Informatics Board of Studies - Course Proposal

Proposed course title: Natural Computing (NC)

Proposer(s): Michael Herrmann

Date: 07/03/18

1. Case for Support – to be supplied by the proposer and shown to the BoS Academic Secretary prior to preparation of an in-depth course description

1a. Overall contribution to teaching portfolio

1b. Target audience and expected demand

1c. Relation to existing curriculum

1d. Resources

2. Course descriptor - this is the official course documentation that will be published if the course is approved, ITO and the BoS Academic Secretary can assist in its preparation

3. Course materials - these should be prepared once the Board meeting at which the proposal will be discussed has been specified

3a. Sample exam question

3b. Sample coursework specification

3c. Sample tutorial/lab sheet question

3d. Any other relevant materials

4. Course management - this information can be compiled in parallel to the elicitation of comments for section 5.

4a. Course information and publicity

4b. Feedback

4c. Management of teaching delivery

5. Comments - to be collected by the proposer in good time before the actual BoS meeting and included as received

5a. Year Organiser Comments

5b. Degree Programme Co-Ordinators

5c. BoS Academic Secretary

[Guidance in square brackets below each item. Please also refer to the guidance for new course proposals at http://www.inf.ed.ac.uk/student-services/committees/board-of-studies/course-proposal-guidelines. Examples of previous course proposal submissions are available on the past meetings page http://www.inf.ed.ac.uk/admin/committees/bos/meetings/.]

1. Case for Support

[This section should summarise why the new course is needed, how it fits with the existing course portfolio, the curricula of our Degree Programmes, and delivery of teaching for the different years it would affect.]

This proposal of a course Natural Computing (NCN) is based on the previously existing course Natural Computing (NAT, INFR09038) to be adapted and offered as a level-11. It accompanies last year's proposal of the distance-learning version (Natural Computing Online course, NCO) of the same course. The online-only version was approved by the Board of Studies in January 2017. Later is was pointed out that the online course should be made available for local students in the standard way as well. The start of the online course was delayed by one-year, because a sabbatical was granted to the proposer shortly after the approval of the NCO course together with the recommendation to start the NCO course only in 2018/19. The course NCN that is proposed here, is planned to start in parallel with NCO.

The approved proposal of the course NCO included already the option of creating a course instance (NCN) for local students in addition to the distance learning course NCO, which is the purpose of the present proposal.

The earlier NAT course (level 9) was delivered until 2011/12. It existed as a non-delivered course instance until 2015/2016. NAT and its predecessor GAGP were generally appreciated by UG students, but were not tightly integrated in the course portfolio of the school, i.e. NAT was not prerequisite to any other courses with the exception of RL, although this dependency was not obvious in either of the courses. NAT did require some mathematical background, but not much material from any of the Informatics courses.

The present proposal is based upon experiences with the inverted-classroom teaching in IVR and the anticipation of interest in natural computing that is obvious from the continued application of natural computing methods in many different areas of applied research. For 2013-2017, Google Scholar lists 140K papers containing „Genetic Algorithms“, 50K papers for „Particle Swarm Optimisation“ and about 20K for each of„Swarm Intelligence“, „Evolutionary Algorithms“ and „Metaheuristic“. Of importance for the course are in particular recent theoretical advances related to convergence, complexity and computational power of natural computing algorithms. Of interest are also recent successes related to techniques that employ natural materials (e.g., molecules) to compute.

Because the course wouldn't be an integral part of the CS/AI UG degrees and because of the intended broad combination of applied and theoretical aspects, it appears that the proposed course that is more suitable for Master students (level 11) as part of AI degrees. As it will cover a good part of a specific research area, NCN will also be interesting as a stand-alone course for distance students.

We propose to deliver NCN and NCO in a combined form first in 2018/19, semester 1. The delivery of the course will be synchronised between distance and local students, although, given a strong demand of the on-line version, other schedules could be considered in future years.

Reasons for proposing a local course are mainly of administrative nature. It may seem unnatural to enrol local students in a distance course at their university. Other courses, such as R:SS, RL, INF2D, ABS, CV, and DMR prepare students for or can make use of the material that will be taught in NCN, such that NCN is not isolated in the curriculum. In addition many MSc thesis projects can benefit from the use of natural computing methods for optimisation, search, and development.

