# Ninth Croatian Computer Vision Workshop

October 20, 2021, Zagreb, Croatia

# BOOK OF ABSTRACTS

University of Zagreb
Center of Excellence
for Computer Vision

# CCVW 2021

9th Croatian Computer Vision Workshop

Online/Zagreb, Croatia, October 20, 2021

Organizing Institution

Center of Excellence for Computer Vision, Croatia

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# Preface

On behalf of the Organizing Committee it is our pleasure to invite you to Zagreb for the 9$^{th}$ Croatian Computer Vision Workshop.

The objective of the Workshop is to bring together professionals from academia and industry in the area of computer vision in order to foster research and encourage academia-industry collaboration in this dynamic field. The Workshop program includes oral and poster presentations of peer reviewed research from Croatia and elsewhere. Furthermore, the program includes invited lecture presenting state-of-the-art in computer vision. Also, in industry session a selection of two croatian companies will present their research and production portfolios in the area of computer vision.

The Workshop is organized by the Center of Excellence for Computer Vision and by the Faculty of Electrical Engineering and Computing of the University of Zagreb.

Zagreb is a beautiful European city with many cultural and historical attractions, which we are sure all participants will enjoy. We look forward to meeting you all in Zagreb for the 9$^{th}$ Croatian Computer Vision Workshop.

October 2021

Sven Lončarić, General Chair

Lidija Mandić, Technical Program Chair

# Acknowledgements

The $9^{th}$ Croatian Computer Vision Workshop is the result of the committed efforts of dedicated volunteers including the members of the Organizing Committee. All included papers are results of dedicated research. Without such contribution and commitment, the Workshop would not have been possible.

The workshop has been organized under the auspices of the Croatian Academy of Engineering and is supported by the IEEE Croatia Section and its three Chapters (CIS11, C16, SP01), who all helped us in granting the high scientific quality of the presentations. We are grateful to both organizations for their continuing support.

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# Organizing Committee

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Tomislav Petković, University of Zagreb, Croatia

# Plenary Lecture

## Elements of Learning Algorithms for Natural Scene Understanding

*S. Šegvić*

*University of Zagreb, Croatia*

Deep learning has led to unprecedented improvement of computer vision, natural language processing and other fields of artificial intelligence. However, our models still underperform on unusual and adversarial test examples, while offering limited interpretability and explainability. Nevertheless, experienced practitioners seldom regard their models as black boxes. Instead, they promote desired behaviour through suitable kinds of inductive bias and careful exploitation of available data. I will illustrate these concepts by describing elements of learning algorithms which have been extensively exploited within my research group in the past few years.

The second part of my talk will describe our ongoing collaborations with the local industry. I will point out advantages of such arrangements for all involved parties. The talk will conclude with a brief overview of current challenges and opportunities in our field.

# Abstracts

## Oral Session 1

### A Baseline for Semi-Supervised Learning of Efficient Semantic Segmentation Models

*I. Grubišić, M. Oršić, S. Šegvić*

*University of Zagreb, Croatia and Microblink, Croatia*

Semi-supervised learning is especially interesting in the dense prediction context due to high cost of pixel-level ground truth. Unfortunately, most such approaches are evaluated on outdated architectures which hamper research due to very slow training and high requirements on GPU RAM. We address this concern by presenting a simple and effective baseline which works very well both on standard and efficient architectures. Our baseline is based on one-way consistency and non-linear geometric and photometric perturbations. We show advantage of perturbing only the student branch and present a plausible explanation of such behaviour. Experiments on Cityscapes and CIFAR-10 demonstrate competitive performance with respect to prior work.

