using FPGAs, 2018.

Small Research Projects

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Journal Papers

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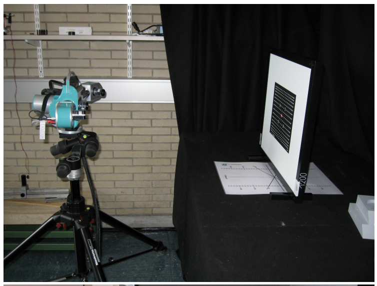
- Zirkler, R., T. Eckhard, and B. Jödicke, "A concept for a multi-spectral snap-shot camera based on single-chip RGB sensor", Forum Bildverarbeitung, pp. Poster, 2018.

Laboratories and Infrastrcture

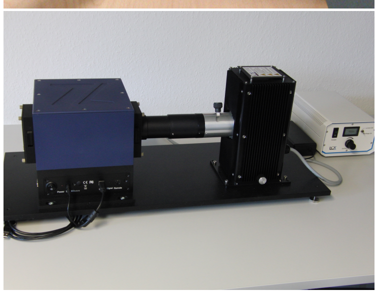
The Institute for Optical Systems laboratories and infrastructure is composed of scientific equipment from the fields of Image Sensing, 2D and 3D Surface Analysis and Reconstruction as well as a powerful computing cluster for machine learning and high performance computing. Our laboratories and infrastructure is located in buildings *E*, *G* and *O* on the university campus.



The laboratory in building G includes equipment with focus on illumination engineering and high precicson stereoscopic surface scanning. The laboratory in buildig E comprises of camera calibration and spectrometric color measurement equipment, multispectral cameras as well as devices for 3D laserscanning, 3D visualization and 3D printing.

The computing cluster located in building *O* consists of GPU as well as CPU-Servers for high performance computing.

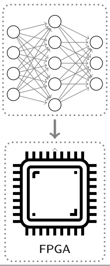
Most of the institutes workspaces are located on floors three and four of building *E*.



Research Activities

Hardware acceleration of Neural Networks using FPGAs

Daniel Dold, Marcel Arpogaus, Dennis Restle



The purpose of this project is to analyze the possibilities of model compression to enable the execution of Neural Networks in real time computer Vision and Object recognition tasks on FPGAs.
The biggest challenge is the transition of the model from a floating point training environment to pure integer arithmetics.

We expose the insights of training, quantizing and transferring the resulting model onto the embedded hardware using commonly know techniques. Additional effort was put into implementing a custom FPGA architecture for CNNs, which we compared to a proprietary closed-source solution.

Motivation

Since the release of *AlexNet CNN*s gained huge popularity in image classification tasks. Ever since it has been a huge challenge and interesting topic of ongoing research to increase the performance of these models, what often lead to an increase in complexity and turns out to become the limiting factor in applying those models in real world application. Especially in industrial applications, where image classifiers are used for error detection, you have strong time constrains and don't want the model to become your bottleneck.

We analyzed the possibilities of model compression and quantization to allow the execution on cheaper and less energy consuming *FPGA*s. The biggest challenge will be the transition of the model from a floating point base training environment to pure integer arithmetics on a *FPGA*. We will expose the insights of training, quantizing and transferring the resulting model onto the embedded hardware comparing commonly know techniques.

Quantization

The parameters from a neural network can appear in a large range and in any precision which makes them predestined for floating point arithmetic. However a floating point operation on a *FPGA* include a huge resource consumption, which is the reason why these operations should be avoided. Therefor a quantization algorithm is required which simulate the lower precision and the smaller range of an integer with floating point values. This leads the ability of simulate the *FPGA* hardware running on a CPU or GPU. Our quantization has the restriction that floating point values are clipped into a range between -1.0 and 1.0. This limitation allows that the FPGA can use a fixed point arithmetic where floating point values are mapped into integer values with 1.

$$W_{int} = W_{float} \cdot 2^{bits-1} \qquad \Big| \; W_{float} \sim N(-1,1) \tag{1}$$

own quantization

With our own quantization the neural network can trained without any adjustment. A z-transformation is used to catch the huge parameter range into a range between minus one and one. To perform the z-transformation standard deviation S and mean $\overline{x}$ is calculated from all weights. Now weights can be shifted with 2 into a good range. Thereby act value nb_σ as an additional hyper parameter. Simulating the lower precision is done with equation 4 [4, p. 3] (discretization part).

