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# Quantitative projections of a quality measure: Performance of a complex task

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## HIGHLIGHTS

- Quantitative measures as approximations to qualitative concept: quality in task performance.
- Ship-bridge simulator as laboratory for humans interacting with advanced technology.
- The same simulator exercise recorded for several crews under identical conditions.
- Quantitative measures of task performance have been constructed.
- The crews differ significantly under these measures.

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## ABSTRACT

Complex data series that arise during interaction between humans (operators) and advanced technology in a controlled and realistic setting have been explored. The purpose is to obtain quantitative measures that reflect quality in task performance: on a ship simulator, nine crews have solved the same exercise, and detailed maneuvering histories have been logged. There are many degrees of freedom, some of them connected to the fact that the vessels may be freely moved in any direction. To compare maneuvering histories, several measures were used: the time needed to reach the position of operation, the integrated angle between the hull direction and the direction of motion, and the extent of movement when the vessel is to be manually kept in a fixed position. These measures are expected to reflect quality in performance. We have also obtained expert quality evaluations of the crews. The quantitative measures and the expert evaluations, taken together, allow a ranking of crew performance. However, except for time and integrated angle, there is no correlation between the individual measures. This may indicate that complex situations with social and man–machine interactions need complex measures of quality in task performance. In general terms, we have established a context-dependent and flexible framework with quantitative measures in contact with a social-science concept that is hard to define. This approach may be useful for other (qualitative) concepts in social science that contain important information on the society.



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## 1. Introduction

Spatial and temporal structures that intuitively are referred to as complex arise in many fields of science [1,2]. Growth processes leading to fractal patterns [3,4], solutions to NP-complete problems [5], and the many geometrical conformations of macromolecules like DNA [6] are but a few examples. In some cases, simple quantitative measures can be found that allow characterization and comparison of structures. An example is the fractal dimension, a single numerical value calculated from complex geometries that allows sorting into universality classes [7].

Complex patterns are also generated from man–machine interactions, during operation of advanced technology. Such patterns reflect both strategic choices, in their large-scale features, and standard modes of operation, on a more detailed (small-scale) level. Analysis of these patterns is useful from a safety perspective, for training, and for technology development. In addition, it may serve as a laboratory for exploring new concepts and measures for complex structures. The data is qualitatively different from what one obtains from purely natural systems and from many-agent systems like the stock market. The differences apply to both large-scale features and the small-scale (noise) level. In the present contribution, we make some modest steps in characterizing geometrical structures generated from human interaction with advanced technology. The aim is to investigate whether these simple quantitative measures reflect quality in task performance.

On the methodological side, there may be two long-term benefits from the strategy we establish in this paper. Firstly, as suggested above, new tools for quantitative analysis may be developed as new types of quantitative data are analyzed. Secondly, and most important, implicit in our approach is an attempt to build bridges between 'classical' social science and statistical physics. Classical social science is very different from the studies published as sociophysics in statistical-physics journals. Much of classical social science is qualitative, and proceeds by using deep and complex concepts like intention, culture, group interest, collaboration, alienation, and solidarity. Concepts like these are not easy to define, but convey deep insight into social structure. Our approach is to explore such concepts by their reflections (or projections) on quantitative measures. In this paper the concept is quality in task performance. Note that in our approach, quantitative measures are used as tentative approximations to the concept under study, and are not of fundamental interest as such. Indeed, the main point of our approach is that we focus not so much on the representations (projections) themselves, but on the process of establishing, changing and adjusting them.

A ship bridge simulator is used as laboratory. Simulators allow man–man and man–machine interactions to be studied repeatedly under near identical conditions. The development of simulators as such (modeling of forces, display technology) and their use (didactic, integration into regulations from the authorities) have been extensively researched [8]. However, we are not aware of previous studies where the data logged by the simulator software has been analyzed quantitatively from a statistical-physics point of view.

We analyze complex maneuvering histories of ships obtained from training sessions on bridge simulators. The participants are professional seamen, and not students (that too often have been used in social-science studies). We suggest and develop measures that characterize variations in the way a task is solved by different crews, and, possibly, quality in performance. An improved understanding of man–machine interactions may be obtained through such quantitative measures. Recently, quantitative methods have been successfully used on social interactions of humans—temporal patterns in communication is one example [9].

The quantitative measures of task performance during maneuvering are compared to expert evaluations from experienced instructors. Expert evaluations are intuitive, integrating assessments of complex situations, based on extensive experience. They cannot always, at least not easily, be broken down to a series of parameter values. Thus, expert evaluations represent an alternative to purely quantitative measures of maneuvering histories seen as geometrical objects.

In many contexts, quality in task performance is a concept that is hard to define and hard to quantify. Similarly, there are many other concepts used in social science that are hard to quantify such as culture (specifically: the safety culture of a company) or alienation (classically split into the chain: alienated product, alienated process, alienated self, alienated relations). Still, such concepts convey important, integrated insights into social systems. In our approach, the quantitative measures are approximations to the basic quality concept. Thus, the main interest is not in the quantitative results as such, but in the tentative interpretations of the concept they offer. The choice of quantitative measures may be varied as the quality concept is explored. Assessment of validity is then not primarily based on quantitative consistency but on the depiction of the concept brought forward by the quantitative measures in combination. We develop this approach below using relatively simple quantitative measures. However, it should be possible to apply our context-dependent framework for other social-science concepts using more advanced quantitative measures from the statistical-physics toolbox.

Advanced ships are used in fields like offshore oil exploration: dive support vessels, supply vessels, anchor handling vessels, tugs, cable layers, and multi-purpose vessels. Due to high demands from the operations carried out, these ships need to have very high maneuverability. This is achieved through a propulsion system with several thrusters, water jets, and rudders in addition to standard propellers. For some operations, like maintenance of subsea installations, it is crucial that the ship accurately keeps a fixed position. Therefore, bridge systems usually incorporate equipment for Dynamic Positioning (DP).

DP is a method to automatically keep ships and semi submersible rigs in a fixed position using the propulsion systems instead of anchors. It may also be used for sailing a vessel from one position to another along a predefined route and, like an autopilot on an airplane, DP may operate without human involvement. The method relies on accurate determination of position from external reference systems like GPS, as well as a continuously adjusted mathematical model of the ship and external forces from wind, waves and currents. There are six degrees of freedom associated with the motion of a vessel: