Sherlock Holmes on Reasoning

Soshichi Uchii

1. How I rediscovered Sherlock Holmes

It was in the fall of 1987. This year, people all over the world celebrated the Centenary of Sherlock Holmes. Of course I knew who Sherlock Holmes was, since I had read several stories of Holmes during my high school days, and watched some TV programs on Holmes, afterward. But, actually, I did not know Holmes really well, because my memories were rather vague, and I did not have any clear idea as regards Holmes' method of reasoning, although I became a scholar and my specialty was logic and philosophy of science. But, fortunately, the Centenary celebration produced many books on Holmes, including reprints of Japanese translation of Holmes stories. One day, I came across, in a bookstore, a thick volume that contains most of Holmes stories. In the evening I began to read *A Study in Scarlet*, the very first book Conan Doyle wrote on Holmes. Guess what happened.

The chapter 2 of this book has the title "The Science of Deduction", and this alarmed me. Dr. Watson began to assess Holmes' repertory of knowledge. He said Holmes had no knowledge of philosophy. He still did not know what sort of job Holmes was doing. A few pages later, a crucial paragraph came, when Watson notices an article in a magazine on the table:

> "From a drop of water," said the writer, "a logician could infer the possibility of an Atlantic or a Niagara without having seen or heard of one or the other. So all life is a great chain, the nature of which is known whenever we are shown a single link of it. Like all other arts, the Science of Deduction and Analysis is one which can only be acquired by long and patient study, nor is life long enough to allow any mortal to attain the highest possible perfection in it." (A Study in Scarlet, 23)

Watson did not like this assertion, but it turns out that the author was Holmes himself! By reading this passage, a hypothesis flashed into my mind: Holmes must have been a good logician! Yes, a "logician" in the sense that the founders of symbolic logic were, such as George Boole (1815-1864), Augustus de Morgan (1806-1871), and

William Stanley Jevons (1835-1882)—Jevons was a student of de Morgan. They all contributed to clarifying the nature of deductive reasoning and scientific reasoning based on probabilities. I immediately began to test this hypothesis, by going through the original English text of Conan Doyle. To my own surprise, the manuscript of book-length was completed in three months (Uchii 1988).

In the following, I am going to explain the essential part of this book. First, I will show a number of evidence for saying that Holmes was a logician. Second, I will analyze his method of reasoning, and relate it with the probabilistic induction that became prevalent in the late 19th century.

2. Sherlock Holmes as a logician

With my hypothesis in mind, I began to read Holmes stories, and soon gathered enough amount of passages which indicate that Holmes know well logic and also know well how to use it in his criminal investigations. By the way, some reader may wonder what logic is; so let me explain briefly. In the preceding quotation, Holmes rightly suggested that logic is the science of deduction and analysis. Deduction, in the strict sense, is an inference from premises to a conclusion, and moreover, each step of this inference has *certainty*. For instance, suppose a father promised his son, "If it is fine tomorrow, we will go on a picnic." Now the next day was fine. Then, the son can surely infer that he will go on to a picnic with his father. This inference is supported by certainty (no exception, necessity), and if the father made that promise, admits that the day was fine, and denies the conclusion "we will go on to a picnic," then he is accused of *inconsistency*. In other words, he is *contradicting* himself. These key words, "certainty", "inconsistency", and "contradiction" show the essential feature of deduction. And logic is a systematic study of various aspects of deduction.

However, although Holmes often uses deduction in this sense, his reasoning is more often looser, allowing a room for uncertainty. For instance, when he first met Watson, he surprised Watson by saying "You have been in Afghanistan, I perceive." This inference is typically Sherlockian, but it is based not only on deduction in the above sense but also on probable inferences. That is, Holmes observed Watson carefully, and he thought, "Here is a gentleman of a medical type, but with the air of a military man." But this does not give certainty to the conclusion that this gentleman was an army doctor, although it may well be probable. For, admitting that a man is of medical type with the air of military man, you can still say *without inconsistency* that he is not an army doctor; he may be an actor, for instance! But Holmes' inference goes on: this gentleman's face is dark but his wrists are fair, so he must have been in the tropics; his left arm seems to have been injured; where in the tropics could an English army doctor have seen much hardship and got his arm wounded? Aha, Afghanistan! These inferences are not certain but probable, and Holmes' expertise of such inferences enabled him to reach a right conclusion.

