EvoCOMNET, EvoHOT, EvoIASP, EvoMUSART, EvoSTOC Rolf Drechsler and Yaochu Jin and Penousal Machado and Elena Marchiori and Juan Romero and George D. Smith and Giovanni Squillero

EvoCOMNET, EvoHOT, EvoIASP, EvoMUSART, EvoSTOC Rolf Drechsler and Yaochu Jin and Penousal Machado and Elena Marchiori and Juan Romero and George D. Smith and Giovanni Squillero computation, which has been proven to have excellent performance on complex problems. In expression data analysis, the most important goal may not be finding the maximum bicluster, as it might be more interesting to find a set of genes showing similar behaviour under a set of conditions. Our approach is based on evolutionary algorithms and searches for biclusters following a sequential covering strategy. In addition, we pay special attention to the fact of looking for high quality biclusters with large variation. The quality of biclusters found by our approach is discussed by means of the analysis of yeast and colon cancer datasets.

Proteins EvoCOMNET, EvoHOT, EvoIASP, EvoMUSART, EvoSTOC Rolf Drechsler and Yaochu Jin and Penousal Machado and Elena Marchiori and Juan Romero and George D. Smith and Giovanni Squillero studied for identification of members belonging to protein sequence families. Classical Viterbi search algorithm which has been used traditionally to calculate log-odd scores of the alignment of a new sequence to a profile model is based on the probability theory. To overcome the limitations of the classical HMM and for achieving an improved alignment and better log-odd scores for the sequences belonging to a given family, we propose a fuzzy Viterbi search algorithm which is based on Choquet integrals and Sugeno fuzzy measures. The proposed search algorithm incorporates ascending values of the scores of the neighbouring states while calculating the scores for a given state, hence providing better alignment and improved log-odd scores. The proposed fuzzy Viterbi algorithm for profiles along with classical Viterbi search algorithm has been tested on globin and kinase families. The results obtained in terms of log-odd scores, Z-scores and other statistical analysis establish the superiority of fuzzy Viterbi search algorithm.

polypeptides EvoCOMNET, EvoHOT, EvoIASP, EvoMUSART, EvoSTOC Rolf Drechsler and Yaochu Jin and Penousal Machado and Elena Marchiori and Juan Romero and George D. Smith and Giovanni Squillero functionality, hence methods for reading such sequences are crucial for many areas of biological sciences. Since direct methods for reading amino acid sequences allow for determining only very short fragments, some methods for assembly of these fragments are required. In this paper, tabu search algorithm solving this problem is proposed. Computational tests show its usefulness in the process of determining sequences of amino acids in long polypeptides.

EvoCOMNET, EvoHOT, EvoIASP, EvoMUSART, EvoSTOC Rolf Drechsler and Yaochu Jin and Penousal Machado and Elena Marchiori and Juan Romero and George D. Smith and Giovanni Squillero expression data. be it classical clustering approaches that aim at finding biologically relevant gene groups or biclustering methods that focus on identifying subset of genes that behave similarly over a subset of conditions. Usually, the measurements of different experiments are mixed together in a single gene expression matrix, where the information about which experiments belong together, e.g., in the context of a time course, is lost. This paper investigates the question of how to exploit the information about related experiments and to effectively use it in the clustering process. To this end, the idea of order preserving clusters that has been presented in [BCKY2002a] is extended and integrated in an evolutionary algorithm framework that allows simultaneous clustering over multiple time course experiments while keeping the distinct time series data separate.

associated with human disease? EvoCOMNET, EvoHOT, EvoIASP, EvoMUSART, EvoSTOC Rolf Drechsler and Yaochu Jin and Penousal Machado and Elena Marchiori and Juan Romero and George D. Smith and Giovanni Squillero associated with common, complex diseases. Identifying gene-gene and gene-environment interactions which comprise the genetic architecture for a majority of common diseases is a difficult challenge. To this end, novel computational approaches have been applied to studies of human disease. Previously, a GP neural network (GPNN) approach was employed. Although the GPNN method has been quite successful, a clear comparison of GPNN and GP alone to detect genetic effects has not been made. In this paper, we demonstrate that using NN evolved by GP can be more powerful than GP alone. This is most likely due to the confined search space of the GPNN approach, in comparison to a free form GP. This study demonstrates the utility of using GP to evolve NN in studies of the genetics of common, complex human disease.

inspired Operators for Ab-Initio Protein Structure Prediction EvoCOMNET, EvoHOT, EvoIASP, EvoMUSART, EvoSTOC Rolf Drechsler and Yaochu Jin and Penousal Machado and Elena Marchiori and Juan Romero and George D. Smith and Giovanni Squillero inspired Operators for Ab-Initio Protein

Structure Prediction In this work we investigate the applicability of a multiobjective formulation of the Ab-Initio Protein Structure Prediction (PSP) to medium size protein sequences (46-70 residues). In particular, we introduce a modified version of Pareto Archived Evolution Strategy (PAES) which makes use of immune inspired computing principles and which we will denote by I-PAES. Experimental results on the test bed of five proteins from PDB show that PAES, (1+1)-PAES and its modified version I-PAES, are optimal multiobjective optimization algorithms and the introduced mutation operators, and are effective for the PSP problem. The proposed I-PAES is comparable with other evolutionary algorithms proposed in literature, both in terms of best solution found and computational cost.