### Multi-Domain Semantic Segmentation with Overlapping Labels

*P. Bevandić, M. Oršić, I. Grubišić, J. Šarić, S. Šegvić*

*University of Zagreb, Croatia*

Deep supervised models have an unprecedented capacity to absorb large quantities of training data. Hence, training on many datasets becomes a method of choice towards graceful degradation in unusual scenes. Unfortunately, different datasets often use incompatible labels. For instance, the Cityscapes road class subsumes all driving surfaces, while Vistas defines separate classes for road markings, manholes etc. We address this challenge by proposing a principled method for seamless learning on datasets with overlapping classes based on partial labels and probabilistic loss. Our method achieves competitive within-dataset and cross-dataset generalization, as well as ability to learn visual concepts which are

not separately labeled in any of the training datasets. Experiments reveal competitive or state-of-the-art performance on two multi-domain dataset collections and on the WildDash 2 benchmark.

## Densely Connected Normalizing Flows

*M. Grcić, I. Grubišić, S. Šegvić*

*University of Zagreb, Croatia*

Normalizing flows are bijective mappings between inputs and latent representations with a fully factorized distribution. They are very attractive due to exact likelihood evaluation and efficient sampling. However, their effective capacity is often insufficient since the bijectivity constraint limits the model width. We address this issue by incrementally padding intermediate representations with noise. We precondition the noise in accordance with previous invertible units, which we describe as cross-unit coupling. Our invertible glow-like modules express intra-unit affine coupling as a fusion of a densely connected block and Nyström self-attention. We refer to our architecture as DenseFlow since both cross-unit and intra-unit couplings rely on dense connectivity. Experiments show significant improvements due to the proposed contributions, and reveal state-of-the-art density estimation among all generative models under moderate computing budgets.

# Oral Session 2

## Outdoor Daytime Multi-Illuminant Color Constancy

*I. Domislović, D. Vršnak, M. Subašić, S. Lončarić*

*University of Zagreb, Croatia*

White-balancing is an important part of the image processing pipeline and is used in many computer vision applications. It removes the chromatic influence of the illumination on objects in the scene. White balancing is important in tasks such as object detection and object tracking. This problem is tackled in a myriad of ways, but most methods use the assumption that images contain only one dominant uniform illuminant. In recent years, neural networks have been used to create state-of-the-art methods for single illuminant white-balancing, but the problem of multi-illuminant white-balancing has been largely ignored. The main reason for this is the lack of multi-illuminant datasets. In this paper, we introduce a convolutional neural network for multi-illuminant (sun and shadow) illumination estimation. For the training and testing of the created model over 100 outdoor daytime images were taken using the Canon EOS 550D camera. We show that the model outperforms existing statistics-based methods on the test data.

## Automated Age Estimation of Adult Panoramic Dental X-Ray Images

*D. Milošević, M. Vodanović, I. Galić, M. Subašić*

*University of Zagreb, Croatia*

Age estimation is one of the fundamental steps of the forensic process. As teeth and the jaw outlast all other tissue when it comes to decomposition, they are a prime target for forensic analysis. Estimating the age of minors is relatively straightforward due to a wide selection of developmental markers, while estimation in adults and seniors still poses a big problem in forensic odontology. Our dataset consists of 4035 anonymized panoramic dental x-ray images with ages ranging from 19 to 85 years. Unlike studies usually conducted in the field of forensic odontology, our samples contain various pathologies. When considered as a dataset of individual teeth, this dataset contains 76416 images, making this one of the largest datasets of its kind in literature. An exhaustive hyperparameter search was used to determine the best performing deep learning model architecture for this task, namely the base feature extraction network, the depth of the final feature map, the presence of the attention mechanism, and the size of the penultimate fully-connected layer. Variants of the model are trained on data with

various regions of interest blocked to determine which part of the anatomy contributes the most to age estimation. Additionally, a series of models was trained on images of individual teeth.