1a. Overall contribution to teaching portfolio

[Explain what motivates the course proposal, e.g. an emergent or maturing research area, a previous course having become outdated or inappropriate in other ways, novel research activity or newly acquired expertise in the School, offerings of our competitors.]

This course was already taught and the plan is to adapt it only slightly to include recent developments and to make it more suitable for distance students.

The earlier NAT course was taught in the same way as many other 10 point courses with 17+1 lectures. 8 tutorials, 2 courseworks (10+20 percent) and an exam (70 percent of the course mark). The on-line course will differ from this scheme in some details, as described in last-year's NCO proposal.

Based on the experiences with the IVR inverted classroom scheme and after discussion with other staff, the course NCN will be taught using these mechanisms:

1) The lectures are delivered as pre-recorded videos via the web. Each lecture consists of 2-4 topic segments. Each topic segment has the PDF slides, references, drill questions, and a video that is available in webm format for download or streaming on the course web page.

2) Students work individually on the two coursework assignments (10 + 20 percent). They are required to submit a report for each assignment including any code used for obtaining the reported results. The coursework is marked based on the report. Assignments will be similar to the assignments of the NAT course.

3) In a weekly presence session spontaneous discussions are encouraged based on the drill questions or questions arising from the coursework and the video content. Pre-submitted questions by the students will be answered either in the chat session or in a video message.

4) All students are required to take short weekly tests (10 multiple choice questions, mainly bookwork, 10 - 15 min per week) which are automatically and instantaneously evaluated. Each test can be taken only in the respective week and is worth 1% of the course mark. One of the weekly test questions will require the use of Matlab code that is provided on the course page. The first two of the ten tests will test relevant background knowledge, i.e. mainly probability theory and linear algebra. Empirical research in online-education has shown that this measure is effective in encouraging a continuous engagement of distance learning students with the course. In order to make the learning experience comparable, also NCN students will be required to take the tests.

5) There is a written exam worth 60%, consisting of one obligatory question (with 10 subparts covering the whole course), and then a choice of one other question out of two questions.

1b. Target audience and expected demand

[Describe the type of student the course would appeal to in terms of background, level of ability, and interests, and the expected class size for the course based on anticipated demand. A good justification would include some evidence, e.g. by referring to projects in an area, class sizes in similar courses, employer demand for the skills taught in the course, etc.]

Natural computing continues to be an attractive subject which is widely applied such that a course that provides applicable knowledge on the efficient use of natural computing algorithms can be expected to be in demand.

NCN will provide a background on biologically inspired computing and a working knowledge of natural computing methods. It will present natural computing in a CS context, i.e. it will present natural computing methods as stochastic algorithms that are applicable to a number of practical problems. It will include a strong theoretical component that provides in-depth insights into the workings of the algorithms rather than dwell on the biological metaphors that are of little use for a clarification of the relations among the algorithms.

We expect that about 60-80 local MSc students will enrol in NCN per year. In addition a number of 20-40 UG students are expected. We also expect about 20 students for the NCO instance.

1c. Relation to existing curriculum

[This section should describe how the proposed course relates to existing courses, programmes, years of study, and specialisms. Every new course should make an important contribution to the delivery of our Degree Programmes, which are described at http://www.drps.ed.ac.uk/12-13/dpt/drps_inf.html. Please name the Programmes the course will contribute to, and justify its contribution in relation to courses already available within those programmes. For courses available to MSc students, describe which specialism(s) the course should be listed under (see http://www.inf.ed.ac.uk/student-services/teaching-organisation/taught-course-information/year-guides/taught-postgraduate-year-guide/degree-requirements/specialist-areas), and what its significance for the specialism would be. Comment on the fit of the proposed course with the structure of academic years for which it should be offered. This is described in the Year Guides linked from http://www.inf.ed.ac.uk/student-services/teaching-organisation/taught-course-information/year-guides.]