EvoCOMNET, EvoHOT, EvoIASP, EvoMUSART, EvoSTOC Rolf Drechsler and Yaochu Jin and Penousal Machado and Elena Marchiori and Juan Romero and George D. Smith and Giovanni Squillero researchers. Such data can be used to create gene networks, where such networks represent the regulatory interactions between genes over time. Reverse engineering gene networks from temporal gene expression data is one of the most important steps in the study of complex biological systems. This paper introduces sensitivity analysis of systematically perturbed trained neural networks to both select a smaller and more influential subset of genes from a temporal gene expression dataset as well as reverse engineer a gene network from the reduced temporal gene expression data. The methodology was applied to the rat cervical spinal cord development time-course data, and it is demonstrated that the method not only identifies important genes involved in regulatory relationships but also generates candidate gene networks for further experimental study.

classification with gene expression data EvoCOMNET, EvoHOT, EvoIASP, EvoMUSART, EvoSTOC Rolf Drechsler and Yaochu Jin and Penousal Machado and Elena Marchiori and Juan Romero and George D. Smith and Giovanni Squillero and its application to cancer classification with gene expression data. The method employs pairs of support vectors of a (linear) SVM classifier for generating a sequence of new SVM classifiers, called local support classifiers. This sequence is used in two Bayesian learning techniques: as ensemble of classifiers in Optimal Bayes, and as attributes in Naive Bayes. The resulting classifiers are applied to four publically available gene expression datasets from leukemia, ovarian, lymphoma, and colon cancer data, respectively. The results indicate that the proposed approach improves significantly the predictive performance of the baseline SVM classifier, its stability and robustness, with excellent results on all datasets. In particular, perfect classification is achieved on the colon cancer dataset.

Statistical and Integer Programming Approaches EvoCOMNET, EvoHOT, EvoIASP, EvoMUSART, EvoSTOC Rolf Drechsler and Yaochu Jin and Penousal Machado and Elena Marchiori and Juan Romero and George D. Smith and Giovanni Squillero brains of Alzheimer diagnosed patients and healthy patients taken as control. A clear pattern of differential gene expression results which can be regarded as a molecular signature of the disease. The results show the complementarity of the different methodologies, suggesting that a unified approach may help to uncover complex genetic risk factors not currently discovered with a single method. We also compare the set of genes in these differential patterns with those already reported in the literature.

Proteins EvoCOMNET, EvoHOT, EvoIASP, EvoMUSART, EvoSTOC Rolf Drechsler and Yaochu Jin and Penousal Machado and Elena Marchiori and Juan Romero and George D. Smith and Giovanni Squillero membrane spanning regions using hidden Markov models and elaborates a set of syntactic rules to model the distinct features of transmembrane proteins. This paves the way to identify the characteristics of membrane proteins analogous to the way that identifies language contents of speech utterances by using hidden Markov models. The proposed method correctly predicts 95.24

classification EvoCOMNET, EvoHOT, EvoIASP, EvoMUSART, EvoSTOC Rolf Drechsler and Yaochu Jin and Penousal Machado and Elena Marchiori and Juan Romero and George D. Smith and Giovanni Squillero functions. This paper presents a system, named GAMBIT, which discovers motifs (particular sequences of amino acids) that occur very often in proteins of a given family but rarely occur in proteins of other families. These motifs are used to classify unknown proteins, that is, to predict their function by analyzing the primary structure. To search for motifs in proteins, we developed a GA with specially tailored operators for the problem. GAMBIT was compared with MEME, a web tool for finding motifs in the TransMembrane Protein DataBase. Motifs found by both methods were used to build a decision tree and classification rules, using, respectively, C4.5 and Prism algorithms. Motifs found by GAMBIT led to significantly better results, when compared with those found by MEME, using both classification algorithms.

EvoCOMNET, EvoHOT, EvoIASP, EvoMUSART, EvoSTOC Rolf Drechsler and Yaochu Jin and

Penousal Machado and Elena Marchiori and Juan Romero and George D. Smith and Giovanni Squillero has been an important approach for exploring metabolic networks. Though various methods were developed for 13C positional enrichment or isotopomer modelling, few researchers have investigated flux estimation problem in detail. In this paper, flux estimation is formulated as a global optimization problem by carbon enrichment balances. Differential evolution, which is a simple and robust evolutionary algorithm, is applied to flux estimation. The algorithm performances are illustrated and compared with ordinary least squares estimation through simulation of the cyclic pentose phosphate metabolic network in a noisy environment. It is shown that differential evolution is an efficient approach for flux quantification.

Least Squares EvoCOMNET, EvoHOT, EvoIASP, EvoMUSART, EvoSTOC Rolf Drechsler and Yaochu Jin and Penousal Machado and Elena Marchiori and Juan Romero and George D. Smith and Giovanni Squillero relationship (QSAR) analysis. This tool, termed GEMPLS, combines a genetic evolutionary method with partial least squares (PLS). We designed a new genetic operator and used Mahalanobis distance to improve predicted accuracy and speed up a solution for QSAR. The number of latent variables (lv) was encoded into the chromosome of GA, instead of scanning the best lv for PLS. We applied GEMPLS on a comparative binding energy (COMBINE) analysis system of 48 inhibitors of the HIV-1 protease. Using GEMPLS, the cross-validated correlation coefficient (q2) is 0.9053 and external SDEP (SDEPex) is 0.61. The results indicate that GEMPLS is very comparative to GAPLS and GEMPLS is faster than GAPLS for this data set. GEMPLS yielded the QSAR models, in which selected residues are consistent with some experimental evidences.

EvoCOMNET, EvoHOT, EvoIASP, EvoMUSART, EvoSTOC Rolf Drechsler and Yaochu Jin and Penousal Machado and Elena Marchiori and Juan Romero and George D. Smith and Giovanni Squillero that deals with the analysis and investigation of such protocols. A performance evaluation framework unveils different facets of a protocol and explores its behaviour under diversified network operations. The nature inspired routing community, at the moment, lacks such a framework. Therefore, in this paper we propose a comprehensive performance evaluation framework that will empower the routing protocol designers to design state-of-the-art algorithms and extensively evaluate their performance. Using our framework, we exhaustively evaluated three state-of-the-art nature inspired routing algorithms. The results show some undiscovered aspects of the algorithms and provide valuable understanding about their merits and demerits. We believe that this will be the first major step in designing, standardising and developing a performance evaluation library that will facilitate an extensive and unbiased evaluation of nature inspired routing algorithms.

