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Selection of output mode for Bayesian optimization in noisy problems

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本文研究的是贝叶斯优化在有噪声问题中如何选择结果输出的方式。在无噪声的问题中，通常会直接使用所有观测值中的最优值对应点作为优化的输出结果。但在有噪声的问题中，由于所有观测值都存在噪声，这种结果的输出方式就可能不太妥当。考虑到代理模型能够提供搜索空间内任一点的预测均值，这使得我们可以选择使用预测性的输出方式。例如输出所有观测点中预测均值最优的点，或是输出整个搜索空间内预测均值最小的点。预测性的输出方式在高噪声的问题中可能会比直接输出观测值更加合适，但输出方式的选择并不仅仅只与噪声的大小有关。目标函数的响应面性质，搜索空间的维度等因素同样也会造成影响。本文使用 BBOB 函数组对带噪声的贝叶斯优化问题做了一些数值实验，并希望能够为输出方式的选择提供一些有指导性的建议。

Key words: Bayesian optimization, output mode, BBOB

1. Introduction

Although it has been around for over a century, margarine was not always the preferred tablespread in the United States. In 1930, per capita consumption of margarine was only 2.6 pounds (vs. 17.6 pounds of butter). Times have changed for the better, though (if you're a margarine manufacturer, that is). Today, per capita consumption of margarine in the United States is 8.3 pounds (including vegetable oil spreads) whereas butter consumption is down to about 4.2 pounds. Furthermore, as shown in Figure 1, it is always butter, not margarine, that is traded off[1] against guns. This leads to the announcement of our result.[2]

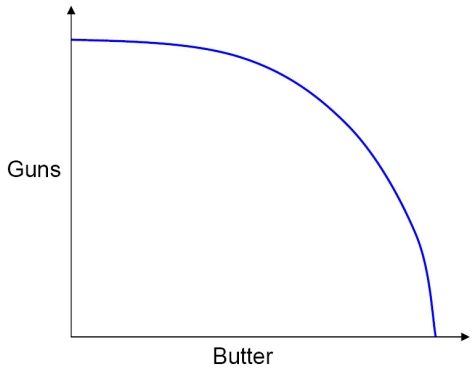

Figure 1 Production Possibilities Frontier.

THEOREM 1. *In a reverse dictionary,* $(\boldsymbol{marg} \succ \boldsymbol{butt} \wedge \boldsymbol{arine} \succ \boldsymbol{er})$. *Moreover, continuous reading of a compact subset of the dictionary attains the minimum of patience at the moment of giving up.*

The proof will be given in the e-companion to this paper.

2. Motivation

Margarine or butter? According to the website of the National Association of Margarine Manufacturers (2005a), "Despite the recommendations of health professionals and leading health organizations to choose margarine, many consumers are confused." But whether or not they are confused, consumers are voting with their pocketbooks. The American Butter Institute (2005), whose slogan is "Things are better with butter!", presents many tempting recipes on its website, but also reports declining sales in its marketing releases.

HYPOTHESIS 1. *Things are better with butter.*

Indeed, even though a reputed chain email letter claims that margarine is "but one molecule from being plastic" (BreakTheChain.org 2005), American consumers appear to be sliding away from butter. Given this trend, a historical review of margarine is in order.

LEMMA 1. *Many consumers are confused.*

LEMMA 2. *Whether or not the consumers are confused, they are voting with their pocketbooks.*

PROPOSITION 1. *American consumers are sliding away from butter.*

3. Historical Timeline

The following are milestones in the history of margarine as reported by the National Association of Margarine Manufacturers (2005b). Note that they have been transcribed verbatim here, which is generally bad practice. Even if the material is explicitly indicated as a quotation, having this much content from another source will almost certainly result in rejection of the paper for lack of originality.

But if not called out *as a quotation*, lifting even a single sentence (or less) from another source is plagiarism, even if the source is cited. Plagiarism is a very serious offense, which will not only lead to rejection of a paper, but will also bring more serious sanctions, such as being banned from the journal, notification of your dean or department chair, etc. So don't do it!