NAT was a level 9 course taken mostly by 3rd year UG and VUG students, but also some MSc students. It was one of the options recommended for AI degrees. The delivery of this course was discontinued because it did not feed into higher courses and seemed therefore less indispensable than other courses. This situation has changed with the increase of the importance of data science, where metaheuristic methods can be expected to continue to play a role. Also for disciplines such as optimisation, network science, (swarm) robotics, computational physics, decision making, modelling, design, natural computing can provide practical solutions, i.e. NCN will present itself as a useful complement for such courses.

1d. Resources

[While course approvals do not anticipate the School's decision that a course will actually be taught in any given year, it is important to describe what resources would be required if it were run. Please describe how much lecturing, tutoring, exam preparation and marking effort will be required in steady state, and any additional resources that will be required to set the course up for the first time. Please make sure that you provide estimates relative to class size if there are natural limits to its scalability (e.g. due to equipment or space requirements). Describe the profile of the course team, including lecturer, tutors, markers, and their required background. Where possible, identify a set of specific lecturers who have confirmed that they would either like to teach this course apart from the proposer, or who could teach the course in principle. It is useful to include ideas and suggestions for potential teaching duty re-allocation (e.g. through course sharing, discontinuation of an existing course, voluntary teaching over and above normal teaching duties) to be taken into account when resourcing decisions are made.]

Course lectures: Slides for lectures of the previous NAT course will be used as part of the video lecture material. All lecture videos will become available by end of August 2018. Currently, the resources are in a custom-designed webpage set, but we expect to move some of the content into a VLE such as LEARN.

Online discussions: We expect these will involve the course demonstrators (current PhD students as a part of their tutoring activity) and will occur through the VLE.

Coursework marking: Assignments will be marked by PhD students.

Student interaction: It is important that distance learning students feel a part of both the cohort and the School/University. Resources are therefore required to engage with and encourage them to work with each other on the coursework, and engage with the tutors and lecturer and rest of the cohort using the VLE social platforms.

Coursework resources: Distance students will do the same assignments as local students did on the NAT course. These will use Matlab.

Exam preparation, delivery and marking will follow the same procedure as for the NAT course and will be similar to other courses at the school.

Course team: PhD students will be recruited as tutors and markers. Dr. Michael Herrmann will be responsible for the delivery of the NCN course.

2. Course descriptor

[This is the official course descriptor that will be published by the University and serves as the authoritative source of information about the course for students. Current course descriptions in the EUCLID Course Catalogue are available from http://www.star.euclid.ed.ac.uk/ipp/cx_sb_infr.htm.]

Undergraduate Course: Natural Computing (INFR09038)

Course Outline

School	School of Informatics	College	College of Science and Engineering

Credit level (Normal year taken)	SCQF Level 11	Availability	Available to all students (incl. distance students)
SCQF Credits	10	ECTS Credits	5
Summary	This module teaches you about bio-inspired algorithms for optimisation and search problem. The algorithms are based on simulated evolution (including Genetic algorithms and Genetic programming), particle swarm optimisation, ant colony optimisation as well as systems made of membranes or biochemical reactions among molecules. These techniques are useful for searching very large spaces. For example, they can be used to search huge parameter spaces in engineering design and spaces of possible schedules in scheduling. However, they can also be used to search for rules and rule sets, for data mining, for good feed-forward or recurrent neural nets and so on. The idea of evolving, rather than designing, algorithms and controllers is especially appealing in AI. In a similar way it is tempting to use the intrinsic dynamics of real systems consisting e.g. of quadrillions of molecules to perform computations for us. The course includes technical discussions about the applicability and a number of practical applications of the algorithms. In this module, students will learn about - The practicalities of natural computing methods: How to design algorithms for particular classes of problems. - Some of the underlying theory: How such algorithms work and what is provable about them. - Issues of experimental design: How to decide whether an metaheuristic algorithm works well. - Current commercial applications. - Current research directions.		
Course description	The lectures will cover the following subjects: - Computational aspects of animal behaviour and of biological, chemical or physical systems. - The basics of Genetic Algorithms: selection, recombination and mutation, fitness and objective functions - Variants of GAs: different types of crossover and mutation, of selection and replacement. Inversion and other operators, crowding, niching, island and cellular models - Theory: the schema theorem and its flaws; selection takeover times; statistical mechanics approaches as a theoretical basis for studying GA issues		

