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ALAIMO Leonardo Salvatore, CONIGLIARO Paola
A partial ordering application in synthetizing dimensions of subjective well-being

The present work originates from a study on the relationships between labour status (LS) and subjective well-being (SWB). It analy, ses Italian data from the European Union Statistics on Income and Living Conditions (EU-SILC) 2013. In that edition, Eurostat adopted an ad-hoc module on SWB, inspired by the Guidelines on Measuring Subjective Well-being (OECD, 2013). These guidelines recommended to consider the three main dimensions of SWB: cognitive, affective and eudaimonic.

According to OECD's Guidelines, the three main dimensions of SWB refer to non-elementary concepts. The Guidelines suggest choosing indicators able to represent the multidimensionality of the concepts. The patterns of analysis must respect this multidimensionality, and the choice of data processing methods must conserve the informative potential of each item (Maggino, 2015).

Eurostat (2015) formulated its analysis comparing national aggregate data. We chose to analyse the micro-data. We applied the analysis to quite 16 thousands of respondents. In order to represent the three dimensions of SWB, we chose: 1) the question on satisfaction with life which is representative of the cognitive dimension; 2) the question on meaning of life, which is considered by Eurostat as a proxi of the eudaimonic dimension; 3) the five items on emotions occurred to respondents during the previous four weeks, which represent the affective dimension.

We started with processing the five ordinal variables describing emotions. We saw that the correlation between the five items concerning affects, were not so high. This result and other observations on conjoint distribution of levels of emotions, showed that there were a significant number of respondents which are both happy and sad, serene and nervous.

We decided to apply a Partial Order methodology to aggregate the five dimensions of emotional status. This methodology allows, in fact, to deal with ordinal variables concerning multidimensional phenomena and to analyse complex relationships at micro level. We defined a Partially Ordered Set (POSET) using Parsec, which is a package developed in R by A. Arcagni and M. Fattore (2014). In that way we obtained a synthetic dimension which we named Emotional Status. Eventually, applying the Partial ordering methodology to the three dimensions of subjective well-being, we calculated a subjective well-being synthetic index. The last step of this analysis compare the results of this method with those of other synthesis methods.

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(Workshop session 2)

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Dependent indicators for environmental evaluation of desalination plants

The selection of appropriate measures of environmental performance for a desalination plant will depend on the nature of performance, type and quantity of information available and the degree of accuracy required in the representation. Many indicators are available and used in different levels in desalination ranking. Some desalination environmental indicators may be correlated to each other, and this helps to reduce the number of indicators and collected data. Our specific approach in this work is to know which type of correlations between environmental indicators can affect decision-making when it is done by ranking and to what extent. In the first stage, random data were generated to represent environmental data sets with objects and indicators. Then different correlations were used to provide dependencies. Finally, decision-making is generated from data using ranking to observe the effect of inclusion/exclusion of dependent data. The methodology is applied to case studies with real desalination data to strengthen the conclusions. Results show that all available indicators should be included in decision-making however in cases of incomplete data sets, dependencies should be investigated to fill for missing data. If this fails; exclusion of dependent data can be done with little risk of incorrect decisions only if the number of indicators are relatively high to the number of objects.

Moreover, this exclusion is safer if the dependence relation is simple.

(Workshop session 6)

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Identifying drivers of land degradation in Xilingol, China, from 1975-2015

Land degradation occurs in all kinds of landscapes over the world, the uncertainty of determinants; degree, distribution and effect have attracted and continue to attract attention all over the world. The drivers of land degradation are not single, are numerous, complex and interrelated, with often context–dependent characteristics (Dimobe et al., 2015). Comparison the land degradation driver and adjust the specific ecological protect measure in some specific area is necessary. Under this background, Multiple–indicators analysis can be using to make prediction and evaluate a range of land degradation process and provide results to decision makers.

Xilingol, located in the centre of Inner Mongolia, China, is renowned for its vast grasslands and nomadic culture. Xilingol grasslands developed under arid and semi-arid continental climate conditions and affected by degradation in recent decades. Comparing and ranking the land degradation drivers at county level, in a bid to developing better strategies for combating land degradation is impending for this region. We have collected 9 kinds of driving factors and grouped them into four categories driving data, using partial order theory, made a comparison of the land degradation drivers at county level. We have identified that: ecological engineering projects have worked effective at some extent, the implementation of policy should be biased according their drivers, like more measures (e.g. fenced heavy degraded area) should be launched in agro-pastoral and high coverage grassland area that have suffered more effect from urbanization/industrialization; as well control the population and livestock in agro-pastoral area and middle coverage grassland area, like considered the support and help poverty, modify the animal husbandry mode firstly in this area.

Results are challenged by a number of laminations referring the data quality, types, temporal-spatial resolution. HDT (Hasse Diagram Technique) is a data driven evaluation method, which neither allows the compensation of indicator values nor the aggregation of different indicators, thus, the HDT is a highly objective and transparent decision support tool which facilities intensive data analysis (Kardaetz et al., 2008). Scientists before me have shown that all collected drivers lead to an accelerated land degradation. With the help of HDT it is possible to perform a much more detailed analysis. It could be shown that large differences at county level allow for measures tailored to the county. The results fill the gap in understanding the extent and driving factors of land degradation in different counties, even though HDT have challenged by a set of limitations referring data quality, like spatial resolution for drivers data, we have provided new empirical insights into the land degradation management.

