Didactic Aspects of Teaching Statistical Distributions for Logistics Engineering Students

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Abstract

We discuss theoretical and practical aspect of effective teaching of statistics topics, in particular statistical distributions, for logistics engineering students. Some typical difficulties in the study process are discussed and ways of overcoming them are proposed. Example simulation-based problem-oriented learning support tools are briefly presented. A detailed description of a case study based on a management simulation game is given.

Keywords

Teaching statistics, statistical distributions, engineering education

Introduction

Due to the usually high "saturation" of statistics with math, to its some inherent ambiguity, in particular w.r.t. method and criteria selection, to frequently missing application context, etc., its study is usually facing specific problems and is known to be not the most favorite among students. However, the ability to understand and correctly treat random phenomena is of vital importance to engineers in many application fields. In particular, logistics system designers, supply chain specialists, etc. have a lot of to do with item distributions, controlling thousands of transport orders, analyzing and predicting customer orders, forecasting customers' and market behavior, etc. Very helpful here is not only knowing the theoretical basics, but as well to possess a deeper understanding of the nature of randomness and its manifestation in logistics domains.

A lot of theoretical and empirical research has been conducted on teaching statistics. Some challenges in this field are highlighted in (Batanero, 2015). A student's perspective on the topic, in the context of a form of blended learning - flipped classroom - is considered in (Chen and Chen, 2015), where a necessity of providing individual levels of support is stressed. Experience in conducting a multidisciplinary project-based statistics course is shared in (Dierker et al, 2016). Efficiency of applying creative problem solving to statistics teaching is illustrated in (Hu et al 2017). In (Kuzmak, 2016), a students' cognitive schema for a mature understanding of random phenomena is proposed. Integrating interactive animations into teaching is considered in (Morales, 2016). Further, (Neto, 2017) describes a virtual learning environment and online open courses in statistics classes. New opportunities for statistics education are presented in (Oliveira et al, 2015). Learning statistics through (statistical) investigations is treated in (Santos and da Ponte, 2014).

In this paper, we argue for the importance of a thorough treatment already of the very fundamentals of statistics, especially of statistical distributions. First, we list some typical problems arising at this stage. Then, some possible steps to improve the situation are proposed and corresponding illustrative examples are presented. Finally, we describe a use case with a management simulation game, where the gained knowledge and competences of the students can be applied.

Teaching Statistical Distributions: Problems and Solutions

The success of teaching advanced and practice-oriented statistical concepts, such as selecting and performing suitable statistical test, making long-term forecasts, etc. depends heavily on how the basics notions of a distribution and its parameters have been mastered by the students. The main problem here is the gap between the acquired knowledge and its practical application (domain specific use cases). This gap results in poor stimulation and motivation for a deeper learning of statistics. The lack of success experience in solving real life problems leads to missing emotional binding. In addition to this general problem, a number of deficiencies exist which can be characterized as “hidden gaps”, or contradictions. These include, in particular, the following (for later referencing, we label the i-th statement by (Gi)):

(G1) while knowing that the variance, standard deviation are “measures of the variation in data” and being acquainted with formulas for their calculation, one often can hardly explain how exactly do their values impact the system’s performance indicators;

(G2) while being able to distinguish and explain probability density functions of different distributions, one can still be unaware of the differences in their real life manifestation and treatment;

(G3) while understanding the importance of the choice of a sample size, one may still tend to derive false conclusions using, e.g., only short-term observations of dynamic processes;

(G4) while being aware of the possible discrepancy between the mean value of a population and that of a sample, one often can use the latter as the only reference value when dimensioning a new system;

and so forth.