- Hybrid algorithms, memetic algorithms
- Pareto optimisation
- Ant Colony Optimisation: Basic method for the travelling salesperson problem, local search, application to bin packing, tuning, convergence issues and complexity.
- Swarm intelligence, particle swarms, differential evolution.
- Greedy randomized adaptive search procedure
- DNA computing, molecular computing, membrane computing.
- Applications such as engineering optimisation; scheduling and timetabling; data-mining; neural net design.
- Comparisons among metaheuristic algorithms, no-free-lunch theorems
- Experimental issues: design and analysis of sets of experiments.

Entry Requirements (not applicable to Visiting Students)

Pre-requisites	It is REQUIRED that students have passed suitable courses in Linear Algebra, Calculus and Probability or Statistics	Co-requisites	
Prohibited Combinations		Other requirements	

Information for Visiting Students

Pre-requisites As above

Course Delivery Information

Course is delivered online

Academic year 2017/18, Available to all students (SV1) Quota: None

Course Start Semester 1

Learning and Teaching activities (Further Info)

Total Hours: 100 (Lecture Hours 16, On-line tutorials 10, Summative Assessment Hours 2, Programme Level Learning and Teaching Hours 2, Directed Learning and Independent Learning Hours 70)

Assessment (Further Info) Written Exam 60 %, Coursework 40 %, Practical Exam 0 %

Additional Information (Assessment) The coursework consists of 10 weekly on-line quizzes 1% each. There are two major pieces of CWs each requiring you to program an algorithm, to perform specified tasks using this algorithm, and to present the results in written reports. The two reports are marked and are worth 10% and 20%, resp.

You should expect to spend approximately 40 hours on the coursework for this course.

Feedback will be given automatically for weekly quizzes and during online chats.

Exam Information:

Exam Diet	Paper Name	Hours & Minutes
Main Exam Diet S1 (December)	NCN	2:00

Learning Outcomes

- Understanding of natural computation techniques in theory and in their broad applicability to a range of hard problems in search, optimisation and machine learning.

- To know when a natural computing technique is applicable, which one to choose and how to evaluate the results.

- To know how to apply a natural computing technique to a real problem and how to choose the parameters for optimal performance.

- Matching techniques with problems, evaluating results, tuning parameters, creating (memetic) algorithms by evolution.

Reading List

- Melanie Mitchell: *An Introduction to Genetic Algorithms*. MIT Press, 1998.
- Floreano & Mattiussi: *Bio-Inspired Artificial Intlligence*, MIT Press, 2008.
- Xin-She Yang: *Nature-Inspired Metaheuristic Algorithms*. Luniver, 2010.
- Patrick Siarry: *Metaheuristics*, Springer, 2016.
- Clarisse Dhaenens and Laetitia Jourdan: *Metaheuristics for Big Data*. Wiley, 2016.
- Brabazon, O'Neill, McGarraghy: *Natural Computing Algorithms*. Springer, 2015

Additional Information

Course URL	http://www.inf.ed.ac.uk/teaching/courses/ncn
Graduate Attributes and Skills	Not entered
Keywords	Not entered

Contacts

Course organiser	N.N.	Course secretary	N.N.

3. Course materials

3a. Sample exam question(s)

[Sample exam questions with model answers to the individual questions should be provided. A justification of the exam format should be provided where the suggested format non-standard. The online list of past exam papers gives an idea of what exam formats are most commonly used and which alternative formats have been http://www.inf.ed.ac.uk/teaching/exam_papers/.]

These will be similar in format to the six exams for the NAT course in 2010/11 and 2011/12 . See: http://www.exampapers.lib.ed.ac.uk.ezproxy.is.ed.ac.uk/Informatics0405.shtml

3b. Sample coursework specification

[Provide a description of a possible assignment with an estimate of effort against each sub-task and a description of marking criteria.]

These will be similar in format to coursework for NAT in previous years, see http://www.inf.ed.ac.uk/teaching/courses/nat/

3c. Sample tutorial/lab sheet questions

[Provide a list of tutorial questions and answers and/or samples of lab sheets.]