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(Workshop session 6)

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Ranking Karnataka districts by the Multidiemsnional Poveryt Index (MPI) and by applying simple elements of partial order theory

This study focuses on the Multidimensional Poverty Index (MPI) ranking (see Alkire and Foster 2007, rev. 2008 for the MPI). The standard ranking process of the MPI produces a single total (linear) rank of units by simply ordering them from the best to the worst (or the inverse) as function of their MPI score (Alkire and Santos 2010). However, units are not necessarily comparable regarding all 10 indicators simultaneously on which the MPI is based. We use the 2012/13 India District Level Household Survey wave four with a special focus on the State of Karnataka. By using partial order theory (i.e. the Hasse Diagram technique and the software package PyHasse, see Bruggemann et al. 2014, Bruggemann and Patil 2011), we found that, in Karnataka, the number of incomparabilities greatly exceeds the number of comparabilities. This indicates that the aggregation process leading to the MPI hides the individual role of indicators. To analyze comparabilities and incomparabilities, we performed several tools provided by partial order theory.

Specifically, we dealt with local partial order, antichain, and average height analysis. In contrast with the standard MPI ranking, partial order theory provides average height which does not only account for comparable districts, but also considers to what extent incomparable districts influence the position of a district in the ranking. We found that the results of partial order ranking deviate considerably from those of the MPI ranking. Because of incomparabilities, for the most of our sample, the MPI ranking does not provide an adequate ranking. Moreover, all our findings show that the multidimensional poverty structure (i.e. types of deprivation among multidimensionally poor people) in the state of Karnataka varies across its districts highlighting the complex nature of poverty configurations (i.e. each district has its specific capability deficits and, therefore, they need their own and specific poverty reduction management plans). Consequently, the Hasse Diagram technique can be seen as a synthetic ranking tool or a robustness tool that complements the standard ranking process of the MPI.

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(Workshop session 5)

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Crucial weights, towards an understanding of weightings by partial order theory

Many decisions based on a Multi-IndicatorSystem (MIS) are performed just by a weighted sum of normalized indicators. This approach is attractive because of its simplicity which facilitates the public acceptance and because the knowledge of stakeholders can be included. The disadvantages are nevertheless obvious: By such an approach potential conflicts expressed by the values of single indicators are suppressed. An idea to combine the advantages of linear weighted sums and partial order theory is to allow the weights to be varied, so that a sharp knowledge about the numerical values of weights is somewhat relaxed. A framework was developed, where the uncertainty in the knowledge of weights is parameterized by an evolution parameter (Bruggemann and Carlsen 2017, Bruggemann et al. 2012).

Here this theoretical concept is extended and applied to MIS arising from environmental chemistry, engineering sciences and sociology.

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(Workshop session 4)

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BRUGGEMANN Rainer, KERBER Adalbert

Evaluations as sets over lattices, application point of view

In many science fields measurements are possible such that metric data are obtained. When a ranking is desired, then a set of metric indicators form a Multi-IndicatorSystem (MIS) to quantify a complex ranking aim, and partial order theory can be applied on them. In several publications it was shown, how concepts of lattice theory can be applied to derive an evaluated set of implications (see Bruggemann et al. 2011, Kerber 2017a, Kerber 2017b, Kerber 2005, Kerber and Bruggemann 2015, Duquenne 1987). Manually performed calculations based on the lattice theoretical concept are in principle simple, nevertheless they are very tedious.

Starting from the concept of t-norms and their residual norms the possibilities of obtaining (evaluated) implications from every subset of objects are discussed. The concept of fuzzy implications is demonstrated by the example of the pollution by lead, cadmium, zink and sulfur along the southern part of river Rhine.

Finally, the necessity of further research will be discussed.

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(Workshop session 3)

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CAPERNA Giulio

Introduction of weights in poset-based synthetic indicators

In this work, an innovative way to introduce the information of weights in the construction of synthetic indicators with poset approach is proposed. The construction of indicators is a consolidated practice to describe complex and unobservable concepts. This purpose is usually achieved following some fundamental steps, such as the definition of the aggregation method and the weights of elementary variables.

In literature, most of the indicators are developed on a macro level to compare large entities, such as countries and other institutions, for this reason, the constituting variables are usually proportions or averages, which are quantitative. As a consequence, the most common aggregation procedures are the arithmetic and geometric mean, and the weights are included in those means.

Nowadays, the request for indicators on the micro level is getting more and more common, and the available information is measured on the ordinal and dichotomous scale in the vast majority of cases. Fortunately, the poset alternative is available. This approach allows to compare the elements of a group according to their reciprocal order and compute a score which represents the position of the element respect to the others (average rank). The concept of average rank can be handy for the synthesis of information, both if we consider its approximation by formula or the sampling of linear extensions. Actually, one of the most significant limitations to the use of this approach for the construction of indicators is the absence of a method to introduce the values of weights in the intuitive form of a number for every constituting variable.