However, as you will see soon, many logicians in the late 19th century studied both deduction and such probable inferences. So it may well be reasonable to characterize Holmes as a logician, in view of this circumstance in the 19th century. Anyway, the treatment of such probable inferences will turn out to be the crucial part when we analyze Holmes' reasoning.

And now, what do you think a logician is like? I know many logicians, great as well as not-so-great, and I was a logician myself when I was young. Thus I think I am qualified to pick out typical characters of a logician.

(1) A logician has to be like a meticulous craftsman, paying careful attention to details but deleting any redundancy inessential to the subject. Any logician will like a beautiful proof, or reasoning, as far as possible; such proofs must be shorter, direct, with no redundancy, and with ingenious twists, if possible.

Does this feature apply to Holmes? Yes, I will emphatically say. See the following quotation:

> "Some facts should be suppressed, or at least, a just sense of proportion should be observed in treating them. The only point in the case which deserved mention was the curious analytical reasoning from effects to causes, by which I succeeded in unravelling it." (The Sign of Four, 90)

I will explain later what "analytical reasoning" is, but the point here is that Holmes' character is quite in conformity with (1), in that he stick to the importance of reasoning. I can also quote another, rather famous passage:

> “I consider that a man’s brain originally is like a little empty attic, and you have to stock it with such furniture as you choose. A fool taken in all the lumber of every sort that he comes across, so that the knowledge which might be useful to him gets crowded out, or at best is jumbled up with a lot of other things, so that he has a difficulty in laying his hands upon it. Now the skilful workman is very careful indeed as to what he takes into his brain-attic. He will have nothing but the tools which may help him in doing his work, but of these he has a large assortment, and all in the most perfect order.” (A Study in Scarlet, 21)

Here, it is abundantly clear that Holmes likes a craftsman’s way, and he is himself a kind of “craftsman of reasoning,” i.e., a logician.

3. How well does Holmes know about logic?

But you may wonder: is this enough for calling him a logician? Maybe “not enough”, and we may need more evidence. In particular, unless one knows well the subject of logic, one cannot be a logician.

(2) A logician must be aware of the peculiar nature of logical inferences.

This feature is also well satisfied by Holmes. For instance, he clearly points out an essential peculiarity of logical inferences, as follows:

> “it is not really difficult to construct a series of inferences, each dependent upon its predecessor and each simple in itself. If, after doing so, one simply knocks out all the central inferences and presents one's audience with the starting-point and the conclusion, one may produce a startling, though possibly a meretricious, effect.” (The Adventure of the Dancing Men, 511)

I think this remark touches on the heart of logic. A single elementary inference is quite easy, e.g., “If A then B, but in fact A, hence B.” No one can deny the validity of this, and unless each step of an inference has such certainty as this, it is not a deduction, as was explained above. But, alas, our human intelligence is not strong enough (except for a few genius minds), so that it can easily lose sight of a chain of connections, if repeated several times. And any reader of Holmes stories should be aware that Holmes often teases Watson by disclosing the intermediate steps of his reasoning.

For example, in Chapter 1 of *The Sign of Four*, Holmes surprises Watson by pointing out that Watson went to the Wigmore Street Post-Office in order to send a telegram. Later, Holmes analyzes this inference as follows: (a) Observation tells him that the reddish mould adhering Watson's shoes comes from the Wigmore Street (the pavement there is under repairs); (b) and the telegram was inferred from his knowledge and observation. This inference is a simple elimination of possibilities, i.e., "Either to send a letter, or to buy stamps or postcards, or to send a telegram; but from what Holmes observed about Watson and his belongings, the first two alternatives are eliminated." And these two, if combined together, produce a conclusion that surprised Watson. That is a good piece of logic!

4. "Eliminate the impossible, what remains must be true"

Moreover, it may be interesting to notice that a famous logician clarified the nature of the eliminative inference explained above, around the middle of the 19th century. The logician was William Stanley Jevons. His idea is roughly as follows. Suppose you have a number of propositions, say, A, B, and C, and you wish to make inferences, from given premises expressed in terms of these. You may wonder, how can we express a conditional proposition such as "If A then B"? Jevons' answer is: you should notice the possibility that *falsifies* this conditional proposition. That is, the proposition becomes false, when A is true but B is false, in short when A and not-B holds (you may recall the case of a promise between father and son). If you realize this, you can also see that when you *assert* "If A then B", you are in fact *eliminating* that possibility, i.e., A and not-B. Likewise, if you also assert "If B then C", you are eliminating the possibility B and not-C. Then, what is the conclusion when you assert these two conditional propositions?