There are many on-line resources to help determine what constitutes plagiarism and how to avoid (see, e.g., CollegeBoard.com). But the simplest rule to follow is "when it doubt, call it out." That is, make very plain what comes from other sources, in properly cited word-for-word quotations or paraphrases.

4. 1800s

1870 Margarine was created by a Frenchman from Provence, France – Hippolyte Mège-Mouriez – in response to an offer by the Emperor Louis Napoleon III for the production of a satisfactory substitute for butter. To formulate his entry, Mège-Mouriez used margaric acid, a fatty acid component isolated in 1813 by Michael Chevreul and named because of the lustrous pearly drops that reminded him of the Greek word for pearl – margarites. From this word, Mège-Mouriez coined the name margarine for his invention that claimed the Emperor's prize.

1873 An American patent was granted to Mège-Mouriez who intended to expand his French margarine factory and production to the United States. While demand for margarine was strong in northern Europe and the potential equally as promising in the U.S., Mège-Mouriez's operations nevertheless failed and he died obscurely.

1878 Unilever began manufacturing margarine in Europe.

1871-73 The U. S. Dairy Company in New York City began production of "artificial butter."

1877 State laws requiring identification of margarine were passed in New York and Maryland as the dairy industry began to feel the impact of this rapidly growing product

函数编号	最优值 (mean)	标准差 (std)	原始序列相对全局最优值	序列 3 相对全局最优值	输出 3 相对全局最优值损	序列 3 相对原始序列最优值	输出 3 相对原始序列最优值
F1	79.48	12.57	0.00%	0.00%	0.00%	0.00%	0.00%
F2	66.95	10044455.67	5.71%	45.31%	59.70%	36.90%	50.71%
F3	77.66	418.57	10.22%	8.40%	27.81%	-1.32%	16.80%
F4	77.66	171.86	5.01%	4.08%	18.19%	-0.85%	12.62%
F5	66.71	29.02	0.00%	0.00%	0.00%	0.00%	0.00%
F6	65.87	237396.11	1.52%	2.58%	3.45%	1.05%	1.89%
F7	92.94	431.55	0.08%	0.08%	0.18%	0.00%	0.10%
F8	98.62	46480.79	0.07%	0.20%	1.75%	0.13%	1.68%
F9	65.61	21715.05	0.12%	0.69%	3.66%	0.57%	3.54%
F10	59.13	9634378.45	15.30%	41.30%	1282.36%	25.07%	1133.40%
F11	76.27	21241083.28	8.50%	48.75%	719.52%	38.60%	656.81%
F12	56.61	9607260659	1645.98%	21840.61%	2907234.96%	2905.92%	1209546.08%
F13	68.42	449.99	0.96%	0.56%	1.78%	-0.38%	0.81%
F14	77.31	41.04	0.01%	0.01%	0.02%	0.00%	0.02%
F15	70.03	521.74	5.26%	5.60%	23.30%	0.36%	17.33%
F16	71.35	79.07	0.74%	0.60%	26.55%	-0.14%	25.71%
F17	69.83	19.00	0.52%	0.38%	4.43%	-0.14%	3.89%
F18	119.54	308.17	0.76%	0.60%	11.46%	-0.16%	10.62%
F19	71.69	74.72	0.25%	0.30%	10.95%	0.05%	10.68%
F20	71.29	45818.02	1.64%	2.41%	5.11%	0.76%	3.41%
F21	124.08	12.21	0.07%	0.05%	0.14%	-0.02%	0.07%
F22	51.57	24.05	0.46%	0.40%	0.75%	-0.06%	0.29%
F23	85.39	20.12	4.48%	4.53%	50.64%	0.10%	44.24%
F24	93.30	18.18	5.11%	4.56%	27.33%	-0.49%	21.20%

1885 When a court voided a ban on margarine in New York, dairy militants turned their attention to Washington, resulting in Congressional passage of the Margarine Act of 1886. The Act imposed a tax of two cents per pound on margarine and required expensive licenses for manufacturers, wholesalers and retailers of margarine. President Grover Cleveland, from the dairy state of New York, signed the law, describing it as a revenue measure. However, the 1886 law failed to slow the sale of margarine principally because it did not require identification of

margarine at the point of sale and margarine adversaries turned their attention back to the states.

1886 More than 30 manufacturing facilities were reported to be engaged in the production of margarine. Among them were Armour and Company of Chicago and Lever Brothers of New York. Seventeen states required the product to be specifically identified as margarine. Various state laws to control margarine were passed in a number of states, but were not enforced. Later that year, New York and New Jersey prohibited the manufacture and sale of yellow-colored margarine.

5. 1900s

5.1. Before the End of WWII

1902 32 states and 80% of the U.S. population lived under margarine color bans. While the Supreme Court upheld such bans, it did strike down forced coloration (pink) which had begun in an effort to get around the ban on yellow coloring. During this period coloring in the home began, with purveyors providing capsules of food coloring to be kneaded into the margarine. This practice continued through World War II.

1902 Amendments to the Federal Margarine Act raised the tax on colored margarine five-fold, but decreased licensing fees for white margarine. But demand for colored margarine remained so strong, that bootleg colored margarine flourished.

1904 Margarine production suffered and consumption dropped from 120 million pounds in 1902 to 48 million.

1910 Intense pressure by competitors to keep prices low and new product innovations, as well as dairy price increases, returned production levels of margarine back to 130 million pounds. The Federal tax remained despite many efforts to repeal it, but consumption grew gradually in spite of it.

1920 With America's entry into World War I, the country began to experience a fat shortage and a sharp increase in the cost of living, both factors in driving margarine consumption to an annual per capita level of 3.5 pounds.

1930 The Margarine Act was again amended to place the Federal tax on naturally-colored (darkened with the use of palm oil) as well as artificially-colored margarine. During the Depression dairy interests again prevailed upon the states to enact legislation equalizing butter and margarine prices. Consumers reacted and consumption of margarine dropped to an annual per capita level of 1.6 pounds.

1932 Besides Federal taxes and licenses, 27 states prohibited the manufacture or sale of colored margarine, 24 imposed some kind of consumer tax and 26 required licenses or otherwise restricted margarine sales. The Army, Navy and other Federal agencies were barred from using margarine for other than cooking purposes.

1941 Through production innovations, advertising and improved packaging, margarine consumption regained lost ground. A Federal standard was established recognizing margarine as a spread of its own kind. With raised awareness of margarine's health benefits from a 1941 National Nutrition Conference, consumers began to take notice of restrictions on margarine that were keeping the product from them and artificially inflating the price.

1943 State taxes on margarine were repealed in Oklahoma. The courts removed color barriers in other states shortly after World War II (see Torbica et al. 2006).

5.2. After the End of WWII

1947 Residual war shortages of butter sent it to a dollar a pound and Margarine Act repeal legislation was offered from many politicians.

1950 Some of the more popular brands prior up until now were Cloverbloom, Mayflower, Mazola, Nucoa, Blue Plate, Mrs. Filbert's, Parkay, Imperial, Good Luck, Nu-Maid, Farmbelle, Shedd's Safflower, Churngold, Blue Bonnet, Fleischmann's, Sunnyland and Table Maid.

1950 Margarine taxes and restrictions became the talk of the country. Finally, following a significant effort by the National Association of Margarine Manufacturers, President Truman signed the Margarine Act of 1950 on March 23 of that year.

1951 The Federal margarine tax system came to an end. Pre-colored margarine was enjoyed by a consumer also pleased with lower prices. Consumption almost doubled in the next twenty years. State color bans, taxes, licenses and other restrictions began to fall.

1960s The first tub margarine and vegetable oil spreads were introduced to the American public.

1967 Wisconsin became the last state to repeal restrictions on margarine (Williams 1994).

1996 A bill introduced by Rep. Ed Whitfield would signal an end to the last piece of legislation that adversely affects the sale of margarine. Currently, federal law prohibits the retail sale of margarine in packages larger than one pound, as well as detailed requirements regarding the size and types of labeling of margarine and a color requirement. This new legislation would remove these restrictions from the Federal Food, Drug, and Cosmetic Act (FFDCA). Rep. Whitfield's bill, the Margarine Equity Act, is part of HR 3200, the Food and Drug Administration (FDA) reform package and addresses dated requirements that are not applicable to the marketplace.

1998 125th anniversary of the U.S. patent for margarine

Source: National Association of Margarine Manufacturers (2005a).

6. Proof of Theorem 1.

To avoid confusion, theorems that we repeat for readers' convenience will have the same appearance as when they were mentioned for the first time. However, here they should be coded by `repeattheorem` instead of `theorem` to keep labels/pointers uniquely resolvable. Other predefined theorem-like environments work similarly if they need to be repeated in what becomes the e-companion.

THEOREM 1. *In a reverse dictionary,* $(\boldsymbol{marg} \succ \boldsymbol{butt} \wedge \boldsymbol{arine} \succ \boldsymbol{er})$. *Moreover, continuous reading of a compact subset of the dictionary attains the minimum of patience at the moment of giving up.*

6.1. Preparatory Material

LEMMA 3. *In a reverse dictionary,* $\boldsymbol{g} \succ \boldsymbol{t}$.

LEMMA 4. *In a reverse dictionary,* $\boldsymbol{e} \succ \boldsymbol{r}$.

Proof of Lemmas 3 and 4. See the alphabet and the tebahpla. □

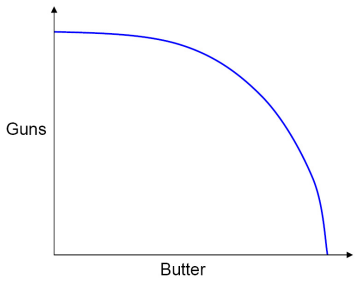

Figure 2 Production Possibilities Frontier Again.

REMARK 1. Note that the title of the proof should be keyed explicitly in each case. Authors can hardly agree on what would be the default proof title, so there is no default. Even `\proof{Proof.}` should be keyed out.

6.2. Proof of the Main Result

Proof of Theorem 1. The first statement is a conseqence of Lemma 3 and 4. The rest relies on the fact that the continuous image of a compact set into the reals is a closed interval, thus having a minimum point. □

7. Conclusions

Since we didn't do anything original in this paper, we don't actually have any conclusions. But we have to have a conclusions section in here, so we're writing one. Don't the margins look good? How about those section headings? Pretty snappy, eh?

However, just because we didn't produce any results, doesn't mean that there isn't good butter re-search going on out there. Many researchers (e.g., Tholstrup et al. 2006, Hodson et al. 2001) continue to push out the envelope of our understanding of butter and its health effects. Others are focusing on related products, such as cheese (see, e.g., Fontecha et al. 2006). Still others are investigating the linguistic (Feldman and Schwan 1990) and sociopolitical (Geisel 1984) implications of butter. So butter remains a hot research area with lots of potential for the future.

All the potential in the world won't amount to much if research isn't cited correctly, though. Make sure you include complete citation information for your references, including publication or re-trieval dates for website citations, publication year and volume and issue numbers for journal articles,

publisher names and locations for books, reports, and conference proceedings, and page numbers for eve-rything, but especially for direct quotes. For citations of unpublished work, you need to include the date of update, as well as the name and address of the organization that sponsored the work. Take a look at the reference section below to see how references should be formatted.

Endnotes

1. Who would expect that?

2. This is really silly. We will demonstrate here how an endnote should look like if it is longer than just one line.

Acknowledgments

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