This work proposes two possible alternatives to overcome this limitation. In the first, the formula for the approximation of average rank is integrated with the information on the importance of the constituting variables (weights). In the second, the same aim is achieved defining a measure of representativity on the sampled linear extensions to compute the sample average rank.

(Workshop session 4)

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Looking for alternatives? Split-shots as an exemplary case

In the news we are virtually on a daily basis confronted with now this or that is not good for humans and/or the environment, which obviously calls for alternatives as many of the suspected, or proven harmful substances are actually in their own sense beneficial for their specific purposes. This process may be rather complicated involving a multitude of steps (NAS, 2014a, b). As an advantageous decision support tool partial order methodology may be introduced. The paper describes the use of partial order methodology applied for the search for suitable alternatives to split shots as an exemplary case. Data are adopted from the

National Academy of Science report on the selection of chemical alternatives (NAS, 2014a).

Split shots have traditionally been produced by lead (Pb) as a relatively soft material that has a good malleability and is corrosion resistant. Further the end product has an excellent availability and is obtainable at a relatively low price. However, Pb is both from an environmental and human health perspective an unwanted compound and thus possible alternatives are searched for. In the present study 5 alternatives were includes (NAS, 2014a, p180), i.e., bismuth (Bi), Ceramic (cer), Steen (ste), Tin (Sn) and Tungsten (W).

An assessment of potential alternatives to Pb for split shots includes a series of indicators in addition to the above-mentioned cost/availability indicators. The indicators are grouped in three main categories, i.e., Technical and Performance Criteria (TRCr), Environmental Criteria (ENCr) and Human Health Criteria (HHCr), respectively, where TPCr includes 5 sub-indicators, whereas both ENCr and HHCr includes 3 sub-indicators each.

Due to the low number of components (6) relative to the total number of indicators (13) a direct partial ordering of the components based on all indicators is not meaningful. Even ordering based on the single indicators groups gives only little sense. Thus, some kind of aggregation of the sub-indicators appears appropriate. This aggregation will be discussed.

The paper will discuss both the ordering of indicators for the 6 components as well as the ordering of the components eventually suggesting the more appropriate alternative to the present lead split shots.

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(Workshop session 6)

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CARLSEN Lars

There is no such thing as a free lunch! Who is paying for our happiness?

In a report published by the Danish Ministry of Environment (HRI, 2012) it is stated that "*it is no longer possible to imagine a future where the pursuit of happiness is not somehow connected to sustainability. As the human species continues its quest for happiness and well-being, more emphasis must be placed on sustainability and the interaction between sustainability and happiness*" and further "*there is a growing awareness of how sustainability and happiness can go hand-in-hand*". However, the term happiness is not uniquely defined, and a somewhat broad definition could be "the experience of joy, contentment, or positive well-being, combined with a sense that one's life is good, meaningful, and worthwhile" (Lyubomirsky, 2008). A more well-defined index for happiness has been reported based on seven indicators:

1. GDP per capita is in terms of Purchasing Power Parity (PPP)
2. Social support (or having someone to count on in times of trouble)
3. The time series of healthy life expectancy at birth
4. Freedom to make life choices
5. Generosity
6. Perceptions of corruption
7. The country's own perception of doing better or worse than the hypothetical country Dystopia

In the present study data from the 2016 World Happiness Index (HI, 2016) ranking 157 countries according to their happiness as expressed by these 7 indicators are used. The resulting Happiness Index (HI) is generated by a simple arithmetic aggregation of the 7 indicator values.

In a recent study this index has been analyzed (Carlsen, 2018) applying partial ordering techniques, disclosing, among other features that the most important sub-indicator appears to be the 'Dystopia' indicator whereas, e.g., the gross domestic product per capita in terms of purchasing power parity plays only an inferior role. On an average basis the following 10 countries were found as the happiest countries: Iceland, Australia, Switzerland, Norway, New Zealand, Denmark, the Netherlands, Finland and Austria, whereas the bottom of the list displays Madagascar, Congo (Brazzaville), Egypt, Benin, Chad, Gabon, Burundi, Angola, Armenia and Yemen as the least happy countries. A short video presentation highlighting the main finding of the study can be found at YouTube.
(see https://www.youtube.com/watch?v=DfCVrVlRB1c).

The obvious question that arises is now: who is paying for our happiness?
To some extent a study of the Happy Planet Index (Jeffrey et al., 2016) may give some answers. The Happy Planet Index (HPI) is focused on sustainable wellbeing for all and is based on 4 indicators, i.e., experienced wellbeing (EWB), life expectancy (LEX), inequality of outcomes (IoO) and the ecological footprint (EFP). An approximate formula for calculating HPI is given by

$$HPI \approx \frac{LEX * EWB * IoO}{EFP}$$

The eventual calculation of HPI uses a somewhat more elaborate formula applying 'some technical adjustments are made to ensure that no single component dominates the overall score' (Jeffrey et al., 2016), where inequality adjusted values of LEX and EWB are used and some scaling constants are incorporated.The ranking based on HPI is significantly different from that based on HI and a posetic based data analysis of the HPI dataset leaves no doubt that the culprit in this respect unequivocally is the ecological footprint. Introducing the GDP expressed as the Purchasing Power Parities (PPP) again discloses the minor role of financial wealth as a factor for sustainability in terms of happiness. Hence, apparently through our (non-sustainable) exploitation of nature we let our planet pay for our happiness! And, with a small rewriting of an old Beatles song, it can (again) be concluded that "I don't care too much for money, money can't buy me happiness".
(see https://www.youtube.com/watch?v=srwxJUXPHvE).