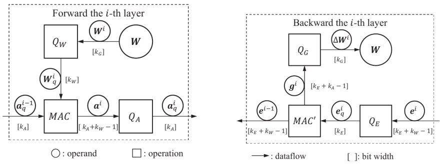
$$z = \frac{x - \overline{x}}{nb_\sigma * S} \tag{2}$$

$$\varepsilon(k) = 2^{1-k}, k \in \mathbb{N}_+ \tag{3}$$

$$Q(x,k) = Clip\left\{\varepsilon(k) \cdot rd\left[\frac{x}{\varepsilon(k)}\right], 1 \pm \varepsilon(k)\right\} \tag{4}$$

WAGE

The *WAGE* algorithm introduced in [4] has the same goal as our own quantization to simulate an integer arithmetic on a floating point device. As an additional feature this algorithm even discretized the gradients in the back propagation part. The algorithms core components are four quantization function applied at each operation [4, p. 3]. Every quantization will quantize values in a range between (-1,1) with minimal distance respectively the integer bit-length it should represent. Therefor every qunatization function can have its own integer bit-length labeled with k.



(a) forward path (b) backward path

Figure 1: Architecture of the *WAGE* algorithm

Transfer learning

Transfer learning is a common technique, to reduce the amount of training time and the risk of over-fitting on small datasets, by exploiting the knowledge already learned on one particular problem and applying it to a similar one.

Especially in case of image processing, there are very good performing models available, but they often require a lot of memory due to there very deep architectures. Special techniques can be used to reduce the amount of parameters tremendously and thus compress the model to a fraction, while the over all performance is preserved [2, 3].

Model compression

In our case[1] we want to exploit the good performance of the VGG network in image classification tasks for detecting anomalies in wood textures. Our goal is to use the VGG19 as an feature extractor and then *PCA* to reduce the generated feature-space and identify outliers.

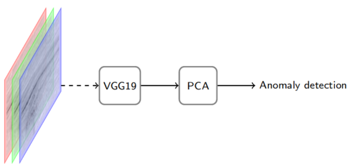


Figure 2: novelty detection using VGG19 features

We assume that only a part of the network is responsible for the activation regarding the anomalies in our wooden textures. We want to extract that information from the model into a much simpler CNN, as shown in 3.

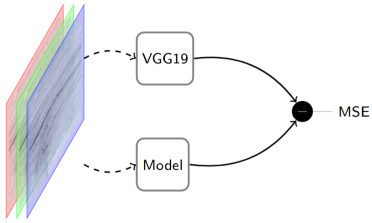


Figure 3: VGG19 model compression

In order to get independent of the input size we use the diagonal of the Gram Matrix $G \in \mathbb{R}^{N \times N}$ to flatten the produced 512 feature maps to a single 512 elements tensor as described in [1, 11]. The model is then fitted by minimizing *MSE*-Loss.

Results

The performance of the compressed VGG19 model with quantization is shown in figure **??**. It turned out that reducing the complexity slightly worsens the detection rate compared to the original model. The quantization part does not significantly degrade the accuracy but has definitely an impact on the results. Future work should focus on finding a better model.

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[1] anomaly detection

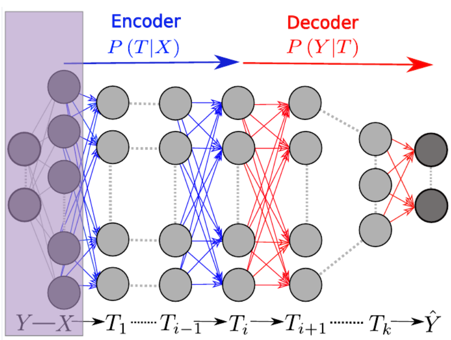
Rediscovering ICA properties in neural networks applied to mixtures of signals problems