Reliability of Complex Networks EvoCOMNET, EvoHOT, EvoIASP, EvoMUSART, EvoSTOC Rolf Drechsler and Yaochu Jin and Penousal Machado and Elena Marchiori and Juan Romero and George D. Smith and Giovanni Squillero reliability of complex networks. The reliability of a network is assessed by employing two algorithms TREPAN and Adaptive Neuro-Fuzzy Inference Systems ANFIS belonging to the HIS paradigm. TREPAN is a technique to extract linguistic rules from a trained Neural Network, and ANFIS is a method that combines fuzzy inference systems and neural networks. A numerical example, related to a complex network, illustrates the application of the approach and shows that HIS is a promising approach for reliability assessment. The structure function of the complex network analysed is properly emulated by training both algorithms on a subset of possible system configurations, generated by a Monte Carlo simulation and an appropriate Evaluation Function. Both algorithms successfully describe the network status through a set of rules, which allows the reliability assessment.

Design Problem EvoCOMNET, EvoHOT, EvoIASP, EvoMUSART, EvoSTOC Rolf Drechsler and Yaochu Jin and Penousal Machado and Elena Marchiori and Juan Romero and George D. Smith and Giovanni Squillero success. This paper investigates the reliable communication network design problem using an iterated local search (ILS) method. This paper demonstrates how the concepts of local search (LS) and iterated local search can be applied to this design problem. A new neighbourhood move that finds cheaper networks without violating the reliability constraint is proposed. Empirical results show that the ILS method is more efficient than a GA

Network EvoCOMNET, EvoHOT, EvoIASP, EvoMUSART, EvoSTOC Rolf Drechsler and Yaochu Jin and Penousal Machado and Elena Marchiori and Juan Romero and George D. Smith and Giovanni Squillero anomaly-detecting algorithm based on an evolutionary artificial immune network is proposed in this paper. An evolutionary artificial immune network is ? evolved? by using unlabelled training sample data to represent the distribution of the original input data set. Then a traditional hierarchical

agglomerative clustering method is employed to perform clustering analysis within the algorithm. It is shown that the algorithm is feasible and effective with simulations over the 1999 KDD CUP dataset.

EvoCOMNET, EvoHOT, EvoIASP, EvoMUSART, EvoSTOC Rolf Drechsler and Yaochu Jin and Penousal Machado and Elena Marchiori and Juan Romero and George D. Smith and Giovanni Squillero networks. In general, registration and paging costs are associated with tracking the current location of a mobile user. Considering minimising the total of paging and registration costs as the main objective, we target to provide corresponding cell-to-switch and cell-to-LA assignments. This paper compares three well-known evolutionary algorithms to measure their suitability for solving location area management problem, which are genetic algorithms, multi-population genetic algorithms and memetic algorithms. To handle multiple objectives of paging and registration, a two-stage multi-population GA is developed. A memetic algorithm is introduced in order to improve the performance of GA with the local search techniques. The effectiveness of these methods is shown for a number of test problems with different network size and characteristics.

EvoCOMNET, EvoHOT, EvoIASP, EvoMUSART, EvoSTOC Rolf Drechsler and Yaochu Jin and Penousal Machado and Elena Marchiori and Juan Romero and George D. Smith and Giovanni Squillero circuits is proposed. These circuits are able to perform different functions (e.g. to switch between the adder and multiplier) only as a consequence of the change of a sensitive variable, which can be a power supply voltage, temperature etc. However, multiplexing of standard solutions is not used. The evolved circuits exhibit a unique structure composed of multifunctional polymorphic gates considered as building blocks instead. In many cases the area-efficient solutions were discovered for typical tasks of the digital design. We demonstrated that it is useful to combine polymorphic gates and conventional gates in order to obtain the required functionality.

EvoCOMNET, EvoHOT, EvoIASP, EvoMUSART, EvoSTOC Rolf Drechsler and Yaochu Jin and Penousal Machado and Elena Marchiori and Juan Romero and George D. Smith and Giovanni Squillero implementation (off-shelf FPGA) is proposed which exhibits extremely robust transient fault-tolerant capability. All cells in this model have identical geno-type (physical structures), and only differ in internal states. In a 3x3 cell digital organism, some individuals which implement a 2-bit multiplier were discovered using evolution that have the ability to recover themselves from almost any kinds of transient faults. An intrinsic evolvable hardware platform based on FPGA was realized to speed up the evolution process.

cores EvoCOMNET, EvoHOT, EvoIASP, EvoMUSART, EvoSTOC Rolf Drechsler and Yaochu Jin and Penousal Machado and Elena Marchiori and Juan Romero and George D. Smith and Giovanni Squillero through a series of subsequent steps. To deliver a flaw free unit at the end of the process, in each stage a verification step is required. While it would be useful to automatically develop the set of test programs for verification concurrently to the design, in most of the existing approach verification is performed manually and starting from scratch. This paper presented a methodology for the automatic completion and refinement of existing verification programs. It shows a new technique for allowing a Genetic Programming-based framework to import an existing test-program set and assimilate it for further test generation. A case study is considered, in which a sample pipelined processor is used, and new test programs are generated starting from existing functional ones. Different metrics are targeted, and preliminary results are reported, showing the effectiveness of the method with respect to a pure random approach.

EvoCOMNET, EvoHOT, EvoIASP, EvoMUSART, EvoSTOC Rolf Drechsler and Yaochu Jin and Penousal Machado and Elena Marchiori and Juan Romero and George D. Smith and Giovanni Squillero automation. A fundamental research problem in the VLSI floorplanning is representation because it determines the size of search space and the complexity of the transformation between a representation and its corresponding floorplan. O-tree representation is one of the most efficient floor plan representations as it has the smallest search space among all the admissible floor plan representations and the computational complexity of transformation between a representation and its corresponding floor plan is only O(n). The efficiency of O-tree representation was demonstrated by a deterministic algorithm proposed by Guo et al.. The deterministic algorithm can quickly find a reasonably good floor plan. However, the deterministic floor planning algorithm, by its nature, is a local search algorithm, and thereby may not be able to find an optimal or near-optimal solution sometimes. This paper presents a genetic algorithm for the VLSI floor planning problem using O-tree representation. Experimental results show that the GA can consistently produce better results than the deterministic algorithm.