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(Workshop session 5)

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A partial order approach to collective choice and other aggregation problems

Orderings and rankings are crucial tools for policymakers, both when they have to make decisions and when they have to define the timing and the target groups of such decisions. Most frequently, though, orderings come in the form of aggregations of distinct preferences, judgements or criteria. It is sometimes overlooked that such aggregations are only meaningful if the procedure to identify them complies with a number of requirements that usually involve a normative-ethical side and a mathematical-formal side. When they don't, they typically fail to represent what the practitioner was expecting. This family of issues have long been studied by branches of economics and mathematics that are collectively known as Social Choice theory and that have provided a full account of the challenges of such discipline, with Arrow's impossibility theorem among its most well-known results.

In this paper, we build on existing literature on Social Choice, expanding it to accommodate two crucial properties that are highly relevant when producing orderings from the individual preferences or judgements of a population: ensuring that the collective ordering of alternatives shows some basic pluralistic requirements and making sure that a collective ordering is still possible when value judgements partially or completely prevent aggregation. The paper is organized in three sections. In the first, we discuss the implications of dropping the requirement that collective preferences be represented as a complete ordering, and the advantages of identifying a complete collective ordering from partially ordered collective preferences rather than, directly, from individual preferences. In the second section, we exploit the well-known generalizability of the problem of aggregating preferences to other aggregation problems involving multidimensional values, criteria and the likes. In this section, we compare the consequences of the procedure we previously discussed with the outcomes of other popular methods to aggregate criteria, illustrating the differences with an example referred to well-being studies. In the third section, we discuss the implications of our approach from a social and economic perspective, with a particular focus of well-being measurement.

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(Workshop session 5)

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DI BELLA Enrico, MAGGINO Filomena, LEPORATTI Lucia

Measuring gender equality: a comparison of different techniques to build synthetic indicators

Gender equality represents a central issue in the socio-economic background of our society and, consequently, its study is gaining an increasing attention in the international debate (consider, for instance, the recent constitution of the W20 group). During the last 20 years, the international literature proposed a number of indicators that aim at measuring gender equality (or gender inequality). Among the others, it is worth recalling the Gender Gap Index by World Economic Forum, the Gender Development Index by United Nations and the Gender Equality Index (GEI) proposed by the European Institute for Gender Equality (EIGE). Although sharing some common characteristics, these indicators differ from one another on crucial points,
above all in the set of variables used to define the domains of gender equality, selection that is naturally driven by the data availability. In Italy various experiences on measuring gender equality at sub-national level have been proposed but the resulting indicators are generally focused on specific domains and there are no studies that analyze this phenomenon as a whole.

The aim of this work is twofold: on one hand we propose a regional decomposition of the EIGE gender equality index (R-GEI); on the other we compare the synthetic indicator obtained following the EIGE methodology with a poset based synthetic indicator (POR-GEI). Albeit many variables used by EIGE can be derived at NUTS-2 (regional) level using Eurostat microdata (EU-SILC; EU Labour Force Survey), sample size is not always adequate to guarantee acceptable standard errors for regional estimates; moreover, some variables are not available (or do not make sense) at subnational level. Therefore, we decided to replace some of the original GEI variables with equivalent variables available or reasonable at regional level. The new R-GEI is obtained reproducing the EIGE methodology and it is compared to the POR-GEI index that exploits poset theory for aggregating indicators. Our findings show that R-GEI and POR-GEI produce quite similar results but the use of POR-GEI brings to some interesting advantages in the interpretation of the territorial differences in gender equality in Italy.

(Workshop session 5)

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Building rankings from hierarchical systems of ordinal indicators

In this study, we address the problem of deriving a ranking of statistical units, starting from a hierarchy of ordinal multi-indicator systems (MISes). The problem is relevant, since in many socio-economic applications, elementary indicators are organized into homogeneous subsets, possibly on different levels, and the problem arises to determine a final ranking, out of such a "pyramidal" indicator structure. A paradigmatic example pertains to the measurement of well-being, where social indicators, economic indicators, subjective indicators… form different MISes; these are often synthesized by indicators which are, in turn, condensed into a final index. Since at each step some information is lost, by reducing MISes to single indicators, the final index may well be scarcely effective, as a synthesis of the whole hierarchy of indicators. In order to reduce as much as possible such information loss, we first represent each MIS in the hierarchy as a poset, whose elements are the profiles of the statistical units over the indicators of the MIS itself; next, we try to "combine" the posets into a new "synthetic structure" (that in the following we call "synthetic poset", rather informally) which keeps as much information as possible on the comparabilities and incomparabilities of the input posets; as the last step, we derive a final ranking, from such synthetic poset. This way, by keeping as much complexity as possible along the process and postponing to