Matthias Hermann, Michael Grunwald, Thomas Gädig and Matthias O. Franz

Despite their great success, there is still no comprehensive theoretical understanding of learning with Deep Neural Networks (DNNs) and their internal characteristics. Previous works proposed to analyze neural networks from a information theoretical point of view (Tishby and Zaslavsky, 2015; Schwartz-Ziv and Tishby, 2017). This work follows this idea and rediscovers properties similar to Independent Component Analysis (ICA) in neural networks. While neural networks are capable of classifying (e.g. cross-entropy) or separating source signals (e.g. mean-squared-error) through optimization a good interpretation on how this is working is often missing. We believe that in order to accomplish these tasks, neural networks need to perform something that is similar to ICA during training phase. To proof this behavior we generate synthetic mixtures of signals with a static mixture matrix and learn classifying them into (0) mixed signal and (1) unmixed signal. Throughout experiments we show that neural networks with non-linear activation functions indeed learn concepts that correspond to unmixing matrices and hence are able to generalize to both seen and unseen signal mixtures. Further results show that neural networks maximize kurtosis (non-Gaussianity) in deeper layers which further relates the training of neural networks to the objective used in ICA.

Introduction

Neural Networks are black boxes
Tishby and Zaslavsky (2015) describe neural networks as Markov chains of successive representations of the input layer and suggested studying them with information theory.

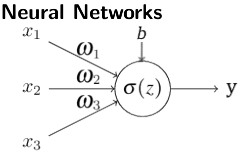


Hypothesis
In order to perform non-linear classification or regression neural networks must implicitly conduct an Independent Component Analysis (ICA).

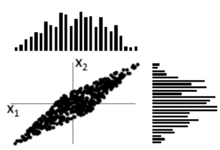
Relevance Knowledge about statistical properties of neural networks enables new initialization, visualization, regularization or optimization techniques. Special focus is on initialization or pre-training in cases with few data labels which is useful in order to train unsupervised or enable transfer learning.

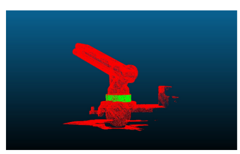
Methods

Neural Networks



Independent Component Analysis (ICA)
Non-linear technique for decorrelating independent signals





Criterion

Maximize Entropy:

$$H(X) = -\sum_{x \in X} p(x) log(p(x)) \tag{5}$$

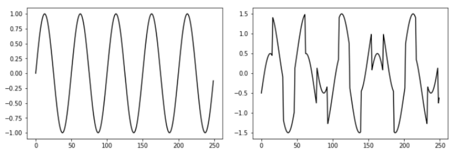
Maximize Kurtosis:

$$Kurz[X] = E[(\frac{X - \mu}{\sigma})^4] \tag{6}$$

Results

Binary mixed signal classification

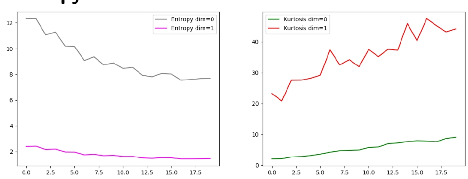
Training data:



Generalization power:

	sin	shark	rect	pyramid	rrect	random
sin	1,00	1,00	1,00	1,00	1,00	0,50
shark	1,00	1,00	1,00	1,00	1,00	0,50
rect	1,00	1,00	1,00	1,00	1,00	0,50
pyramid	1,00	1,00	1,00	1,00	1,00	0,50
rrect	0,99	0,99	0,99	0,99	0,99	0,49
random	0,50	0,50	0,50	0,50	0,50	0,50

Entropy and Kurtosis of a MNISTS classifier



Hidden layer before output layer:

- Entropy decreases during training indicating non uniform data distribution Entropy not well suited for measuring continuous random variables (binning)
- Kurtosis i.e. non-Gaussianity increases during training indicating ICA criterion Comparison in non-linear space difficult

Future work

- Adding negentropy as a more robust measure for non-Gaussianity
- Using natural images with added distortions instead of mixtures of signals
- Formulating ICA as decision problem
- Analyze mutual information between input and output

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Klassifikation geometrischer Primitive unter Einsatz von neuronaler Netze

Patrick Fiur, Georg Umlauf, Pascal Laube

Ziel dieser Thesis ist zu ergründen, wie sich geometrische Primitiven am besten erkennen lassen. Dazu wird ein künstliches neuronales Netzwerk mit Szenen trainiert, die geometrische Primitiven enthalten, welche es zu klassifizieren gillt.