These will be similar in format to coursework for NAT in previous years,

NCN has 10 sets of tutorial-style questions that will be made available via the web page as a test., see http://www.inf.ed.ac.uk/teaching/courses/nat/ for examples. The students will be given candidate solutions that contain pull-down options to be chosen by the student. The tests will be evaluated immediately, while explanations of the solutions will be provided online after the test is closed.

3d. Any other relevant materials

[Include anything else that is relevant, possibly in the form of links. If you do not want to specify a set of concrete readings for the official course descriptor, please list examples here.]

All resources listed on the course web page will be accessible to the distant students.

4. Course management

4a. Course information and publicity

[Describe what information will be provided at the start of the academic year in which format, how and where the course will be advertised, what materials will be made available online and when they will be finalised. Please note that University and School policies require that all course information is available at the start of the academic year including all teaching materials and lecture slides.]

Course content will be served from a VLE hosted by the University, pointing to the video lecture set, reading list, assignments and other relevant materials which are hosted on the normal NCN web page.

This course will be advertised alongside other Informatics courses.

4b. Feedback

[Provide details on feedback arrangements for the course. This includes when and how course feedback is solicited from the class and responded to, what feedback will be provided on assessment (coursework and exams) within what timeframe, and what opportunities students will be given to respond to feedback.

The University is committed to a baseline of principles regarding feedback that we have to implement at every level, these are described at http://www.docs.sasg.ed.ac.uk/AcademicServices/Policies/Feedback_Standards_Guiding_Principles.pdf. Further guidance is available from http://www.enhancingfeedback.ed.ac.uk/staff.html.]

Students will get formative feedback through weekly tests via automatic evaluation of test questions, and the VLE's online discussion forum.

The tutors will give feedback on the 5 non-assessed drill exercises. Summative feedback will occur through written feedback on their assignments and the exams.

Additionally, we will monitor class issues through the use of a class student representative, and also occasional SurveyMonkey (or equivalent) polls.

Engagement of students with the course will be tracked continuously and compared to patterns that are reported in the online education literature.

4c. Management of teaching delivery

[Provide details on responsibilities of each course staff member, how the lecturer will recruit, train, and supervise other course staff, what forms of communication with the class will be used, how required equipment will be procured and maintained. Include information about what support will be required for this from other parties, e.g. colleagues or the Informatics Teaching Organisation.]

We expect that the course tutor(s) will provide support to course students and flag any issues that arise related to the delivery of the course, as is the case with the normal delivery of local courses. As this course will also be part of the Data Science and later RAS Distance Education effort, the Data Science team or University support teams will handle most issues concerned with remote content delivery, e.g. issues with university-hosted software or VLE. Communication with the distant students will primarily occur via the VLE and a course emailing list. Minimal support is required from the ITO beyond the normal support for the local cohort of the course.

5. Comments

[This section summarises comments received from relevant individuals prior to proposing the course.]

5a. Year Organiser Comments

[Year Organisers are responsible for maintaining the official Year Guides for every year of study, which, among other things, provide guidance on available course choices and specialist areas. The Year Organisers of all years for which the course will be offered should be consulted on the appropriateness and relevance on the course. Issues to consider here include balance of course offerings across semesters, subject areas, and credit levels, timetabling implications, fit into the administrative structures used in delivering that year.]

5b. Degree Programme Co-Ordinators

[Degree Programme Co-Ordinators are responsible for maintaining the official Degree Programme Specifications and Degree Programme Table for a given subject area which, among other things, specify the content of courses taken in a Degree Programme. The Degree Programme Co-Ordinators of the relevant subject areas that the course is proposed for should comment on the fit with the current curriculum of the relevant Degree Programmes. Issues to consider here are dependencies arising from pre-, co-requisites, and forbidden combinations, balance of different topics in a Degree Programme, etc.]

5c. BoS Academic Secretary

[Any proposal has to be checked by the Secretary of the Board of Studies prior to discussion at the actual Board meeting. This is a placeholder for their comments, mainly on the formal quality of the content provided above.]