the end the "dimension reduction" step (i.e., the ranking extraction), information loss is likely to be reduced. To accomplish this procedure, we represent each input poset by means of its mutual ranking probability (MRP) matrix and turn the problem of building the synthetic poset into the problem of building a MRP matrix which approximates, as much as possible, the input MRP matrices. The approximation problem is addressed in an information-theoretical way, measuring distances between MRP matrices using so-called Jensen-Shannon divergences. As a generalization of this approach, we also consider the case where some frequency distributions are defined on the input posets, as usually happens when real data are considered, and many statistical units may share the same poset elements. In order to develop such a ranking procedure, some preliminary results must be worked out, which are of interest on their own. In particular, the possibility to define a metric between posets, via the JensenShannon divergence of the corresponding MRP matrices, paves the way to the possibility of developing clustering procedures on families of partial orders and/or applying other dimensionality reduction algorithms (like Multidimensional Scaling or Isomap), to perform pattern analysis on complex ordinal structures.

We test this new approach to ranking extraction, by applying the above logic thread to a real dataset and implement the needed functions in the R language, within the PARSEC package.

(Workshop session 2)

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Complex information. A whistle-stop tour of contemporary statistics

This paper intends to review existing analytical tools in statistics "through bitesize coverage of key topics" (see Everitt 2011). In other words, it intends to provide nonspecialists with a bird's-eye overview of some well-known and available statistical tools to deal with the fundamental task of measuring complex phenomena.

Official statistics has treated complex phenomena by different means, for example by developing composite indicators or by defining dashboards of indicators. The paper will present these two cases, with particular attention on their advantages and drawbacks.

Measuring complex phenomena requires first of all defining the relevant information base. In several domains, the information base that is used for policy purposes takes the form of a multi-indicator system, which is normally assembled in form of a scoreboard. Notable examples in the EU are: • macroeconomic imbalance: MIP scoreboard • short-term economic performance: PEEIs dashboard • society: Pillar of Social Rights or Quality of Life indicators • sustainability: 2020 strategy Our review will cover "standard" multivariate statistical techniques such as principal component analysis, factor analysis, cluster analysis, multidimensional scaling, together with some tools borrowed from neighbouring disciplines (i.e. operations research) such as data envelopment analysis.

New impetus has been brought in this field by the consideration of qualitative information, which requires a further level of conceptualisation and different techniques. First attempts were based on the discretisation of qualitative information, which can however be questionable. Methods derived from partial order theory have been considered as an alternative because do not require transforming qualitative information into numbers.

The paper will first introduce some considerations about complexity and indicators and will then focus on three different steps: conceptualisation, measurement and analysis. The analysis part will cover the above-mentioned techniques. A section with applications of some of the illustrated methods will close the paper, showing how they are used in particular contexts.

The authors do not intend to suggest any ranking or preference among the presented tools. Each method has its own relevance, and most of them are actually meant to be complementary to each other. What the authors suggest is that the use of any method should be cast into a holistically and organically designed systemic process.

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(Workshop session 1)

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KERBER Adalbert, BRUGGEMANN Rainer

Evaluations as sets over lattices, mathematical basis

Evaluations using parameters can usually be considered as sets over lattices. This has the advantage that we can choose a suitable set theory on these sets, with a logic, and based on the concept of residual t-norms (see Bruggemann et al. 2011, Kerber 2017a, Kerber 2017b, Kerber 2005). Hence, for example, we can use either a strict or a less strict argumentation. In this first part the mathematical idea is described

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(Workshop session 3)

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LENFERS Ulfia A., BRUGGEMANN Rainer

An attempt to explore survival strategies of African trees and bushes in two different landscape by partial ordering techniques

Land use and climate changes induce shifts in plant functional diversity and community structure. Comparing the past, current, and potential future distribution of indicator species is important for detecting these biodiversity shifts. Therefore, a thorough understanding of the main factors affecting the distribution of those species is necessary. Because of the complexity of the underlying systems, a multivariate method should be applied.

The mathematical concept of partial orders was recently used to analyse existing data in some domains, e.g. chemistry. For this study, it was applied to plant ecology in two different plant communities in South Africa. The resulting partial order ranking is visualized by Hasse diagrams. One example shows different tree species of the savanna ecosystems within the Kruger National Park, South Africa. The second example is concerning plant species in the shrub plant community within the Karoo. Different leaf traits were mathematically contrasted against different species in the same ecosystem.

We found that partial orders in conjunction with Hasse diagrams are interesting tools to analyse multivariate systems. It can be utilized to sharpen new research hypotheses and is also very valuable for conceptual modelling.

(Workshop session 7)

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Indicators in the framework of partial order

Indicators play an increasing role in characterizing complex systems and -to some degree- in decision problems, when a ranking is thought of as an intermediate step for a selection of optimal, or depending on external constraints - suboptimal options.