EvoCOMNET, EvoHOT, EvoIASP, EvoMUSART, EvoSTOC Rolf Drechsler and Yaochu Jin and

Penousal Machado and Elena Marchiori and Juan Romero and George D. Smith and Giovanni Squillero electrical power. Since the standard binary gates are not usually reversible we use the Fredkin gate in order to achieve reversibility. An algorithm for designing reversible digital circuits is described in this paper. The algorithm is based on Multi Expression Programming (MEP), a Genetic Programming variant with a linear representation of individuals. The case of digital circuits for the even-parity problem is investigated. Numerical experiments show that the MEP-based algorithm is able to easily design reversible digital circuits for up to the even-8- parity problem.

EvoCOMNET, EvoHOT, EvoIASP, EvoMUSART, EvoSTOC Rolf Drechsler and Yaochu Jin and Penousal Machado and Elena Marchiori and Juan Romero and George D. Smith and Giovanni Squillero meta-heuristic, which allows for a resource-efficient implementation on Field Programmable Gate Arrays. In comparison to the standard ACO approach in software on a sequential machine, the implementation of C-ACO in hardware leads to significant asymptotic speed-ups. In experimental studies, we investigate the performance of the proposed C-ACO algorithm. Furthermore, we introduce and examine alternative means of integrating heuristic information into the optimisation process, thereby considering the requirements of the hardware architecture.

EvoCOMNET, EvoHOT, EvoIASP, EvoMUSART, EvoSTOC Rolf Drechsler and Yaochu Jin and Penousal Machado and Elena Marchiori and Juan Romero and George D. Smith and Giovanni Squillero Classic manual or automatic optimisation methods do not always yield satisfactory results, being either too labour-intensive or unsuitable for some specific class of problems. The advantage of using an evolutionary approach is twofold: on the one hand it does not introduce any arbitrary assumptions about what kind of solution shows the best promise; on the other hand, being intrinsically non-deterministic, it allows the whole process to be repeated in search of better solutions. A generic evolutionary tool originally developed for a totally different application area, namely test program generation for microprocessors, is employed for the optimisation process. The results show both the versatility of the tool (it? s able to autonomously choose the number of array elements) and the validity of the evolutionary approach for this specific problem.

to Image Analysis EvoCOMNET, EvoHOT, EvoIASP, EvoMUSART, EvoSTOC Rolf Drechsler and Yaochu Jin and Penousal Machado and Elena Marchiori and Juan Romero and George D. Smith and Giovanni Squillero sensing images. This method performs feature weighting in a wrapper approach. The proposed method combines several local specialists, each one extracting one cluster only and using different feature weights. A new clustering quality criterion, adapted to independant clusters, is defined. The weight learning is performed through a cooperative coevolution algorithm, where each species represents one of the clusters to be extracted.

EvoCOMNET, EvoHOT, EvoIASP, EvoMUSART, EvoSTOC Rolf Drechsler and Yaochu Jin and Penousal Machado and Elena Marchiori and Juan Romero and George D. Smith and Giovanni Squillero colonisation of a bidimensional world by a number of populations. The individuals, belonging to different populations, compete to occupy all the available space and adapt to the local environmental characteristics of the world. We present experiments with synthetic images, where we show the efficiency of the proposed method and compare it to other segmentation algorithm, and an application to medical images. Reported results indicate that the segmentation of noise images is effectively improved. Moreover, the proposed method can be applied to a wide variety of images.

EvoCOMNET, EvoHOT, EvoIASP, EvoMUSART, EvoSTOC Rolf Drechsler and Yaochu Jin and Penousal Machado and Elena Marchiori and Juan Romero and George D. Smith and Giovanni Squillero multifractal denoising algorithm that serves as a basis for this technique is adapted to complex images and signals, and depends on a set of parameters. As the tuning of these parameters is a difficult task, highly dependent on psycho-visual and subjective factors, we propose to use an interactive EA to drive this process. Comparative denoising results are presented with automatic and interactive EA optimisation. The proposed technique yield efficient denoising in many cases, comparable to classical denoising techniques. The versatility of the interactive implementation is however a major advantage to handle difficult images like IR or medical images.

EvoCOMNET, EvoHOT, EvoIASP, EvoMUSART, EvoSTOC Rolf Drechsler and Yaochu Jin and Penousal Machado and Elena Marchiori and Juan Romero and George D. Smith and Giovanni Squillero pattern recognition approach to support computational vision systems when it is necessary to automatically check the presence of specific objects on a scene, and, besides, to describe their position, orientation and scale. The developed methodology involves the use of a genetic algorithm to find known 2D object views in the image. The proposed approach is fast and presented a robust performance in several test

instances including multiobject scenes, with or without partial occlusion.

EvoCOMNET, EvoHOT, EvoIASP, EvoMUSART, EvoSTOC Rolf Drechsler and Yaochu Jin and Penousal Machado and Elena Marchiori and Juan Romero and George D. Smith and Giovanni Squillero algorithm to solve the problem of dense stereo matching. Dense stereo matching is used for 3D reconstruction in stereo vision in order to achieve fine texture detail about a scene. The algorithm presented in this paper incorporates two different epidemic automata applied to the correspondence of two images. These two epidemic automata provide two different behaviours which construct a different matching. Our aim is to provide with a new strategy inspired on evolutionary computation, which combines the behaviours of both automata into a single correspondence process. The new algorithm will decide which epidemic automata to use based on inheritance and mutation, as well as the attributes, texture and geometry, of the input images. Finally, we show experiments in a real stereo pair to show how the new algorithm works.

the Presence of Noise EvoCOMNET, EvoHOT, EvoIASP, EvoMUSART, EvoSTOC Rolf Drechsler and Yaochu Jin and Penousal Machado and Elena Marchiori and Juan Romero and George D. Smith and Giovanni Squillero tendency to increase the visibility of noise when they enhance the underlying details. In this paper, a new kind of image analysis tool - ridgelet frame - is introduced into the arena of image enhancement. We design an enhancement operator with the advantages that it not only enhance image details but also avoid the amplification of noise within source image. Different from those published previously, our operator has more parameters, which results in more flexibility for different category images. Based on an objective criterion, we search the optimal parameters for each special image using Immune Clone Algorithm (ICA). Experimental results show the superiority of our method in terms of both subjective and objective evaluation.