## A Review of Body Measurement Using 3D Scanning

*K. Bartol, D. Bojanić, T. Petković, T. Pribanić*

*University of Zagreb, Croatia*

The understanding of body measurements and body shapes in and between populations is important and has many applications in medicine, surveying, the fashion industry, fitness, and entertainment. Body measurement using 3D surface scanning technologies is faster and more convenient than measurement with more traditional methods and at the same time provides much more data, which requires automatic processing. A multitude of 3D scanning methods and processing pipelines have been described in the literature, and the advent of deep learning-based processing methods has generated an increased interest in the topic. Also, over the last decade, larger public 3D human scanning datasets have been released. This paper gives a comprehensive survey of body measurement techniques, with an emphasis on 3D scanning technologies and automatic data processing pipelines. An introduction to the three most common 3D scanning technologies for body measurement, passive stereo, structured light, and time-of-flight, is provided, and their merits w.r.t. body measurement are discussed. Methods described in the literature are discussed within the newly proposed framework of five common processing stages: preparation, scanning, feature extraction, model fitting, and measurement extraction. Synthesizing the analyzed prior works, recommendations on specific 3D body scanning technologies and the accompanying processing pipelines for the most common applications are given. Finally, an overview of about 80 currently available 3D scanners manufactured by about 50 companies, as well as their taxonomy regarding several key characteristics, is provided.

# Industry Session

## AI Powered Autonomous Mobile Robots

*D. Guja*

*Gideon Brothers d.o.o., Croatia*

Gideon Brothers is Croatian robotics and AI solutions company founded in 2017. Gideon specializes in the automation of material handling processes for logistics, manufacturing, and retail businesses. With advanced AI&3D vision autonomous mobile robots and complete software solutions, Gideon represents a new generation of technology for self-driving robotic vehicles. Although in its early stage, the company is already building solutions for some of the world's leading, most demanding customers. ABI Research, an independent tech advisory firm, listed Gideon as a Top Innovator in their market segment.
This presentation will provide a brief introduction to the company and Gideon's AI-powered autonomous mobile robots.

**Website:** `https://www.gideonbros.ai/`

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**E-mail:** `daniel.guja@gideonbros.ai`

# Visage Technologies – Computer Vision in Automotive and Beyond

*L. Orsag, I. Peris*

*Visage Technologies d.o.o., Croatia*

Visage Technologies is a computer vision company founded in 2002 in Linköping, Sweden. In the last several years, the company has been continually growing, now counting 120 team members most of whom work from the Croatian subsidiary located in Zagreb. With more than 250 clients worldwide and a trend of strong growth, Visage Technology has been listed among "Sweden Technology Fast 50" companies by Deloitte since 2017. The company's first division, Face Technology Division, develops visage|SDK that supports face and head tracking, eye and gaze tracking, gender, age and emotion estimation, and face recognition. It has been used across various industries–from simple face filters to a sophisticated biometric-based border control system. The second division—Automotive Division—was formed exclusively for a collaboration on a major R&D project in the field of advanced driver-assistance systems and autonomous driving. The division develops mono and stereo vision systems based on forward-looking cameras. The focus of the work is on detecting and tracking objects visible from the vehicle in order to facilitate various functionalities such as autonomous car braking, adaptive cruise control, lane departure warning, and more.
This presentation will provide a brief introduction to the company and the technology developed by its two divisions.

**Website:** `https://visagetechnologies.com/`

# Poster Session: Current Computer Vision Research Activities in Croatia

## Human Detection in Aerial Images for Search and Rescue Operations

*N. M. K. Dousai, S. Lončarić*

*University of Zagreb, Croatia*

In this poster, we propose a deep learning-based approach for human detection in aerial images of Mediterranean mountain landscapes from Balkan regions captured using Unmanned Aerial Vehicle (UAV), used in Search And Rescue (SAR) operations. Detecting humans in aerial images is still a complicated task due to the challenges like camouflaged environment and the varying altitude. In most of the aerial images captured from UAV, the humans cover a negligible part of the image of around 0.1-0.2%. To address this problem of small coverage of interest of object we propose ensemble learning based on EfficientDET with Bi-FPN and FC-FPN for HERIDAL dataset. The training results are well-plotted and tested on different sizes of the HERIDAL dataset to show the differences in training computational time and accuracy.