When ranking is the aim, then usually the ranking aim cannot be described by a single indicator, but needs a set of indicators, called a Multi-Indicatorsystem (MIS). Typically an analysis of MIS is confronted with the following problems:

• Scaling level: What to do, if the indicators are on a nominal, ordinal or metric level • Relevance of indicators: Are we confronted with somewhat which may be called information noise? • Role of the inherent characteristic of partial orders, the incomparabilitiy. Is incomparability really an unavoidable disadvantage?

Methods to check these points are presented and critically discussed.

(Workshop session 1)

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Assessing inhomogeneous indicator-based typologies through the reverse clustering approach

The paper addresses the following problem: We are given a typology of spatial units (in this case: Polish municipalities, close to 2 500 in number), elaborated for planning and monitoring purposes. This typology was developed on the basis of a complex procedure, involving quite a number of indicators. Moreover, the set of indicators used was not uniform across all (types of) municipalities, for the procedure had a "branching" character, implying different subsets of criteria for particular types. At the same time, quite naturally, the number of types had to be kept "reasonable" for pragmatic purposes. This gives rise to such questions as: what about the municipalities, which tend to fall close to the (implicit) "borders" of the thus defined types? can we, at all, speak in an intelligible manner of such "borders"? and: what about the criteria that cannot easily be expressed numerically along with the other ones for all the units (the effects of the clear incommensurability of some of the criteria)?

In view of these questions an exercise was performed by the authors, aimed at (1) providing a comparative material for the typology elaborated, (2) basing this comparative material on a uniform set of data (variables, indicators), (3) identifying the effects of (a) inhomogeneity of the original criteria and (b) of existence of incommensurable variables, hard to express on a par with the others.

This exercise was based on the "reverse clustering" approach, developed before by the authors. This approach consists in attempting to recreate some given strict partition, P_A, of a set of n objects, on the basis of a set of data on these objects, X, composed of vectors x_i, $x_i = [x_{i1},\ldots,x_{im}]$, i.e. objects, characterised by m variables. We wish to obtain some partition P_B of the set of objects that would be as close to P_A as possible (e.g. in terms of the Rand index). The procedure of minimisation of "distance" between the two partitions is performed with evolutionary algorithms, as most of the classical algorithms would fail in a very cumbersome "landscape" of optimisation.

Namely, actually, the optimisation procedure is applied to the vector Z, describing the clustering algorithm that yields the partition P_B. This vector is composed of: (i) the very choice of the clustering algorithm, (ii) the choice of its essential parameter(s) – e.g. the number of clusters, or some threshold distance etc., (iii) the weights, or choice, of variables, (iv) the distance definitions used (e.g. as expressed through Minkowski exponent).

The paper presents the issue considered, the approach applied, and, most of all, the results from the exercise, with some attempts of answering the questions, related to the aims of the exercise. In the latter, the emphasis is placed on the consequences of inhomogeneity in the indicator system and of incommensurability of some of the criteria used.

Finally, some broader implications are suggested for the use of a similar approach in other settings, where either continuous variables are used along with the "strongly" discrete ones to categorise objects, or the procedure applied involves branchings.

(Workshop session 2)

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PANAHBEHAGH Bardia, BRUGGEMANN Rainer

Some efficient sampling designs based on partial order sets

In order to obtain a sample, we are going to present some efficient sampling designs based on ranking information of the units. For this purpose, first, we relax the restriction of selecting just one unit from each set in ranked set sampling as a sampling in an equal size post-stratified population. Then in the case of multivariate variables we use linear extensions for ranking the units. Linear extensions are different projections of the partial order into a complete order that respect all the relations in the partially ordered set. In this new method of ranking, units are ranked in sets based on linear extensions leading to sampling in an unequal size post-stratified population. Generally, the determination of all linear extensions is computationally a hard problem; therefore, the approximation by Bubley and Dyer (1999) is applied. The presented sampling design based on partial order sets and (sampled) linear extensions is more flexible than the other designs and is executable with acceptable initial sample size. Furthermore, this new design is generally more efficient than its rival designs because for ranking the units considers all the variables simultaneously whereas its rival designs just consider some of the variables or consider the variables separately. Unbiased estimators for the population means of the variables are calculated for the all presented designs. At the end, based on some real case studies, we evaluate the presented designs.

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(Workshop session 4)

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Indicators for sustainability assessment in the procurement of civil engineering services

Berliner Wasserbetriebe (BWB) have the goal to support effective procurement and supply chain management. Therefore, indicators for sustainability assessment in the procurement of civil engineering services are to be developed. For this, the top-down approach of the Agenda 2030 was linked to the problem-oriented bottom-up approach. Indicators that have been already used in procurement process of the Berliner Wasserbetriebe are the

status quo indicators. The other indicators that should be integrated into the company's procurement process are the target indicators. However, the indicators must be assessed for their applicability and their relevance in the specific field for procurement of civil engineering. In a technical workshop with employees of relevant departments, the indicators for the procurement process were selected. Afterwards the selected indicators were tested for their causal relationship.