EvoCOMNET, EvoHOT, EvoIASP, EvoMUSART, EvoSTOC Rolf Drechsler and Yaochu Jin and Penousal Machado and Elena Marchiori and Juan Romero and George D. Smith and Giovanni Squillero GP may be used is image analysis. There are several works using evolutionary methods to process, analyse or classify images. All these procedures need an appropriate fitness function, that is a similarity measure. However, computing such measures usually needs a lot of computational time. To solve this problem, the notion of efficiently computable fitness functions was introduced, and their theory was already examined in detail. the practical aspects of these fitness functions are discussed.

EvoCOMNET, EvoHOT, EvoIASP, EvoMUSART, EvoSTOC Rolf Drechsler and Yaochu Jin and Penousal Machado and Elena Marchiori and Juan Romero and George D. Smith and Giovanni Squillero clonal algorithm (ICA) is proposed for the case of classification. ICA, a new intelligent computation method simulating the natural immune system, characterised by rapid convergence to global optimal solutions, is employed to select a suitable subset of the trained component SVMs to make up of an ensemble with high generalisation performance. The experimental results on some popular datasets from UCI database show that the selective SVMs ensemble outperforms a single SVM and traditional ensemble method that ensemble all the trained component SVMs.

EvoCOMNET, EvoHOT, EvoIASP, EvoMUSART, EvoSTOC Rolf Drechsler and Yaochu Jin and Penousal Machado and Elena Marchiori and Juan Romero and George D. Smith and Giovanni Squillero the notion of sensory-motor coordination as an explanation for intelligent behaviour. However, there has been little research on sensory-motor coordination in tasks that go beyond low-level behavioural tasks. In this paper we show that sensory-motor coordination can also enhance performance on a high-level task: artificial gaze control for gender recognition in natural images. To investigate the advantage of sensory-motor coordination, we compare a non-situated model of gaze control (incapable of sensory-motor coordination) with a situated model of gaze control (capable of sensory-motor coordination). The non-situated model of gaze control shifts the gaze according to a fixed set of locations, optimised by an evolutionary algorithm. The situated model of gaze control determines gaze shifts on the basis of local inputs in a visual scene. An evolutionary algorithm optimises the model's gaze control policy. From the experiments performed, we may conclude that sensory-motor coordination contributes to artificial gaze control for the high-level task of gender recognition in natural images: the situated model outperforms the non-situated model. The mechanism of sensory-motor coordination establishes dependencies between multiple actions and observations that are exploited to optimise categorisation performance.

Metaheuristic EvoCOMNET, EvoHOT, EvoIASP, EvoMUSART, EvoSTOC Rolf Drechsler and Yaochu Jin and Penousal Machado and Elena Marchiori and Juan Romero and George D. Smith and Giovanni Squillero over segmented images. The initial segmented image is described by a modified

Region Adjacency Graph model. In a second phase, this graph is successively partitioned in a hierarchical fashion into two subgraphs, corresponding to the two most significant components of the actual image, until a termination condition is met. This graph-partitioning task is solved as a variant of the min-cut problem (normalised cut) using a Hierarchical Social (HS) metaheuristic. We applied the proposed approach on different standard test images, with high-quality visual and objective segmentation results.

EvoCOMNET, EvoHOT, EvoIASP, EvoMUSART, EvoSTOC Rolf Drechsler and Yaochu Jin and Penousal Machado and Elena Marchiori and Juan Romero and George D. Smith and Giovanni Squillero approach to evolutionary computation. The problem is partitioned into a set of homogeneous elements, whose individual contribution to the problem solution can be evaluated separately. These elements are allocated in a population with the goal of creating a single solution by a process of aggregation. Thus, the goal of the evolutionary process is to generate individuals that jointly form better solutions. Under the proposed paradigm, aspects such as problem decomposition and representation, as well as local and global fitness integration need to be addressed. Experimental results illustrate significant improvements, in terms of solution quality and computational cost, when compared to canonical evolutionary approaches

EvoCOMNET, EvoHOT, EvoIASP, EvoMUSART, EvoSTOC Rolf Drechsler and Yaochu Jin and Penousal Machado and Elena Marchiori and Juan Romero and George D. Smith and Giovanni Squillero algorithms is described. The filter is decomposed into component filters where coefficients can be sparsely scattered using filter networks. Placement of coefficients in the filters is done by genetic algorithms and the resulting filters are optimised using an alternating least squares approach. The method is tested on a 2-D quadrature filter and the method yields a higher quality filter in terms of weighted distortion compared to other efficient implementations that require the same amount of computations to apply. The resulting filter also yields lower weighted distortion than the full implementation.

Vocalization in Robotics EvoCOMNET, EvoHOT, EvoIASP, EvoMUSART, EvoSTOC Rolf Drechsler and Yaochu Jin and Penousal Machado and Elena Marchiori and Juan Romero and George D. Smith and Giovanni Squillero learning the articulatory mechanisms which produce spoken phonemes. It uses a set of fuzzy rules and genetic optimisation. The former represents the relationships between places of articulations and speech acoustic parameters, while the latter computes the degrees of membership of the places of articulation. That is, the places of articulation are considered as fuzzy sets whose degrees of membership are the articulatory features. Subjective listening tests of sentences artificially generated from the articulatory description resulted in an average phonetic accuracy of about 76Through the analysis of a large amount of natural speech, the algorithm can be used to learn the places of articulation of all phonemes.

Learning EvoCOMNET, EvoHOT, EvoIASP, EvoMUSART, EvoSTOC Rolf Drechsler and Yaochu Jin and Penousal Machado and Elena Marchiori and Juan Romero and George D. Smith and Giovanni Squillero parameters regulating video-based tracking systems. It does not make assumptions about the type of tracking system used. The paper proposes an evaluation metric to assess system performance. The illustration of the method is carried out using three very different video sequences in which the evaluation function assesses trajectories of airplanes, cars or baggage-trucks in an airport surveillance application. Firstly, the optimization is carried out by adjusting to individual trajectories. Secondly, the generalisation problem (the search for appropriate solutions to general situations avoiding over fitting) is approached considering combinations of trajectories to take into account in the ES optimisation. In both cases, the trained system is tested with the rest of trajectories. Our experiments show how, besides an automatic and reliable adjustment of parameters, the optimisation strategy of combining trajectories improves the generalisation capability of the training system.