Jevons devised a fine way to make this sort of eliminative inference. Each proposition can be either affirmed or negated; so let us express affirmation by an upper-case italic, e.g., *A*, and negation by a lower-case italic, e.g., *a*. Since we are considering three propositions A, B, and C, we can enumerate all possibilities (eight, in total) in terms of these propositions, by the following combinations:

ABC, ABc, AbC, Abc, aBC, aBc, abC, abc

These are the atoms of information, so to speak, when we consider any propositions in terms of the three propositions. Jevons called them "logical alphabets." Notice that each atom is inconsistent with any other (since if one has affirmation, the other must have negation of the same proposition), and all the atoms together exhaust all possibilities. With this preparation, you can nicely solve the problem of eliminative inference. Given premises "If A then B", "If B then C". Let us see which atoms each premise eliminates. The first premise eliminates *AbC* and *Abc*, the second premise eliminates *ABc* and *aBc*. Thus only four atoms remain, and the right conclusion is in them! If you want to ask "if A then?", you can look at the atoms with *A*, and in our case only *ABC* remains, so that you get the answer "If A then C." See the following Table.

ABC		
ABc	×	Eliminated by "If B then C"
AbC	×	Eliminated by "If A then B"
Abc	×	Eliminated by "If A then B"
aBC		
aBc	×	Eliminated by "If B then C"
abC		
abc		

Table 1. Eliminate the Impossible!

In this way, Jevons has shown that all deductive inferences can be reduced to elimination of possibilities (atoms). You see that this is quite in conformity with Holmes' saying, "When you have eliminated the impossible, whatever remains must be the truth" (Sign of Four, 111). Do you think that Holmes can make such a statement without knowing logic of his day? Surely not, and we must conclude that Holmes knew something like Jevons' analysis of eliminative inferences. That is, Holmes must have had advanced knowledge of logic of his day.

5. Analysis and analytic reasoning

Having seen Jevons' reconstruction of deductive reasoning, it is timely to explain Holmes' strange use of the word "analytic reasoning." It is also called "reasoning backward", as in the following passage:

> "In solving a problem of this sort, the grand thing is to be able to reason backward. That is very useful accomplishment, and a very easy one, but people do not practise it much. In the everyday affairs of life it is more useful to reason forward, and so the other comes to be neglected. There are fifty who can reason synthetically for one who can reason analytically." (A Study in Scarlet, 83)

It is quite understandable that Watson did not follow this remark at all. However, if you, together with Watson, understand this, you will realize that Holmes knows philosophy rather well, contrary to Watson's assessment. First, it is easy to see that Holmes calls "reasoning backward" *analytic*, and "reasoning forward" *synthetic*. And what he means is this. Given a sequence of events, most people can predict what the next result is, and this is what Holmes calls reasoning forward, or synthetic reasoning. On the other hand, given a result, few people can say what steps of events produced this result, and this is reasoning backward, or analytic reasoning.

The distinction between *analytic* and *synthetic* was frequently used by Kant, but this distinction actually goes back to Descartes, the famous French philosopher in the 17^{th} century. In his *Discourse on Method* (1637), he propounded the method of analysis and synthesis, for obtaining new knowledge. Taking a geometer's method as his model, Descartes' analysis first supposes that a given problem was solved (this corresponds to Holmes' "result"), and looks for the steps leading to this solution. For example, suppose a given angle was equally divided; how can we bring about this result, using only a ruler and a pair of compasses? Going back to simpler steps leading to the solution is called analysis. In contrast to this, the proof that such and such steps does indeed lead to this solution is called synthesis. This distinction indeed coincides with Holmes' distinction of reasoning backward and forward.

Moreover, you should realize that Jevons' clarification of the deductive reasoning was precisely in accordance with the method of analysis! Descartes argued that we should analyze the given problem into simpler parts, as simpler as is necessary and sufficient for solving any given problem. You may remember the logical atoms, or logical alphabets, in the Table 1. They exactly fulfill Descartes' requirement; given an appropriate set of logical atoms, all deductive reasoning can be reduced to eliminative inferences, which go back to logical atoms. Thus, although it may sound very strange to laymen, Holmes' use of the analytic-synthetic distinction is quite in accordance with philosophical traditions.