By testing the indicators, applicability and practicability should be reviewed, so the indicators can be readjusted. The high variability of sustainability requires regular revision and adaptation of the theoretical and practical target indicators. The selected indicators were tested on four case studies. The goal was to identify the more sustainable variant. The variants were analyzed with Dashboard of Sustainability, Value Analysis and Partial Order. With the utility analysis all case studies could be evaluated. It is also positive that the evaluation does not require precise numerical values. However, this also suggests accuracy where it is absent. Dashboard of Sustainability is a free but old software and is based on Excel. The application is very simple and self-explanatory. And the individual dimensions can be clearly displayed. Partial Order allows objective examination of the variants but could yield no results due to the small number of variants. Low suitability for flexible use in the daily procurement process. In addition, the data had to be edited beforehand, which is associated with increased effort. But PyHasse was suitable for an examination of the indicators. For this, the case studies were considered individually and in their entirety. The examination tools for both cases were identical. The separation and dominance were examined. There was no dominance detected, which speaks for a diverse set of indicators.

(Workshop session 7)

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PIRINTSOS Stergios, BARIOTAKIS Michael, BRUGGEMANN Rainer

Linking niche modelling and partial order analysis

Undoubtedly, the use of niche modelling has extensively been expanded over the last years, especially in the fields of spatial ecology and biogeography. On the other side, partial order analysis, a valuable approach which has successfully contributed in data analysis of a broader spectrum of problems including issues of social and economic studies, has been well established, with many possible future implementations. Nevertheless, a dialogue between the two methodological approaches, which could further expand the potentialities of both, has not been developed yet. Here, we attempt and discuss the linking of outputs from these two methods, promoting a possible interaction between them.

(Workshop session 7)

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Conceptualising and evaluating dominance in sports

In a data driven and increasingly complex world, developing and employing sound methods to aggregate data in a meaningful way (i.e. in a way that is truthful or, at least, trustworthy) is of paramount importance. This affects all the fundamental tasks that characterise statistical production, namely: conceptualising reality, measuring phenomena, analysing and interpreting the resulting data. Partial order theory and related disciplines offer a toolkit to address all of these tasks in an innovative way.

The rise of Big Data has made data nearly ubiquitous so that, differently from the past, data collection seems no problem at all anymore. In several domains data are abundant, available in real-time, at different levels of detail and granularity. The main challenge that is posed to statisticians, in such a context, is: how to extract meaningful information out of such a mass of numbers? In other terms: how is possible to combine data at different levels of detail and granularity into a meaningful message? Is averaging numbers into a composite indicator the only option at hand?

Tools derived from partial order theory appear to be relevant in this context, since they offer some sort of algebra of rankings, meaning that they allow to combine different rankings into a single one, eventually giving rise, of course, to incomparabilities. Each of the constituent rankings could result from a different information base, possibly at different levels of detail and granularity. Why averaging the whole information base into a single composite indicator, when we can directly study the comparabilities and incomparabilities implied by combining different rankings instead?

The goal of this paper is to test new tools using analogies and examples, whence our decision to focus on a popular but not too serious theme, so to say, namely "sports". The choice of this theme is justified by several reasons among which:

1. Sports is a field in which EU's responsibilities are relatively new, so that the policy debate around sports is much more limited with respect to other policy areas. As a consequence, official statistics about sports are currently less developed with respect to other domains;
2. Sports is a field with a long tradition of extensive use of data analytics. Several media companies, such as Opta Sports for example, continuously broadcast to their customers extremely detailed live data feeds that cover several events, in various disciplines;
3. In several countries sports is capable of provoking authentic popular passion, like baseball in the US, Cuba or Japan, or ice hockey in nordic countries, or association football on a global scale. This generates a sort of popular wisdom about sport related phenomena, against which we can test the plausibility of the results obtained using different methods.

Somebody said that simplifying is an art. This paper aims to humbly explore this art in the realm of statistics, trying to address a question which appears simple, but might turn to be complex indeed: "which EU country is the most dominant in sports?"

(Workshop session 2)

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Tournament tables, power-weakness ratio and Hasse diagrams: an informative combination for multi-criteria decision-making

The theory of the weighted regularized Hasse matrices was proposed in 2015. The method aims to generate a family of Hasse matrices, reducing the incomparabilities and allowing a deep statistical analysis of obtained different ranks (Grisoni et al. 2015). In the same year, a study about the so-called Power-Weakness Ratio was also performed showing its ability to perform optimal rankings (Todeschini et al. 2015).

In both the cases, the starting point is the transformation of a data set X into a tournament table (dominance matrix). Let **X** be a data matrix comprising *n* objects described by *p* criteria. A weighted count matrix (**T**^{W}) is obtained by defining its elements (t_{ij}^{W}) as follows:

$$t_{ij}^{W} = \sum_{k=1}^{p} w_k \cdot \delta_{ij,k} \quad \text{where} \quad \delta_{ij,k} = \begin{cases} 1 & \text{if } x_{ik} \rhd x_{jk} \\ 0.5 & \text{if } x_{ik} \square x_{jk} \\ 0 & \text{if } x_{ik} \lhd x_{jk} \end{cases} \quad \text{and} \quad \sum_{k=1}^{p} w_k = 1$$

where w_k is the weight given to the *k*-th criterion and x_{ik} is the value of the *k-th* criterion for the *i-th* object.