Object Detection EvoCOMNET, EvoHOT, EvoIASP, EvoMUSART, EvoSTOC Rolf Drechsler and Yaochu Jin and Penousal Machado and Elena Marchiori and Juan Romero and George D. Smith and Giovanni Squillero evolve both the feature construction stage and the classification stage of an object detection algorithm. Evolving both stages simultaneously allows highly accurate solutions to be created while needing only a fraction of the number of features extracting as in generic approaches. Scalability issues in the previous system have motivated the introduction of a multi-stage approach which has been shown in the literature to provide large reductions in computational requirements. In this work we show how using the idea of coevolutionary feature extraction in conjunction with this multi-stage approach can reduce the computational requirements by at least two orders of magnitude, allowing the impressive performance gains of this technique to be readily applied to many real world problems.

EvoCOMNET, EvoHOT, EvoIASP, EvoMUSART, EvoSTOC Rolf Drechsler and Yaochu Jin and Penousal Machado and Elena Marchiori and Juan Romero and George D. Smith and Giovanni Squillero Genetic Programming (CGP) in which the specific location of genes within the chromosome has no direct or indirect influence on the phenotype. The mapping between the genotype and phenotype is determined by self-organised binding of the genes, inspired by enzyme biology. This representation has been applied to a version of CGP developed especially for evolution of image processing filters and preliminary results show it outperforms the standard representation in some configurations.

Recognition EvoCOMNET, EvoHOT, EvoIASP, EvoMUSART, EvoSTOC Rolf Drechsler and Yaochu Jin and Penousal Machado and Elena Marchiori and Juan Romero and George D. Smith and Giovanni Squillero object recognition problems. A weight parameter is introduced to each link between two nodes in a program tree. The weight is defined as a floating point number and determines the degree of contribution of the sub-program tree under the link with the weight. Changing a weight corresponds to changing the effect of the sub-program tree. The weight changes are learnt by gradient descent search at a particular generation. The programs are evolved and learned by both the genetic beam search and the gradient descent search. This approach is examined and compared with the basic genetic programming approach without gradient descent on three object classification problems of varying difficulty. The results suggest that the new approach works well on these problems.

EvoCOMNET, EvoHOT, EvoIASP, EvoMUSART, EvoSTOC Rolf Drechsler and Yaochu Jin and Penousal Machado and Elena Marchiori and Juan Romero and George D. Smith and Giovanni Squillero relatively new field of enquiry. While there have been some important developments, it might be argued that to date, successful results in this domain have been limited. Much of the present research can be characterised as finding ad-hoc methods that can produce subjectively interesting results. In this paper, it is argued that a stronger overall research plan is needed if the field is to develop in the longer term and attract more researchers. Five open problems are defined and explained as broad principle areas of investigation for evolutionary music and art. Each problem is explained and the impetus and background for it is described in the context of creative evolutionary systems.

EvoCOMNET, EvoHOT, EvoIASP, EvoMUSART, EvoSTOC Rolf Drechsler and Yaochu Jin and Penousal Machado and Elena Marchiori and Juan Romero and George D. Smith and Giovanni Squillero algorithm for rendering real images in an impasto painterly style. We argue that figurative artworks are salience maps, and develop a novel painting algorithm that uses a genetic algorithm (GA) to search the space of possible paintings for a given image, so approaching an optimal artwork in which salient detail is conserved and non-salient detail is attenuated. We demonstrate the results of our technique on a wide range of images, illustrating both the improved control over level of detail due to our salience adaptive painting approach, and the benefits gained by subsequent relaxation of the painting using the GA.

Art EvoCOMNET, EvoHOT, EvoIASP, EvoMUSART, EvoSTOC Rolf Drechsler and Yaochu Jin and Penousal Machado and Elena Marchiori and Juan Romero and George D. Smith and Giovanni Squillero population of agents. The strategies include the emergent maintenance of separate agent sub-populations and migration between them, and the introduction of virtual diseases that co-evolve parasitically within their hosts. The method looks to Artificial Life and epidemiology for its inspiration but its ultimate concerns are in studying epidemics as a process suitable for application to generative electronic art. The simulation is used to construct a prototype artwork for a fully interactive stereoscopic virtual-reality environment to be exhibited in a science museum.

EvoCOMNET, EvoHOT, EvoIASP, EvoMUSART, EvoSTOC Rolf Drechsler and Yaochu Jin and Penousal Machado and Elena Marchiori and Juan Romero and George D. Smith and Giovanni Squillero into a render farm with the purpose of animating and evolving artificial life-forms known as sheep. The votes of the users form the basis for the fitness function for a genetic algorithm on a space of fractal animations. Users also may design sheep by hand for inclusion in the gene pool. This paper describes the system and its algorithms, and reports statistics from 11 weeks of operation. The data indicate that Electric Sheep functions more as an amplifier of its human collaborators' creativity rather than as a traditional genetic algorithm that optimises a fitness function.

EvoCOMNET, EvoHOT, EvoIASP, EvoMUSART, EvoSTOC Rolf Drechsler and Yaochu Jin and Penousal Machado and Elena Marchiori and Juan Romero and George D. Smith and Giovanni Squillero swarm of tech-tiles, where each tech-tile is a rectangular element of an image or a sequence of audio samples. An entire image can be converted to a single tech-tile, which can be performed as a composition, or a swarm of small tiles can fly over the image, generating a sonic improvisation. In

each case, spatial (visual) structure is mapped into temporal (sonic) structure. The construction of a tech-tile from an image file or a sound clip and the swarm/attractor dynamics is explained in some detail. A number of experiments report on the sonic textures derived from various images.