Einleitung

Geometrische Objekte im Raum zu erkennen ist für den Menschen eine Selbstverständlichkeit, für eine Maschine hingegen ist dies ein komplizierter Prozess. Einem Computer zu vermitteln ob ein Objekt ein Würfel oder eine Kugel ist, ist ein aufwändiges Unterfangen, denn hierfür müssen die Objekte zuerst definiert werden. Desweiteren müssen Sonderfälle betrachtet werden, welche unter bestimmten Voraussetzungen nicht sicher unterschieden werden können. Beispielsweise ist eine Ellipse aus bestimmten Blickwinkeln nicht von einer Kugel zu unterscheiden. Abhilfe schaffen hierbei künstliche neuronale Netze, wodurch die explizite Definition der Objekte umgangen wird, indem Anhand von Beispielen eine Konditionierung antrainiert werden kann. Hierzu werden Trainingsdaten erzeugt, die die Problemstellung repräsentieren.

Geometrische Primitiven

Für die Trainingsdaten werden Objekte zum einen mit einem Laserscanner digitalisiert. Desweiteren werden auch synthetisch erzeugte Objekte verwendet. Hieraus resultiert eine Punktwolke des Objekts, welches in Voxel umgewandelt wird.

(a) Punktwolke (b) Voxeliert

Figure 4: Mit Hilfe eines Laserscanners digitalisiertes Feuerwehrauto (a) und selbiges durch Voxel repräsentiert (b).

Die geometrischen Primitiven werden mit dem "Region growing Algorithmus" aus der eingescannten Szene herausgefiltert [1].

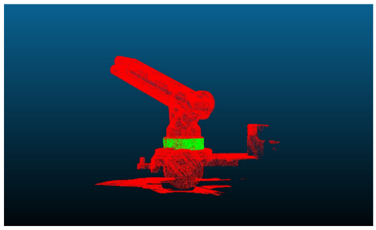

Figure 5: Mit dem Region growing Algorithmus extrahierte geometrische Primitive (Zylinder in grün)

Die Objekte werden gelabelt und für das Training des neuronalen netzwerks genutzt. Die geometrischen Primitiven die es zu erkennen gillt sind Kegel, Zylinder, Ellipsoid, Kugel, Torus und Ebene.

Topologie des Netzwerks

Wie auch im 2D-Raum werden im 3D-Raum convolutional Layer genutzt. Diese unterscheiden sich vom üblichen zweidimensionalen Layer vorwiegend durch die zusätzliche Dimension.

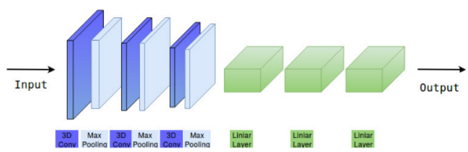

Figure 6: zeigt ein neuronales Netzwerk, mit dem in dieser Thesis gearbeitet wird.

Der Input, der eine Größe von 64x64x64 hat, wird als erstes von einem Convolution-Layer.Dieser hat ein local receptive field mit einer Größe von 3x3x3. Der darauffolgende Max-pooling-Layer (hier hellblau) generiert 8 feature maps. In diesem Netzwerk arbeiten drei Convolution-Layer und Max-pooling-Layer direkt hintereinander. Als Aktivierungsfunktion wird ReLu verwendet.

Das Training des Netzwerks wird mit einem Datenset bestehend aus 50 000 paaren (Objekt und Label) durchgeführt. Trainiert wird auf einer Geforce 1050Ti, welche ca. 10 Minuten Pro Epoche benötigt. Nach 12 Epochen erreicht das Training seinen Höhepunkt wobei AdaDelta als Optimierungsverfahren mit 95% die höchste Genauigkeit liefert.

