Master Thesis Topics for Dual Degree Program UNICAL – AUSTRIA

Last update the 2nd of March 2018

Title: An adaptive topological grid for segmentation of bone fragments

Supervisor: Prof. Dr. Werner Backfrieder (& Prof. G. Terracina, Prof. F. Calimeri)

The successful treatment of traumatic accidents mainly relies on accurate and seamless repositioning of fracture parts to enable optimal bone healing. Furthermore if not a single bone is affected by the fracture, but a complicated anatomical situs, e.g. the ankle joint, surgical planning may be necessary. This joint consists of several, even very small, bones and in case of a traumatic event the fracture pieces may be dislocated, rotated and stuffed or shifted into each other.

A major prerequisite for surgical planning is the exact and accurate segmentation of all bone fragments, but the following properties of CT images are major drawbacks for this approach:

- Beam hardening, i.e. different gray values for bones with the same radiographic density
- Inhomogeneous bone-density, i.e. for spongy and cortical bone
- Irregular fractional parts
- Stuffed particles

After a rough overall segmentation, mostly bone fractures are connected to each other. A further separation step is needed to distinguish particles from each other.

An adaptive grid is used for this purpose. This grid is modelled as a series of mass points ordered on a topological patttern. The mass points are tied together by springs. Some mass points are fixed (initialized) on top of the bone surface. The adaption of the remaining grid points follows a kinetic model, where the external forces are modelled by the gradients of the volume data. The temporal evolution of the grid is calculated until a stationary solution is achieved.

The segmentation is part of a Matlab environment with interface to an existing planning application. The functions with high numerical efforts are implemented as MEX functions to improve run-time behavior.

The initial grid is positioned in a GUI. Results are visualized in 3D.

Title: Voxel gradient renderer in a CUDA-MEX context

Supervisor: Prof. Dr. Werner Backfrieder (& Prof. Spataro, Prof. D'Ambrosio)

Today's surgical planning environments are complex high specialized software packages, generally not open for easy extension with new user defined functionality. These packages heavily rely on surface rendering methods for efficient and floating 3D display of morphological segments in a scene.

But on contrast in the medical community volume rendering is heavily manifested for display of anatomy. In this approach a volume rendering method is investigated for utilization in an open surgical planning environment.

The tasks comprise:

- Development of a voxel gradient shader implementing Phong's algorithm for ambient, diffuse and specular reflection
- The shader is based on gray-level volume data and binary volume masks to speed up display of objects
- The binary object mask are associated with object composing properties, e.g. color and opacity
- Implementation as a MEX file with CUDA support.
- Existing Matlab prototype with basic functionality.

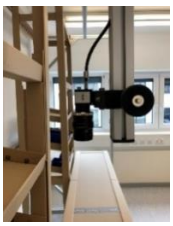
CUDA Implementation of the OpenCAL library.

Supervisors: Donato D'Ambrosio, William Spataro (& Prof. Dr. Werner Backfrieder?)

Cellular Automata (CA) represent a parallel computing methodology for modelling complex systems, such as lava and debris flows, forest fires, agent based social processes such as pedestrian evacuation and highway traffic problems, besides many others (e.g., theoretical studies).
Many Cellular Automata software environments and libraries exist. However, when non-trivial modelling is needed, only non-open source software are generally available. This is particularly true for eXtended Cellular Automata (XCA), adopted for simulating phenomena at a macroscopic point of view, for which only a significant example of non free software exists.
OpenCAL (Open Cellular Automata Library) is a cross-platform cellular automata library, developed at the Department of Mathematics and Computer Science of the University of Calabria (Italy), for the seamless implementation of XCA. Presently, besides a serial version (executable on CPUs), two parallel ones, based on OpenMP and OpenCL, permit to fruitfully take advantage of multicore and GPU based machines, respectively.
This thesis proposal regards the OpenCAL optimization by means of General-Purpose Computation with Graphics Processing Units (GPGPU) through the NVIDIA Compute Unified Device Architecture (CUDA). In particular, the thesis focuses on the reorganization of the of the library in order to apply a heterogeneous parallel approach by exploiting the faster memory layouts (e.g., shared memory), thus obtaining even more efficient CA simulations.

Task Recognition in a Smart Factory with Machine Vision and Deep Learning
Supervisor: Prof. Dr. Werner Kurschl (& Prof. M. Alviano)






HCW4i – [Human Centered Workplace for Industry] is a research project running from 11/2016-10/2020, where we try to build a contextual feedback system for the industrial worker in a typical production environment. Our industrial partners are B&R, Engel, Fronius, Kuka, TGW, COPA-DATA. The Hagenberg research facility provides a specific lab (40 m^2), where industrial workplaces are prototypical built with cardboard (see picture).