EvoCOMNET, EvoHOT, EvoIASP, EvoMUSART, EvoSTOC Rolf Drechsler and Yaochu Jin and Penousal Machado and Elena Marchiori and Juan Romero and George D. Smith and Giovanni Squillero model to evolve ant paintings. Our model is inspired by the recent work of Monmarch et al. The two critical differences between our model and that of Monmarch's are: (1) we do not use an interactive genetic algorithm, and (2) we allow the pheromone trail to serve as both a repelling and attracting force. Our results show how different fitness measures induce different artistic styles in the evolved paintings. Moreover, we explore the sensitivity of these styles to perturbations of the parameters required by the genetic algorithm. We also discuss the evolution and interaction of various castes within our artificial ant colonies.

EvoCOMNET, EvoHOT, EvoIASP, EvoMUSART, EvoSTOC Rolf Drechsler and Yaochu Jin and Penousal Machado and Elena Marchiori and Juan Romero and George D. Smith and Giovanni Squillero represented as a graph. We show how the graph can be searched for similarities of different kinds using interchangeable similarity measures based on viewpoints. A segmentation algorithm using the EA for automatically finding structures in a score based on a specific-to-general ordering of the viewpoints is proposed. As an example a fugue by J. S. Bach is analysed, revealing its extensive use of inner resemblance.

Evolution Systems EvoCOMNET, EvoHOT, EvoIASP, EvoMUSART, EvoSTOC Rolf Drechsler and Yaochu Jin and Penousal Machado and Elena Marchiori and Juan Romero and George D. Smith and Giovanni Squillero often depends on subjective or hard to express concepts, the automating fitness assignment becomes a difficult problem. This paper discusses the application of Zipf's Law in evaluation of music pleasantness. Preliminary results indicate that a set of Zipf-based metrics can be effectively used to classify music according to pleasantness as reported by human subjects. These studies suggest that metrics based on Zipf's law may capture essential aspects of proportion in music as it relates to music aesthetics. We discuss the significance of these results for the automation of fitness assignment in evolutionary music systems.

EvoCOMNET, EvoHOT, EvoIASP, EvoMUSART, EvoSTOC Rolf Drechsler and Yaochu Jin and Penousal Machado and Elena Marchiori and Juan Romero and George D. Smith and Giovanni Squillero monophonic Jazz standards recordings by a skilled saxophonist. We use a melodic transcription system which extracts a set of acoustic features from the recordings producing a melodic representation of the expressive performance played by the musician. We apply genetic algorithms to this representation in order to induce rules of expressive music performance. The rules collected during different runs of our system are of musical interest and have a good prediction accuracy.

EvoCOMNET, EvoHOT, EvoIASP, EvoMUSART, EvoSTOC Rolf Drechsler and Yaochu Jin and Penousal Machado and Elena Marchiori and Juan Romero and George D. Smith and Giovanni Squillero parameter settings of an FM synthesiser, with the aim of mimicking known synthesized sounds. The work is considered as a precursor to the development of synthesis plug-ins using evolution directed by a user. Attention is focused on the fitness functions used to drive the evolution: the main result is that a composite fitness function D based on a combination of perceptual measures, spectral analysis, and low-level sample-by-sample comparison D drives more successful evolution than fitness functions which use only one of these types of criterion.

EvoCOMNET, EvoHOT, EvoIASP, EvoMUSART, EvoSTOC Rolf Drechsler and Yaochu Jin and Penousal Machado and Elena Marchiori and Juan Romero and George D. Smith and Giovanni Squillero pheromone substances for mass recruitment in ants. We will describe two different uncoordinated groups of very simple virtual micro-painters: the Colombines and the Anti-Colombines. These painters have very limited perception abilities and cannot communicate directly with other individuals. The virtual canvas, besides being a computational space for depositing paint, is also a pheromone medium (that mirrors the painting patterns) influencing the painters' behaviour. Patterns are the emergent result of interaction dynamics involving the micro-painters and their pheromone medium.

Evolution Strategy EvoCOMNET, EvoHOT, EvoIASP, EvoMUSART, EvoSTOC Rolf Drechsler and Yaochu Jin and Penousal Machado and Elena Marchiori and Juan Romero and George D. Smith and Giovanni Squillero evolutionary sound matching work. In doing so, the convergence characteristics are shown to provide a synthesis method that produces interesting sounds. The method implements an Evolution Strategy to optimise a set of real-valued Frequency Modulation parameters. The development

of the evolution is synthesised as optimisation takes place, and the corresponding dynamic sound can be observed developing from initial disorder, into a stable, static tone.

EvoCOMNET, EvoHOT, EvoIASP, EvoMUSART, EvoSTOC Rolf Drechsler and Yaochu Jin and Penousal Machado and Elena Marchiori and Juan Romero and George D. Smith and Giovanni Squillero network of spiking artificial neurons to generate grain events. The system plays randomly selected sound grains from a given sound sample when any one of a weakly coupled network of up to 1000 neurons fires. The network can exhibit loosely correlated temporal solutions and also collective synchronised behaviour. This leads to very interesting sonic results, particularly with regard to rhythmic textures which can be controlled with various parameters within the model.

EvoCOMNET, EvoHOT, EvoIASP, EvoMUSART, EvoSTOC Rolf Drechsler and Yaochu Jin and Penousal Machado and Elena Marchiori and Juan Romero and George D. Smith and Giovanni Squillero with the results usually interpreted graphically. Music can also be represented by grammars, and it is possible to interpret L-systems musically. We search for simultaneous pleasing graphical and musical renderings of L-systems

EvoCOMNET, EvoHOT, EvoIASP, EvoMUSART, EvoSTOC Rolf Drechsler and Yaochu Jin and Penousal Machado and Elena Marchiori and Juan Romero and George D. Smith and Giovanni Squillero In general the mapping of CA states to note-level music representations has focused on pitch mapping and downplayed rhythm. This paper reports experiments in the application of one-dimensional cellular automata to the generation and evolution of rhythmic patterns. A selection of CA tendencies are identified that can be used as compositional tools to control the rhythmic coherence of monophonic passages and the polyphonic texture of musical works in broad-brush, rather than precisely deterministic, ways. This will provide the composer and researcher with a clearer understanding of the useful application of CAs for generative music.