## Underwater Camera Calibration

*D. Zoraja, T. Pribanić, T. Petković*

*University of Zagreb, Croatia*

A common laboratory setup for underwater imaging places a camera in the air to capture the image of an object placed in a water-filled tank and observed through a flat glass interface. In such a setup light is refracted twice, at air-glass and glass-water interfaces, and this refraction of light is physical phenomenon which makes the underwater camera calibration difficult. Such an underwater camera may be calibrated using a standard planar calibration object. First, a standard in-air calibration is performed to recover the projection matrix and the distortion parameters of the in-air camera. Next, the calibration board is submerged in thewater-filled tank, is imaged, and coordinates of calibration points on the board are extracted. The core part of the underwater camera calibration then proceeds in the following steps: First, the eight point algorithm is used to estimate the essential matrix. Second, pose parameters of the glass interface w.r.t. the camera (rotation and axis) are estimated. Third, the layer thicknesses are estimated for air and glass. Finally, a numerical optimization of all recovered parameters may be performed to refine them. The described calibration procedure is implemented in MATLAB and is used to recover the imaging parameters of the laboratory

setup for underwater imaging. The obtained parameters are used to visualize imaging geometry showing that the calibration results match the expected values.

## SmartUTX – Smart Ultrasonic Analysis

*D. Medak, L. Posilović, F. Milković, T. Petković, M. Subašić, S. Lončarić*

*University of Zagreb, Croatia*

Non-destructive evaluation (NDE) is a set of techniques used for material testing and efect detection. Ultrasonic testing (UT) is one of many NDE methods, commonly used due to its simplicity and ability to precisely determine defects' locations and sizes. Ultrasonic testing is used in various power plants, aeronautics, and oil and gas industry.Ultrasonic testing data analysis is currently done manually by trained experts. Automating this process would make the analysis faster, objective and more reliable. Deep learning-based approaches can be used to accomplish this. Three main tasks that can be done using a deep learning approach are: defect detection, anomaly detection, and ultrasound B-scan generation. With the increase of UT applications and the advancements of UT devices, data analysis is becoming a bottleneck of ultrasonic inspection. The developed methods can improve the efficiency and make a significant impact in the area of non-destructive valuation in the future. Some of them are already being deployed in computer software for ultrasonic data analysis and are helping inspectors around the world to perform more reliable and fast analysis.

## Robust Image Steganography Method Suited For Printing

*P. B. Jelušić, A. Poljičak*

*University of Zagreb, Croatia*

The motivation behind this research lies in the fact that, currently, there are no print-based DFT steganography methods available in state-of-the-art literature. Developing such a method would present progress in the field. By using the Discrete Fourier Transform (DFT), and combining it with Gray Component Replacement, the method is able to sustain the aggressive print-scan communication channel, while keeping the imperceptibility of the method high. Furthermore, by using the block-based approach, it is possible to transfer entire messages to the decoder.

## Dense Open-Set Recognition with Synthetic Outliers Generated by Real NVP

*M. Grcić, P. Bevandić, S. Šegvić*

*University of Zagreb, Croatia*

Today's deep models are often unable to detect inputs which do not belong to the training distribution. This gives rise to confident incorrect predictions which could lead to devastating consequences in many important application fields such as healthcare and autonomous driving. Interestingly, both discriminative and generative models appear to be equally affected. Consequently, this vulnerability represents an important research challenge. We consider an outlier detection approach based on discriminative training with jointly learned synthetic outliers. We obtain the synthetic outliers by sampling an RNVP model which is jointly trained to generate datapoints at the border of the training distribution. We show that this approach can be adapted for simultaneous semantic segmentation and dense outlier detection. We present image classification experiments on CIFAR-10, as well as semantic segmentation experiments on three existing datasets (StreetHazards, WD-Pascal, Fishyscapes Lost & Found), and one contributed dataset. Our models perform competitively with respect to the state of the art despite producing predictions with only one forward pass.