Ergebnisse

Anhand der erzeugten Trainings- und Validierungsdaten konnte kein zufriedenstellendes Modell trainiert werden. Nachfogende Tabelle zeigt die Genauigkeit der richtig klassifizierten Objekte.

	Genauigkeit
Kegel	37%
Zylinder	16%
Ellipsoid	0%
Kugel	55%
Torus	14%
Ebene	4%

Figure 7: Genauigkeit der Klassifizierung

Wie anhand der Tabelle 7 zu erkennen ist, werden mehr als die Hälfte der Kugeln als selbige korrekt erkannt. Die restlichen Objekte hingegen werden nur mit geringerer Genauigkeit zugeordnet. Das Schlusslicht hierbei bilden die Ellipsoide, welche überhaupt nicht erkannt werden können. Hierbei ist Problematisch, dass Ellipsoide je nach Perspektive nicht von der Kugel unterschieden werden können.
Interessant hierbei ist, dass die Ebene nur zu 4% erkannt wird, worüber in dieser Zusammenstellung der Objekte nur spekuliert werden kann.

Zum einen ist zu Erwähnen, dass 50 000 Trainingsdaten für ein Netzwerk welches mit 64x64x64 großen Eingangsdaten arbeitet zu Gering. In Anbetracht der Größe des verwendeten Netzwerks wird klar, dass wesentlich mehr Daten benötigt werden um alle Gewichte des Netzwerks anpassen zu können. Zusätzlich ist anzumerken, dass die verwendete Grafikkarte nur 4Gb Grafikspeicher besitzt, welche die verwendbare Architektur ebenfalls beschränkt. Schlussendlich sollte die Möglichkeit nicht ausgeschlossen werden, dass das Validierungsset nicht repräsentativ für das angelernte Muster durch das Trainingsset ist. Dadurch ließe sich auch erklären, weshalb nur 4% der Ebenen erkannt werden.

Bibliography

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Effiziente Verarbeitung von nicht-euklidischen Datenstrukturen zur maschinellen Objekt- und Fehlererkennung

Prof. Dr. Georg Umlauf, Matthias Hermann

Ein stetig fortschreitender Automatisierungsgrad und die Individualisierung von Industrieprodukten auf personifizierte Kundenbedürfnisse sind in den kommenden Jahren eine DER technologischen Herausforderungen für die Industrie. Damit einher geht ein immer größerer Bedarf an Informationen, auf deren Basis Maschinen ihr Umfeld und die zu bearbeitende Objekte erkennen und situationsabhängig bewerten können. Optische Systeme und Lösungsansätze aus der Photonik für solche maschinelle Objekt- und Fehlererkennungsaufgaben bieten für die Industrie sehr großes Potenzial, diesen Herausforderungen gerecht zu werden. So können zukünftig Aufgaben entlang der gesamten Wertschöpfungskette unterstützt oder gänzlich automatisiert werden.

Viele Fragestellungen wie das Finden von Oberflächenfehlern oder Spezifikationsverletzungen sind heute ohne Automatisierung nicht mehr umsetzbar. So werden vorhandene schwellwert- und objektbasierte Algorithmen zunehmend durch Mustererkennung und selbst-lernende Techniken ersetzt. Fortschrittliche maschinelle Verfahren, welche häufig als *Maschinelles Lernen* oder *Künstliche Intelligenz* bezeichnet werden, gehören so heute bereits z.B. bei der Defektklassifikation in der Oberflächeninspektion zum Standardrepertoire optischer Systeme. Der industrielle Fortschritt erfordert allerdings stetig höhere Fertigungsgeschwindigkeiten, kleinere Losgrößen und komplexere Anwendungsdomänen. Auf darauf resultierenden Datenformate, Datenvolumen und Datenstrukturen sind heutige Methoden des maschinellen Lernens oftmals nicht anwendbar oder nur schwer übertragbar.