EvoCOMNET, EvoHOT, EvoIASP, EvoMUSART, EvoSTOC Rolf Drechsler and Yaochu Jin and Penousal Machado and Elena Marchiori and Juan Romero and George D. Smith and Giovanni Squillero music-theoretic tenets alone are unsuitable as prescriptive principles and could be profitably complemented by attempts to represent and recreate dynamical structures of music. Examples of ongoing work using adaptive dynamical processes for generating dynamic structures are presented.

EvoCOMNET, EvoHOT, EvoIASP, EvoMUSART, EvoSTOC Rolf Drechsler and Yaochu Jin and Penousal Machado and Elena Marchiori and Juan Romero and George D. Smith and Giovanni Squillero environments. Different types of changes in the environment benefit from different types of mechanisms to handle the change. In this study, the mechanisms used in literature are categorised into four groups. A new EA approach (MIA) which benefits from the EDA-like approach it employs for re-initialising populations after a change as well as using different change handling mechanisms together is proposed. Experiments are conducted using the 0/1 single knapsack problem to compare MIA with other algorithms and to explore its performance. Promising results are obtained which promote further study. Current research is being done to extend MIA to other problem domains.

EvoCOMNET, EvoHOT, EvoIASP, EvoMUSART, EvoSTOC Rolf Drechsler and Yaochu Jin and Penousal Machado and Elena Marchiori and Juan Romero and George D. Smith and Giovanni Squillero Problem. For a network consisting of routers and application servers the DPC problem is to find a good clustering for packets that are sent between the servers through the network. The clustering is done according to a data vector in the packets. In the dynamic version of DPC the packets data vector can change. The proposed algorithms to solve the dynamic DPC are inspired by the odour recognition system of ants. We analyse the new algorithms for situations with different strengths of dynamic change and for different number of routers in the network.

EvoCOMNET, EvoHOT, EvoIASP, EvoMUSART, EvoSTOC Rolf Drechsler and Yaochu Jin and Penousal Machado and Elena Marchiori and Juan Romero and George D. Smith and Giovanni Squillero simultaneous development of a robust conceptual front. It involves a hierarchy of abstractive descriptions of the design, and a structured EC approach. The robustness, treated here by a novel MOEA approach, is for uncertainties, which result from delaying decisions during the conceptual design stage.

EvoCOMNET, EvoHOT, EvoIASP, EvoMUSART, EvoSTOC Rolf Drechsler and Yaochu Jin and Penousal Machado and Elena Marchiori and Juan Romero and George D. Smith and Giovanni Squillero Optimisation algorithm on dynamic environments is provided and discussed on widely used test problems. Results are very promising compared to the corresponding results of the standard Particle Swarm Optimization algorithm, indicating the superiority of the new scheme.

Systematic Controlled Observation in Dynamic Environments EvoCOMNET, EvoHOT, EvoIASP,

EvoMUSART, EvoSTOC Rolf Drechsler and Yaochu Jin and Penousal Machado and Elena Marchiori and Juan Romero and George D. Smith and Giovanni Squillero (GAs) in dynamic environments, work still needs to be done in investigating the fundamental behaviour of these algorithms in changing environments. When researching the GA in static environments, it has been useful to use test suites of functions that are designed for the GA so that the performance can be observed under systematic controlled conditions. One example of these suites is the hyperplane-defined functions (hdfs) designed by Holland [Holland00]. We have created an extension of these functions, specifically designed for dynamic environments, which we call the shaky ladder functions. In this paper, we examine the qualities of this suite that facilitate its use in examining the GA in dynamic environments, describe the construction of these functions and present some preliminary results of a GA operating on these functions.

Optimization Problems EvoCOMNET, EvoHOT, EvoIASP, EvoMUSART, EvoSTOC Rolf Drechsler and Yaochu Jin and Penousal Machado and Elena Marchiori and Juan Romero and George D. Smith and Giovanni Squillero structural optimisation problems. The HEA is composed by a lower level evolutionary algorithm (LLEA) and a higher level evolutionary algorithm (HLEA). The HEA has been applied to the design of grounding grids for electrical safety. A compact representation to describe the topology of the grounding grid is proposed. An analysis of the decision space is carried out and its restriction is obtained according to some considerations on the physical meaning of the individuals. Due to the algorithmic structure and the specific class of problems under study, the fitness function of the HLEA is noisy. A statistical approach to analyse the behaviour and the reliability of the fitness function is done by applying the limit theorems of the probability theory. The comparison with the other method of grounding grid design shows the validity and the efficiency of the HEA.

EvoCOMNET, EvoHOT, EvoIASP, EvoMUSART, EvoSTOC Rolf Drechsler and Yaochu Jin and Penousal Machado and Elena Marchiori and Juan Romero and George D. Smith and Giovanni Squillero common mating criteria among animals is assortative mating, where individuals mate according to their phenotype similarities (or dissimilarities). This paper explores the effect of including assortative mating in genetic algorithms for dynamic problems. A wide range of mutation rates was explored, since comparative results were found to change drastically for different mutation rates. The strategy for selecting mates was found to interact with the mutation rate value: low mutation rates were the best choice for dissortative mating, medium mutation values for the standard GA, and higher mutation rates for assortative mating. Thus, GA efficiency is related to mate selection strategies in connection with mutation values. For low mutation rates typically used in GA, dissortative mating was shown to be a robust and promising strategy for dynamic problems.

to perform Robust Designs EvoCOMNET, EvoHOT, EvoIASP, EvoMUSART, EvoSTOC Rolf Drechsler and Yaochu Jin and Penousal Machado and Elena Marchiori and Juan Romero and George D. Smith and Giovanni Squillero Interval Arithmetic (IA) as an alternative technique to obtain robust system design. CES are an approach that combines the Evolution Strategy techniques with concepts from Cellular Automata in order to optimise a given function, while IA is used as a checking technique that guarantees the feasibility of the design. IA is able to consider simultaneously the effects of uncertainty of all of the parameters on a performance function and to provide strict bounds (minimum and maximum values) with only one evaluation. CES and IA are used to obtain, by an iterative process, a robust design, that is, the maximum size of each variable deviation that allow to comply with a set of specifications. The proposed approach is an indirect method based on optimisation instead of a direct method based on mapping from the output into the input space. A numerical example, related to an electronic circuit system design, illustrates the application of the approach.