## Diesel Spray Segmentation with Cone Angle Determination

*F. Huzjan, S. Lončarić*

*University of Zagreb, Croatia*

Although the development of internal combustion engines for passenger cars is significantly reduced due to electrification, their development is still essential for the heavy-duty transport sector. Spray systems and injection strategies contribute to the overall engine efficiency, combustion process, and pollutant formation inside the internal combustion engines. For optical measurement, different techniques are being implemented, such as shadowgraphs, x-ray imaging and others. After the images are captured with high-speed imaging, image processing algorithms are applied in order to define spray macroparameters such as spray cone angle and spray penetration. In this poster three image segmentation algorithms were presented as well as two new methods for spray cone angle determination. Proposed methods were compared with two literature cone angle methods and results were presented in form of table and graphs.

## Local Gray World Method for Single Image Dehazing

*V. Stipetić, S. Lončarić*

*University of Zagreb, Croatia*

Images taken outdoors are often degraded by atmospheric conditions such as fog and haze. These degradations can reduce contrast, blur edges, and reduce saturation of images. In this paper we propose a new method for single image dehazing. The method is based on an idea from color constancy called the gray world assumption. This assumption states that the average values of each channel in a picture are the same. Using this assumption and a haze degradation model we can quickly and accurately estimate the haze thickness and recover a haze free image. The proposed method is validated on a synthetic and natural image dataset and compared to other methods. The experimental results have shown that the proposed method provides comparable results to other dehazing methods.

# Oral Session 3

## Generation of Synthetic Wildfire Smoke Images with Generative Adversarial Networks

*D. Božić-Štulić, D. Stipaničev, D. Krstinić*

*University of Split, Croatia*

Wildfire surveillance systems monitor large areas where detection distance can range from a few hundred meters to tens of kilometers. These systems work in harsh environmental conditions, the field of vision can be occluded by fog or dust particles, exposed to direct sunlight, or disturbed by light effects. The main prerequisite for the development of deep learning algorithms is the availability of large data sets. Therefore, to develop an efficient algorithm for early forest fire detection, it is necessary to collect a database of images with smoke, as a first visible sign of fire. It should be emphasized that the focus is on the smoke of the forest fire in its earliest stage which is usually represented by a small number of pixels in high resolution image. The smoke itself is, fortunately, rare phenomena on surveillance images, which makes the task of collecting training data even more demanding. Although there are databases of wildfire images, much of these images show developed and well-defined smoke from a blazing wildfire. In our research we are focused on developing a novel method for synthetic wildfire smoke image generation based on Generative Adversarial Networks (GANs). We aim to use available images of emerging smoke for the generation of a large set of synthetic images that go beyond simple data augmentation techniques. Proposed GAN architecture is based on SRGAN. For training the proposed GAN architecture we used images of emerging smoke collected from HOLISTIC wildfire surveillance system deployed in Croatia, enriched with selected images from the FUEGO dataset.To evaluate the proposed GAN architecture, we have conducted series of experiments in which VGG-16 classifier was trained to distinguish images with smoke from images without smoke. The classifier was trained on different data sets. In some of the experiments, only real images were used, while in other train data set is formed from real images and synthetic images generated by the proposed GAN network. In all experiments, the resulting classifier is evaluated on the same set of test images formed only from real images taken from HOLISTIC surveillance locations that were not used to collect images for the training data set to ensure the objectivity of the evaluation methodology. The obtained results confirm the quality of artificially generated images and strongly indicate the possibility of their application in the training of deep learning architectures.