Heutige Verfahren des maschinellen Lernens und auch des *Deep Learnings* (vielschichtige Neuronaler Netze) basieren im Kern auf euklidischer Geometrie. Zukünftige Industrieszenarien umfassen allerdings auch die Verarbeitung von Daten aus anderen Domänen wie z.B. Graphen-Datenstrukturen (siehe hierzu Abb. 8). Diese Strukturen sind elementar für die Beschreibung von geometrischen Objekten (Riemann Mannigfaltigkeiten), Sensor- und Soziale-Netzwerken oder Modellen aus der Teilchenphysik und Molekularchemie. Ganz allgemein charakterisieren nicht-euklidische Domänen eine fehlende globale Parametrisierung und keine einheitlichen Koordinatensysteme und Vektorräume. Als Folge sind für das maschinelle Lernen notwendige Basisoperatoren wie Faltung, Filterung und Spektralanalyse nicht oder nur lückenhaft definiert.

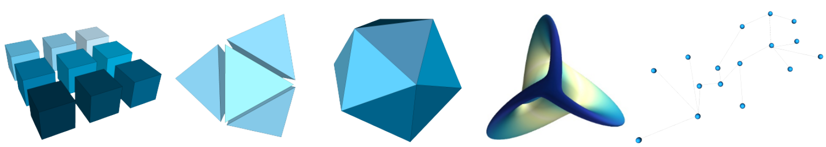

Figure 8: Schematische Darstellung verschiedener Domänen (von links nach rechts): 1) Grid, 2) Tetraeder 3) Ikosaeder 4) Boy-Mannigfaltigkeit 5) Graphstruktur/Punktwolke

Die erfolgreiche Mitwirkung des Instituts für Optische Systeme am oben genannten Forschungsfeld sicherte eine ganze Bandbreite wissenschaftlicher Arbeiten und Industriekooperationen, vorwiegend im Bereich der Geometrie-Verarbeitung. Um die daraus resultierenden technischen und wissenschaftlichen Fragestellungen zur Verarbeitung von nicht-euklidischen Datenstrukturen adressieren zu können, war eine intensive Vorbereitung und Recherche des Stands der Technik bzw. relevanter wissenschaftlichen Arbeiten notwendig. Weiter wurde als vorbereitende Maßnahme eine Machbarkeitsstudie anhand einer Pilotanwendung durchgeführt.

Konkret wurden im Rahmen des vorgeschlagenen *Small Research Projekts (SRP)* folgende Themen erarbeitet:

- Intelligente Objekt- und Fehlerdetektion auf nicht-euklidischen Domänen mit Methoden des maschinellen Lernens,
- Anwendung von Sparse-Tensor-Processing auf Grafikkarten für die Verarbeitung von Geometrien,
- Robuste automatisierte Geometrieakquisition entlang der gesamten Geometriepipeline (Vorverarbeitung).

Die Ergebnisse des Projekts sind einerseits in die bestehende Projekte am Institut für Optische Systeme eingefloßen, wurden aber auch in Form eines Konferenzbeitrags auf (1) Solid and Physical Modeling, (2) Shape Modelling International, (3) Conference for Curves and Surfaces mit peer-review-Verfahren verwertet. Die zu entwickelnde Anwendung wurde außerdem am Institut für Optische Systeme in die bestehende Laborumgebung integriert und damit der Nutzen des Labors für zukünftige Forschungsprojekte sichergestellt.

Die Umsetzung der Pilotanwendung wurde durch eine wissenschaftliche Hilfskraft durchgeführt. Hierbei war die Erarbeitung des wissenschaftlichen Hintergrunds als auch die Integration in bestehende Infrastruktur Teil des Prozesses. Aufgrund der hohen Komplexität wurde die wissenschaftliche Hilfskraft von zwei Doktoranden am Institut für Optische Systeme betreut und unterstützt.

Prof. Dr. Georg Umlauf, Matthias Hermann
Institut für Optische Systeme (IOS)

Institut für Optische Systeme
Hochschule Konstanz
Brauneggerstr. 55
78462 Konstanz
www.ios.htwg-konstanz.de