The Efficient and Viable Country-Oriented Attainment of Absolute Environmental Sustainability: A Demonstration on the ESI 2002

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ABSTRACT

A country-oriented methodology for attaining absolute environmental sustainability (ES) is proposed and demonstrated on the environmental sustainability index (ESI) 2002. The optimal means of deriving the ES levels/scores of the participating countries from the various ESI 2002 constructs is established and, subsequently, encoded in a real-valued evolution strategy (EvS) for the viable and flexible country-specific ES improvement towards maximal ES. The EvS employs: (a) constraints concerning the number and combinations of constructs that can be concurrently improved; (b) limited and progressively decreasing construct improvements expressing the escalating difficulty of improving any construct as the construct and/or overall ES approach(es) maximum. Demonstrations on countries with diverse characteristics and comparisons with alternative optimization methodologies highlight the versatility and applicability of the proposed procedure to any country with data that is compatible to that of the participating countries.

KEYWORDS

Country-Specific, Environmental Sustainability (ES), Environmental Sustainability Index (ESI) 2002, ES Maximization, Evolution Strategy (EVS), Gradual, Viable Improvement

1. INTRODUCTION

The attainment of absolute environmental sustainability (ES, Financial Times Lexicon) constitutes a prerequisite for the survival of life on Earth as we know it. Global ES is focused upon the conservation - and, ideally, the improvement - of the “health status” of the flora, fauna and natural resources worldwide, with the attainment of absolute ES defined in the Brundtland Report (Brundtland, 1987) as “a state in which the demands placed on the environment can be met without reducing its capacity of allowing all people1 to live well, now and in the future”. Further to an aspiration of ES-oriented groups, societies and organizations as well as countries, absolute ES is a prerequisite for the survival of life on Earth as we know it.

A multitude of ES-related indices appears in the relevant literature and the Web (the interested reader is referred to Tambouratzis (2016) for a representative list), with most of them focusing upon the three pillars - economic, environmental and social - of ES (Elkington, 1994). In this piece of research, the environmental sustainability index (ESI) 2002 (Samuel-Johnson, Esty, Levy et al., 2002) is used for guiding any interested country - either participating or with data that is consistent with

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that of the participating countries - towards the attainment of maximal ES. The specific index has been selected as it constitutes the first complete version of the ESI, a methodology that has become a landmark of ES-related indices and continues to be updated and published biennially to this day in the form of the environmental performance index (EPI, Hsu & Zomer, 2016). In order to assess the confidence that can be attributed to the proposed ES improvement/optimization procedure, an investigation of the means and consistency of construction of the ESI 2002 is initially performed, with the ESI 2002 dataset (NASA earth data, 2002) used for modelling the means of deriving the ESI scores from the two ESI 2002 constructs (namely z-score/indicators² and components). The most accurate, general and simple ESI construct(s)-score relationship is subsequently employed as fitness function to a real-valued evolution strategy (EvS, Rechenberg, 1973; Schwefel, 1974; Beyer, 1996) which instigates a realistic country-bespoke, step-by-step monotonic procedure for the maximally effective - yet gradual - as well as consistent attainment of (near-)maximal ES. The - characteristic of EvS – lack of crossover is combined with exclusively positive mutations and constraints concerning

1. A realistic upper limit to the number of constructs that can be concurrently improved
2. Combinations of constructs that can/cannot be modified at the same time
3. The rising difficulty of enhancing any construct as its value and/or country ES increases, which collectively promote the versatility, robustness and overall applicability of the proposed approach for ES maximization at the country level.

The remainder of this contribution is organized as follows:

- Section 2 (Materials and Methods) introduces the ESI 2002 dataset and describes the construction of the ESI 2002 index in terms of inspiration, building blocks, construction, participating countries and corresponding levels of ES (Materials), followed by the implementation of mathematical, statistical and computational intelligence-based methodologies (Methods) for accomplishing maximally accurate duplication/reproduction and, subsequently, generalization/prediction of the ESI 2002 scores, rankings and clusters. Concurrently, evolutionary strategies (EvSs) are put forward as a suitable evolutionary computation (EC)-based means of steering any country (either participating in the creation of the ESI 2002 index or with data that is compatible to that of the participating countries) towards the attainment of maximal ES.
- Section 3 (Results) quantitatively evaluates the competence of the proposed EvS at guiding any interested country (a) through a step-wise ES increase and (b) towards the attainment of absolute ES, in a realizable, flexible as well as efficient manner. The evaluation is followed by a critical analysis of the obtained results and a comparison with alternative methodologies.
- Section 4 (Conclusions) summarizes the findings of, and puts forward future extensions to, the presented research.

2. MATERIALS AND METHODS

2.1. Materials - The ESI 2002

The ESI 2002 dataset was conceived by the Global Leaders of Tomorrow Environment Task Force during the 2002 World Economic Forum Annual Meeting and was, subsequently, implemented in collaboration with the Yale Center for Environmental Law and Policy (Yale University) and the Center for International Earth Science Information Network (Columbia University). The aim of that collaboration was to create a gauge of ES which “quantitatively expresses the trajectory (progress in time) towards ES” (Samuel-Johnson, Esty, Levy et al., 2002), as applied to 142 “participating” countries in terms of their ESI scores and rankings (shown in the first three columns of Appendix I). The collected data (NASA Earth data, 2002) was:
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