## Split Port Surveillance using Artificial Intelligence and High Performance Computing

*S. Gotovac, L. Matić, V. Papić, D. Božić-Štulić, H. Turić, V. Pleština*

*University of Split, Croatia*

Digital technology, broadband and 5G communications, sensors, especially digital high-resolution high-speed cameras, data and high-performance computing centers as well as development and optimization of the machine learning and artificial intelligence algorithms with supported software environment is driving force of new Smart Cities. In this paper a smart solution for monitoring the activities in Split harbor is presented. It is based on high resolution smart PTZ cameras and object detection and localization solution based on YOLOv5 artificial intelligence algorithm. Activities in Split harbor have been monitored and recorded for 30 days in various weather conditions and part of day. The characteristic images are selected labeled from video in order to obtain training and validation image set. YOLOv5 algorithm has been trained on Google Colab HPC. Detailed selection procedure and optimization of the training parameters has been presented. The trained model has shown satisfactory performance.

## Medical Image Processing

*A. Pinjuh, D. Božić-Štulić, L. Vicković, S. Gotovac*

*University of Mostar, Bosnia and Hercegovina and University of Split, Croatia*

Medical image analysis and processing has become popular among the researches to help improve patient care and diagnostic process. Recently, deep learning based models have been efficient in object detection on medical images and applied in several medical disciplines. Our main goal is to show use of deep learning based detector to detect growth plates in knee bones as it can be indicator of chronological age of the patient. In this paper, we provide an overview of object detection algorithms in field of medical imaging, describe and test our approach employing CNN with region proposal called Faster R-CNN to detect growth plates on knee MRs, and present preliminary results.

# Oral Session 4

## InfrareDesign

*V. Žiljak, K. Pap, I. Žiljak Stanimirović, J. Žiljak Gršić*

*University of Zagreb, Croatia*

The innovation InfraeDesign refers to applying the infrared effect in printing technology with application in graphic product security against counterfeiting, regardless of the fact whether the print is made on paper, glass, ceramics or plastic surfaces, using only process printing inks cyan, magenta, yellow and black without any additional inks, independent of the screening type and the type of printing technology, in a single printing run. This solution determines CMYK color generating with a completely different behavior in areas under the influence of IR light. Detecting IR response is possible only with instruments that "see" in wavelengths above 700 nm and convert an IR graphic into an area visible to the human eye.

By making use of a specific algorithm method that may be applied for digital and conventional CMYK printing, algorithms have been derived that include printing of two or more CMYK color combinations that are of the same color (in daylight), but with a completely different behavior in IR light. The same image is separated with a double algorithm depending on the targeted continuous visibility or continuous invisibility in IR light. Continuous alternating of certain graphic surface color areas change in accordance with the desired intensity from the continuous image mask with the help of the method's set equations.

## Robust Structured Light Coding for 3D Imaging in Difficult Conditions

*T. Petković*

*University of Zagreb, Croatia*

Surface 3D scanning using structured light (SL) has numerous applications including among others industrial metrology, human body scanning, documenting cultural heritage and robot sensing. In SL scanning an active light source illuminates an object using a specific pattern which is observed by a camera. Decoding the observed pattern enables surface profile recovery via triangulation. The key to the successful 3D scanning is the selected SL pattern and the associated coding function. Most of the existing SL scanners, both commercial and scientific, are limited to 3D surface imaging in controlled environments such as dark rooms where interferences and other unwanted effects are negligible. To mitigate current limitations and to bring the 3D scanner outside of the lab novel SL patterns

and associated novel coding functions must be designed. This research goal is summarized by the following quite difficult question: "What are the optimal coding functions?". The aim of this project is to produce both theoretical and applied contribution which will bring us closer to answering this question. In this project robust coding functions for 3D surface imaging in difficult conditions will be investigated. The difficult conditions which will be considered include global interference in the form of direct sunlight and the problem of SL imaging in scattering media which is best investigated in an underwater scanning scenario including both clear and turbid water. The expected theoretical contribution is multi-scope as it falls at the intersection of signal processing, computer vision and optics and concerns the design of robust coding functions for 3D imaging. The expected applied contribution is a working system for 3D scanning in the open and underwater whose operation is experimentally verified.

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