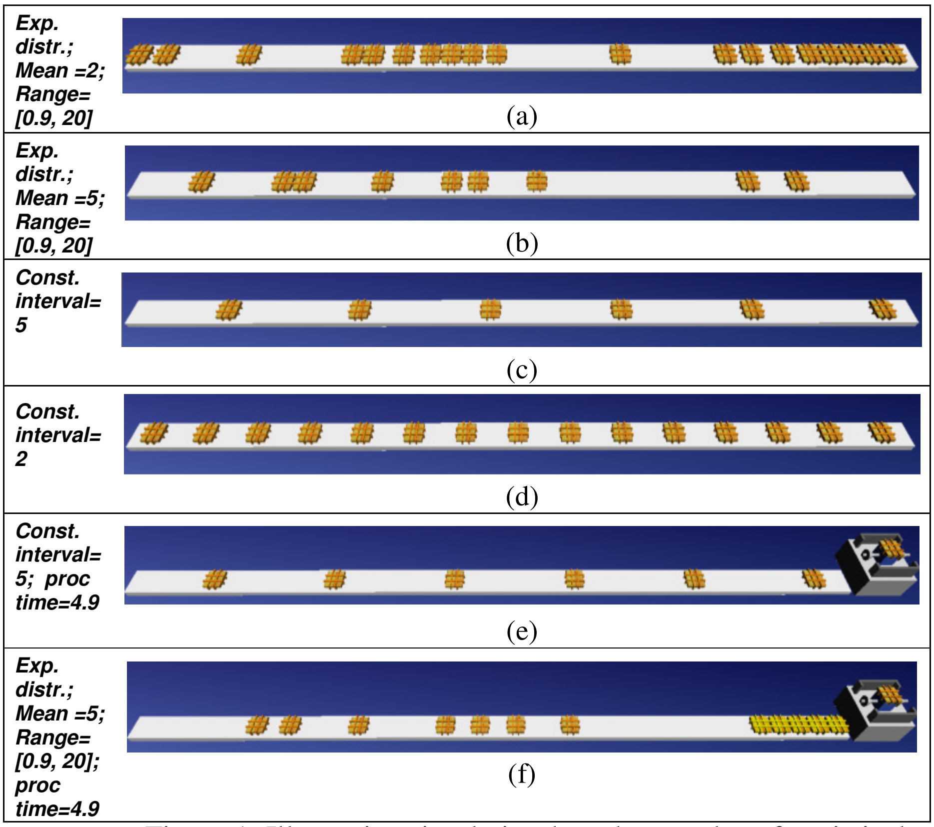

Figure 1: Illustrative simulation-based examples of statistical attributes

To close the above gaps, students should be involved into active learning process, preferably using interactive simulation based examples.

Figure 1 shows some such examples: of a queuing system represented by a conveyor belt with boxes on it. Figures (a) and (b) are obtained for two remarkably *different mean arrival times* – 2 s (a) vs 5 s (b), under exponential distribution; the pictures themselves however does not manifest that large difference and may thus mislead an external observer (comp. (G3)). At the same time, the difference 2 s vs 5 s is obvious in the case of *constant* intervals: pictures (c) and (d). The pair (e) and (f) illustrates the impact of the variability: while under the *constant* flow no queue at all arises at the entry to the processing unit if its processing time is shorter or even the same as the arrival interval (e), under *stochastic* behavior, with the *same arrival mean value* and the *same processing time* as in (e), queues do episodically occur (comp. (G1)).

With a simulation support, flow parameters are interactive adjusted to illustrate the corresponding impact on the queue length, etc. Directly registerable are such values as box arrival time on a line, track arrival times, etc. In addition to computer simulation, a number of values can be used for illustrative purposes directly in the classroom: the number of students on different chair lines in the classroom, the distance to the home of different students, the number of post packages obtained during the last week, and so forth.

Further, the main features of some commonly used distributions - exponential, normal, binomial – can be easily illustrated with the help of a parameterized simulation model. Arrival times, number of orders, etc. can be automatically (in the model) or manually (externally, after adjusting the model time) registered and afterwards processed.

Further enhancement can be achieved via using real videos of logistics systems. Figure 2 symbolically illustrates a manual registration of system states and events with the purpose of identifying stochastic distributions as well as their parameters: the box arrival times (using the playback speed control and the time display on the video player), track arrival or departure times, etc. with a subsequent calculation of the mean values, variance, etc. Very important here is an accompanying commenting from the (expert) application view, e.g.: "higher variation may require more buffer capacity".

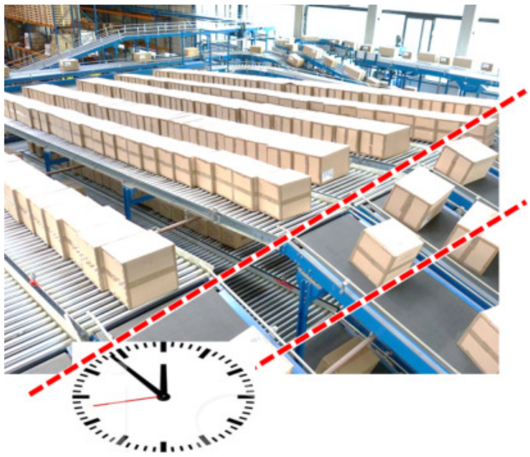

Figure 2: Registration of stochastic data and throughput calculation using videos

A gradual "motivating" introduction to the field can be organized as follows: (1) presenting counterexamples: when neglecting the nature of the distribution lead to miscalculations, design errors, big fails, etc.; (2) presenting positive examples: when the knowledge helps to understand and predict the system's behavior; (3) giving possibly contrasting examples of different distribution types; (4) explaining the meaning of the mean value; (5) illustrating variation and its impact (e.g., different average waiting times under different variations).