Problem

In a typical industrial production environment worker usually have to follow certain instruction, how to build a specific product. The instruction are either printed or displayed with a LCD-screen. With the upcoming industry 4.0 or digital transformation, industrial production is moving away from mass production to highly customized products. To ensure, that the worker makes these highly customized products in the right way, a contextual feedback system should track each production step. Tracking each step would allow the system to inform the worker *i)* if the right parts were taken, *ii)* the order or production tasks are consistent, *iii)* no tasks was missing, *iv)* and it could automatically turn over the instructions to the next step.

Goals

- *Studying the foundations of deep learning*
- *Design and implementation of a prototype* with TensorFlow or a similar deep learning open source framework
- *Evaluation of a prototype with a user study*

Expected Results

- Software prototype
- Evaluation

Literature

- Funk, Markus; Kosch, Thomas; Schmidt, Albrecht: *Interactive Worker Assistance: Comparing the Effects of In-situ Projection, Head-Mounted Displays, Tablet, and Paper Instructions.* In: Proceedings of the 2016 ACM International Joint Conference on Pervasive and Ubiquitous Computing, S. 934--939, 2016. Alexander Bannat, *Ein Assistenzsystem zur digitalen Werker-Unterstützung in der industriellen Produktion*, Dissertation, 2014
- Markus Funk et al., *Teach Me How! Interactive Assembly Instructions Using Demonstration and In-Situ Projection*, S. 49-73, Assistive Augmentation, Springer, 2018
- Oliver Korn, *Context-Aware Assistive Systems for Augmented Work. A Framework Using Gamification and Projection*, Dissertation, 2014
- Ian Goodfellow, Yoshua Bengio and Aaron Courville, *Deep Learning (Adaptive Computation and Machine Learning)*, 2016, MIT Press

Title: Dynamic Streaming of 3D Scenes into Unity Environments
Supervisor: Dr. Christoph Anthes (& Prof. Donato D'Ambrosio)

Virtual Environments consist of assets and datasets, composed by triangles, which represent the scenery. These Environments can be experienced in real-time with the help of VR hardware. This real-time exploration requires frame rates of at least 60 frames per second, which can be achieved easily if the scenes have a low complexity. In real world use cases the complexity of the raw data to be displayed often does not allow the real-time framerates. In most cases it has to be pre-processed and simplified. If the details of the dataset have to kept and simplification by reducing the amount of polygons is not possible or desirable alternative strategies have to be found.

The task of this thesis is to develop an approach to dynamically stream the relevant components of the dataset on the graphics board and thus allow for real-time display in large environments. The datasets should not be simplified or compressed. Algorithms will have to be developed which analyse and separate the generic scene data into individual streamable parts. Based on the camera position in the scene it will have to determined which scene or dataset components will be loaded and which ones will be removed from memory.

Title: A comparison of multi-controller interaction techniques

Supervisor: Dr. Christoph Anthes (& Prof. M. Alviano)

3D interaction in Virtual Reality (VR) is still an unsolved problem. Current VR systems are often equipped with two controllers for interaction with the virtual world. In the research community interaction techniques as well as a large variety of interfaces have been developed in the past.

Following the recent trend of two controllers, the existing interaction techniques should be revisited. An extensive literature review should identify their potential applicability on the modern 2 controller input setups. A set of interesting techniques will be selected and implemented prototypically. To compare the techniques a test setup should be designed and generated. The implemented techniques will have to be compared to each other with the help of extensive quantitative and qualitative user studies.

Title: Symbolic Regression Approximation of Periodic signals by Symbolic Regression

Supervisor: Prof. Michael Affenzeller (& Prof. F. Calimeri)

From mathematical theory it is known that continuous periodic signals can be approximated by Sine and Cosine functions of different frequency and amplitude; so called Fourier series.
The research question stated in this master thesis is to examine to what extent genetic programming based symbolic regression is able to find the harmonic terms of the corresponding Fourier series without knowing anything about Fourier series.
This question is also related to the so called AI ratio (the “artificial-to-intelligence” ratio) of a problem-solving method which is defined as the ratio of that which is delivered by the automated operation of the artificial method to the amount of intelligence that is supplied by the human applying the method to a particular problem.
If Genetic Programming based symbolic regression would be able to discover relevant parts of the Fourier series corresponding to a certain signal this would be an example of a high AI ratio as the method does not know anything about the theory of Fourier series.

Title: Open Ended Symbolic Regression with Age-Layered Population Structures

Supervisor: Prof. Michael Affenzeller (& Prof. F. Calimeri)

Age-Layered Population Structures (ALPS) denote a modern flavor of evolutionary computation structuring the population in age layers where individuals are allowed to enter the next age-layer if they surpass a certain fitness value after a certain number of generations; otherwise they are canceled.