In other words, for each *k* criterion ($1 \le k \le p$), each *i*-th element will dominate against the *j*-th if its value is better than that

of *j* (i.e. $x_{ik} \rhd x_{jk}$). If the contrary happens ($x_{ik} \lhd x_{jk}$), the *j*-th element will dominate over *i*. Finally, if the values are equal ($x_{ik} \square x_{jk}$), the two objects "tie the comparison" for the *k*-th criterion and half a credit is given to both. This weighting scheme was already introduced in our previous work [1], as it is a very simple and efficient way to weight criteria and compare objects. Note that all the values of $\mathbf{T}^{W}$ range from 0 to 1 and $t_{ij}^{W} + t_{ji}^{W} = 1$. The family of Hasse matrices is derived by using the different thresholds (greater than 0.5) arising by the weighted count matrix $\mathbf{T}^{W}$.

In this presentation, the Power-Weakness Ratio (PWR) is also used by the weighted count matrix $\mathbf{T}^{W}$ to rank the objects and a quantitative graphical representation is proposed, called PWR diagram, also highlighting incomparabilities. Also, in this case, the use of a set of thresholds allows the evaluation of a coherent family of PWR rankings.

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(Workshop session 3)

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TSAKOVSKI Stefan

Implementation of Hasse Diagram technique in environmental risk assessment

The environmental risk assessment (ERA) is a multistage process, which needs reliable information about the environmental compartments usually derived from environmental monitoring. The "threshold" practice to compare environmental indicators with empirically defined limits does not ensure reliable ERA. Multivariate statistical methods for classification and modelling of environmental monitoring results prove to be more reliable approach, since they consider the environmental system as multivariate and treat it correspondingly.

Source apportionment modelling originates from air quality studies and later on implemented in soil and water ERA. These modelling studies include two stages: (i) revealing of natural and anthropogenic sources; (ii) source impact assessment. In general, source apportionment models could be divided with respect to the extraction of latent factors to orthogonal and non-orthogonal ones.

The application of HDT (Hasse diagrams technique) as consecutive step for visualization of partial order relations between different environmental sites (objects) could deliver important information concerning risk assessment and environmental management as a whole. Such a poset could be used for prioritization of sources, selection of scenarios and ranking of environmental objects. The HDT decision support potenital could be also demonstrated in optimization of environmental monitoring scheme and selection of appropriate environmental management actions.

This combines the advantages of two apportioning techniques (Absolute Principal Component Analysis and Multivariate Curve Resolution) for assessment of the impact of natural and anthropogenic sources on the environmental compartments and the decision support possibilities of HDT. The abovementioned combination is applied on different environmental data sets related to different environmental medias. Special attention is paid on the comparison between results obtained by orthogonal and non-orthogonal source apportioning techniques.

(Workshop session 6)

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WITTMANN Jochen

Demands on and specification of indicators for modelling and simulation environmental systems

Indicators are necessary and widely used means to understand system behaviour. This paper will provide a pragmatic discussion where indicators come from, how they are used especially in the field of modelling and simulation and how a complex indicator should be designed. Starting with the basic definition, indicators primarily are system quantities that can easily be observed and measured but standing for a more difficult to measure or hidden or inaccessible value the user is interested in intrinsically. This basic usage however loses importance when indicators are applied to system modelling and simulation. In the modelling context, there are no "inaccessible" model quantities because model description does not distinguish between readable and not readable variables.

In this context, indicators mainly are used to manage complex, modular hierarchically built systems (or the models of them). Indicators in such a context help to understand optimize those complex systems and to avoid critical system states by indicating them as crossing a critical threshold for the indicator value. In this situation the paper analyses the situation by discussion of the following four main topics:

1. The functionality of indicators first by introducing three levels (transmission, judging, aggregating).

a) Transmission means taking the indicator value instead of the value of a hidden and less accessible model quantity

b) Judging means introducing a classification for the values of the indicator quantity and thus introducing classes of interpretation as well

c) Aggregating is the usage mainly applied: several aspects of a system are classified (see under point b)), weighted to each other, and functionally combined to one single final value. Special interest lies on the weights but also on the way of functional processing.

2. The workflow for building indicators. Such as selection of system quantities – defining indicator quantity – defining indicator value range – aggregating indicator values – introducing thresholds for risc estimation – classification of indicator value according to the risc

3. The structure of complex indicators with sub-indicators and weightings. The guiding visualization for an indicator value is the picture with the indicator as the top of an iceberg representing the complete structure not seen under sea-level respective in the "black-box" with the complex system under observation in it.

a) Discussion of the weights (linear, logarithmic, …)

b) Discussion of the functional aggregation method: addition, multiplication, integration, others …

4. The sensitivity of indicator values concerning the composition functions and the weightings of the sub indicators.

The conclusion of the deliberations is the fact, that indicators themselves are constructs that model system structure. Therefore, even indicators have to be submitted to a proper indicator design (according to the model design), an indicator validation (according to model validation), and an intensive sensitivity analysis. Finally, the paper tries to define some demands on the formulation and the functionality of indicators from the point of view of a user of indicators not deeply acquainted with the mathematical details.

(Workshop session 1)

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