Gaming and Management Simulation Games

Explaining Students Decision Theory in certain as well as in uncertain situations is part of the standard teaching program in Business lessons with our logistics students at the University of Kaiserslautern. Combined with management decision rules like e.g. the SAVAGE-NIEHANS criterion we deal with the basics of gaming theory particularly with the "Prisoners´ Dilemma." Usually in discussions our students claim that in a comparable situation they would never trait their accomplices. Based on an altered example given by (Dixit and Nalebuff, 1993), students were asked within a management simulation game how they would act if they were confronted with a situation described as follows.

In this mentioned Management Simulation Game (Topsim, 2018), 23 students formed in seven groups from three to four students each, the student compete against one another running seven department stores in a fictional city. After a few rounds of simulation (we fancy one year to each round played) the students find out that they can gain profits in the field of sport items, household goods, clothing (at best), and consumer electronics. In the department of food however all seven enterprises achieve losses. At this moment a cartel contract is suggested by one of our research assistants supporting the game leader. The suggestion is that each of the 23 students runs a bigger department store in a much bigger city. If all department stores restrict the range and the variety of food products the contribution margin could be raised, so lately all stores could gain profits in the difficult field of dealing food. The described payoff situation for the students in this example is given in Table 1. Each student thereafter is given a piece of paper and an envelope. At first, each student was asked to write his or her matriculation number on the piece of paper and then whether he (or her) would decide to obey to the contract, or whether to cheat.

Cheating, that was made clear to the students, would improve their single economic situation, however they would harm the market situation as a whole. The game entails to a situation in which each cheating actor will improve his contribution margin by 138.000€ by cheating. As on average the companies incurred losses at about 250.000€, the cartel contract seemed to be a helpful tool to reach the "Break Even Point" for most department stores. The right column of Table 1 shows that as long as more than 19 decision makers cooperate to the cartel, the whole market becomes profitable.

The decision of the students proved that in five different classes there always was a majority of students deciding to "Cheat." Even after a discussion, in which our research assistant would urge the students to follow the conspiracy, it would not work, as long as the students were allowed to fill their papers´ secretly. The range of students to obey to the cartel contract varied between 0 and 8. There always was a majority of decision makers who had decided to cheat. Once one of our assistant joining the game stated: "I will never trust anybody for the rest of my life." As the game leader knows he was one of those who had refused to cooperate.

Number of Students deciding "Obey"	Payoff for each student deciding to "obey"	Payoff for each student deciding to "cheat"	Profit of the hole market
0		150.00 €	-2.300.00 €
1	12.00 €	162.00 €	-2.174.00 €
2	24.00 €	174.00 €	-2.048.00 €
3	36.00 €	186.00 €	-1.922.00 €
4	48.00 €	198.00 €	-1.796.00 €
5	60.00 €	210.00 €	-1.670.00 €
6	72.00 €	222.00 €	-1.544.00 €
7	84.00 €	234.00 €	-1.418.00 €
8	96.00 €	246.00 €	-1.292.00 €
9	108.00 €	258.00 €	-1.166.00 €
10	120.00 €	270.00 €	-1.040.00 €
11	132.00 €	282.00 €	-914.00 €
12	144.00 €	294.00 €	-788.00 €
13	156.00 €	306.00 €	-662.00 €
14	168.00 €	318.00 €	-536.00 €
15	180.00 €	330.00 €	-410.00 €
16	192.00 €	342.00 €	-284.00 €
17	204.00 €	354.00 €	-158.00 €
18	216.00 €	366.00 €	-32.00 €
19	228.00 €	378.00 €	94.00 €
20	240.00 €	390.00 €	220.00 €
21	252.00 €	402.00 €	346.00 €
22	264.00 €	414.00 €	472.00 €
23	276.00 €		598.00 €

Table 1: Payoff situation for the described management simulation game

Conclusions

Statistics competences are highly important for engineering professionals. Unfortunately, statistics courses are often not unproblematic. A heavy abstract mathematical workload combined with lack of application field contexts is an obstacle for effective learning, especially for pragmatically oriented engineering students. Hence, a systematic accompanying presentation of clear domain specific use cases in the course of study must become a rule. Interactive simulation-based and video illustrations of characteristics of statistical distributions should be conducted on a regular basis. A possible generic "teaching sequence" can be: informal motivation and definition > motivating video or simulation example > formal definition > elaborated domain specific example of the impact of the considered characteristic(s) > further video or simulation examples with calculations > concluding part, recommendations.

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