This leads to a structure of individuals in which the fitness becomes higher together with the age layer. At the same time ALPS is able to adapt to changing environmental conditions due to the new diversity which is permanently supported at the lowest age layer.

When being applied to supervised learning of structured numerical data ALPS becomes able to adapt to changing characteristics of the underlying systems behavior. However, in supervised machine learning a better quality just means a better fit on the training data which may already be overfit in terms of a certain application. In terms of application solution candidates of lower age layers may therefore be better than models of higher age layers if they are overfit.

The ALPS variant proposed in this thesis is aimed to permanently evaluate the best individuals of all age layers on a validation dataset and select that model which fits best on the validation data. By this means it should become possible to design permanently optimizing system which is able to return the best model in terms of generalization even under changing environmental conditions.

The master thesis is aimed to implement a prototype in HeuristicLab based on already existing ALPS implementations for static optimization and evaluate its characteristics based on artificially generated data streams.

Title: Recommender Systems and Deep Learning

Supervisor: Prof. Pasquale Rullo, Dr. Giuseppe Manco (& Prof. Stephan Dreiseitl)

Recommender systems are software components and mathematical models aimed at understanding users' preferences with the objective of filtering contents of interest for them. The Technology behind Recommender Systems has matured significantly in the last years and the application fields are spread. Meanwhile, deep learning's revolutionary advances in speech recognition, image analysis and natural language processing have gained significant attention. Recent studies also demonstrate the effectiveness of deep learning in coping with information retrieval and recommendation tasks.

The purpose of the thesis is to delve into the task of applying Deep Learning techniques to the problem of recommendation, and to develop deep learning architectures which guarantee a better understanding of user's demands, item's characteristics and historical interactions between them. The thesis will cover the recent Deep learning architectural infrastructures (Tensorflow, PyTorch) and will focus on relevant application scenarios which combine spatio-temporal, social and multimedia information management and filtering.

Title: Object characterization from images

Supervisor: Prof. Pasquale Rullo, Dr. Giuseppe Manco (& Prof. Stephan Dreiseitl)

The purpose of this thesis is to develop Deep Learning models capable of predicting properties (such as weight, assembly components, nutritional facts,…) from a picture taken in a mobile environment. The thesis has two key aspect: from a theoretical point of view, themes such as transfer, reinforcement and adversarial learning should be mastered in order to develop an effective predictor. From a practical point of view, the model should be delivered within a mobile app and thus a fundamental requirement is the study of libraries for performing integration between PyTorch/Tensorflow and Android or IOS (see, e.g., the CoreML library just released by Apple).

Title: Stochastic optimization and Bayesian learning for Deep Neural Networks

Supervisor: Prof. Pasquale Rullo, Dr. Giuseppe Manco (& Prof. Stephan Dreiseitl)

Machine learning has made significant recent strides due to large-scale learning applied to "big data". Large-scale learning is typically performed with stochastic optimization, and the most common method is stochastic gradient descent (SGD). Alternative methods, such as Variational Inference, or Markov-Chain Monte Carlo methods (such as Gibbs Sampling) rely on strong mathematical foundations which in principle overcome the limitation of SGD learning (such as overfitting avoidance), but in practice do not work on large-scale learning problems. The purpose of this thesis is to review the recent advances of the literature and to experiment the combination of stochastic optimization and Bayesian learning, with particular emphasis on the application of such techniques to Deep Neural Networks.

Title: Debugging Answer Set Programs

Supervisor: Prof. Francesco Ricca (& Prof. Michael Affenzeller or Prof. Gabriel Kronberger)

Answer Set Programming (ASP is a declarative programming paradigm which has been proposed in the area of non-monotonic reasoning and logic programming. The idea of ASP is to represent a given computational problem by a logic program whose answer sets correspond to solutions, and then use a solver to find such a solution. The language of ASP is very expressive. Furthermore, the availability of some efficient ASP systems made ASP a powerful tool for developing advanced applications. The ASP programming paradigm can provide the needed reasoning capabilities at a lower (implementation) price than traditional imperative languages. ASP applications belong to several fields, from Artificial Intelligence to Information Integration and Knowledge Management. These applications of ASP have confirmed, on the one hand, the viability of the exploitation in real application settings and, very recently, stimulated some interest also in industry.

Despite ASP features a simple syntax and an intuitive semantics, errors are common during the development of ASP programs. The declarative nature of the language makes unfeasible the usage of traditional debugging approaches for imperative programming languages.

Nonetheless, in the last few years a number of debugging approaches have been proposed. The most effective ones cam point the user directly to a set of logic rules involved in the bug, which might be refined (up to the point in which the bug is easily identified) by asking the programmer a sequence of questions on an expected behaviour. However, the approach is applicable only in case of failure of a positive test case (the expected answer is not found), and features a prototypical user interface that was not integrated tightly with Integrated Development Environments (IDEs) for ASP.

The thesis will focus on extending and possibly mixing existing debugging approaches for ASP, and implementing an graphical interface for debugging logic programs that has to be integrated in an IDE for ASP.

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Gerhard Brewka, Thomas Eiter, Miroslaw Truszczynski: *Answer set programming at a glance.* Commun. ACM 54(12): 92-103 (2011)

Nicola Leone, Francesco Ricca: *Answer Set Programming: A Tour from the Basics to Advanced Development Tools and Industrial Applications.* Reasoning Web 2015: 308-326

Title: Web-based environment for developing logic programs

Supervisor: Prof. Francesco Ricca (& Prof. Michael Affenzeller or Prof. Gabriel Kronberger)

Answer Set Programming (ASP is a declarative programming paradigm which has been proposed in the area of non-monotonic reasoning and logic programming. The idea of ASP is to represent a given computational problem by a logic program whose answer sets correspond to solutions, and then use a solver to find such a solution. The language of ASP is very expressive. Furthermore, the availability of some efficient ASP systems made ASP a powerful tool for developing advanced applications. The ASP programming paradigm can provide the needed reasoning capabilities at a lower (implementation) price than traditional imperative languages. ASP applications belong to several fields, from Artificial Intelligence to Information Integration and Knowledge Management. These applications of ASP have confirmed, on the one hand, the viability of the exploitation in real application settings and, very recently, stimulated some interest also in industry.

The development of applications is made easier by programming environments and IDEs and ASPIDE is one of the most comprehensive solutions for ASP. On the other hand, ASPIDE the development of ASPIDE started more than 7 years ago as a standalone Java application. This limits the usage of ASPIDE to desktop computers with Java installed. The advancement of web-based technologies would allows, nowadays, to offer an equivalent and easy to distribute version of the IDE, *the development of such web-based IDE by using Web 2.0 technologies will be the subject of this thesis.*

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Nicola Leone, Francesco Ricca: *Answer Set Programming: A Tour from the Basics to Advanced Development Tools and Industrial Applications.* Reasoning Web 2015: 308-326

Title: Learning domain-heuristics for speeding-up propositional solvers on industrial instances

Supervisor: Prof. Francesco Ricca (& Prof. Michael Affenzeller)

The Conflict Driven Clause Learning (CDCL) algorithm is the leading solution adopted by state-of-the-art solvers for boolean Satisfiability (SAT), Satisfiability Modulo Theories (SMT), and Answer Set Programming (ASP) to mention a few. Notably, CDCL solvers have been applied with success for solving several real-world problems ranging from hardware and software model checking, planning, equivalence checking, bioinformatics, configuration problems, hardware and software test, software package dependencies, cryptography and more.

As a matter of fact the performance of a CDCL solver heavily depends on the adoption of heuristics that drive the search for solutions. State-of-the-art CDCL implementations feature very good general purpose heuristics belonging to the family of VSIDS. Nonetheless, no general heuristic is known to be the best possible choice for all problems. Pioneering work on employing domain-specific heuristics corroborates the validity of that idea. In particular, Beame et al. demonstrated the utility of a domain-specific branching heuristic for solving the pebbling formulas with a CDCL solver. Moreover, Gerhard Friedrich in his joint invited talk at CP-ICLP 2015 described a number of experiences in which "domain-specific heuristics turned out to be the key component in several industrial applications of problem solvers". However, domain heuristic can be defined productively only by domain experts. *In this thesis automatic methods for learning domain heuristics from sets of instances will be studied to ease the design and the evaluation of new heuristics for CDCL solvers.*

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Title: Turing machine visual designer and simulator

Supervisor: Prof. Marco Manna (& Prof. Michael Affenzeller or Prof. Stephan Dreiseitl)

The Turing machine was invented in 1936 by Alan Turing [1], who called it an a-machine (automatic machine). A Turing machine is a mathematical model of computation that defines an abstract machine, which manipulates symbols on a strip of tape according to a table of rules. Despite the model's simplicity, given any computer algorithm, a Turing machine capable of simulating that algorithm's logic can be constructed. Turing machines are fundamental for studying computability and complexity.

Elaine A. Rich, in [2], proposed a convenient didactic high-level formalism for the specification of Turing machines. However no tool is available to support this formalism. The availability of visual designer and simulator would greatly simplify the task of teaching and understanding computability topics.

The thesis will focus on the development of the above-mentioned tool using a modern graphical user interface development technology.

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