Further, Holmes introduced new twists. He extended the analytic-synthetic distinction to inferences of causal relations, and moreover, to inferences in terms of probabilities! And this extension is, again, essentially due to Jevons. We are now getting into the most interesting part of Holmes' reasoning.

6. Causal Sequences

In criminal investigations, that is, the business of Sherlock Holmes, we usually start from the result, a crime is committed, and then investigate by whom and how the crime is committed. Thus it is clear we have to reason backward. Therefore, we can recognize an apparent similarity with analysis in Descartes' sense. But the problems is that the reasoning backward in this case is not going back to simpler elements, as was the case in Descartes' and Jevons' examples. So, clearly, Holmes extended the meaning of "analysis." That is the *first* twist made by Holmes.

Holmes is quite right when he said that reasoning forward is much easier than reasoning backward. For, in ordinary life, given a known cause, it is easy to predict what the result will be. For instance, if you release a coin from your fingers, it will certainly fall to the floor. In contrast, looking at a coin on the floor, it is quite hard to tell why this coin is there; there are a number of possible causes; someone may have accidentally dropped it from his pocket, or someone may have intentionally placed it, etc. In order to tell why this coin is on the floor, you have to eliminate all incorrect stories, or sequences of causes. Presumably, because of this need for eliminative inferences, Holmes called reasoning backward "analytic reasoning."

Now, the question is how we should carry out such elimination. That's precisely Holmes' main business!

7. How do we make reasoning?

Since we have targeted our main problem in the last section, it may be instructive to reflect on the circumstances under which we begin to reason. Given some information ("a coin is on the floor") and a few questions about it ("why is it there, and what is the causal sequence which produced that result?"), we begin to reason, in order to get right answers to such questions. Since the information is *insufficient*, and various *uncertainties* are involved, we can never expect that such reasoning will be always successful. Needless to say, this applies to our hero, Sherlock Holmes too. But Holmes is a hero because his reasoning succeeds very often, far oftener than Watson, Lestrade, or Gregson (the last two, from Scotland Yard). Thus the success of Holmes' reasoning is a matter of *probabilities*, and we may suppose that in many cases, at least, his reasoning also involves probabilities, unlike deductive reasoning. This suggests a working hypothesis to us, that Holmes makes good use of probabilistic inferences or statistical inferences, in addition to deductive reasoning. Then, his elimination of many hypotheses, which may lead to a correct solution, should also be a matter of probabilities. This is nothing but what I mean by his *second* twist, as regards "analytic reasoning."

The reader may become suspicious: Is Holmes really engaged in such complicated reasoning? But wait a second! We can easily find many examples of probabilistic or statistical inference in our ordinary life. Suppose you commute from your house in a suburb to your company in downtown by train. Our (Japanese) transportation system is famous for it exact timetable! So if you take a train at 8:30 *am*, you'll reach your company on time, just before 9:00 *am*. Well, *except for* a few accidental cases! A few exceptions emerge, in a couple of years! Maybe traffic accidents, or bad weather. So the inference "if you take this train, you will reach your company on time" turns out to be a matter of probabilities. It is not certain, as a deductive inference.

Many other examples can be found. You don't feel well today with sore throat and visit a doctor; he diagnoses that you have caught a cold, and gives you a prescription. Fine, but is the doctor always right? His diagnosis may be wrong, because it is based on probabilistic inferences: given such and such symptoms, the patient probably caught a cold. And the drug prescribed may be ineffective, although that case may be exceptional. Again, this is a matter of probabilities or of statistics.

However, we do have many ways to reduce uncertainties, or to increase probabilities. Many will try to get *more* information. In the previous train case, you can check the weather by various means, newspapers, radio, TV, or your own experience and observations: “I’m sure no typhoon is coming, so surely no delay!” Or you can also check traffic information, “no accidents so far along the line.”

Likewise, Sherlock Holmes obtains more information by his investigations, by his keen observations. But it is not the amount of information that matters, but *relevant* information. Holmes is a keen observer, because he is very good at gathering relevant information. Then, how can we distinguish relevant from irrelevant pieces of information? This is another crucial question. But Holmes has already given a good clue: “man’s brain as a little attic” (see section 2 above).

8. Systematic knowledge: Attic with assorted tools

You cannot tell whether or not this piece of information is relevant, in a vacuum; you need a theory or hypothesis, together with background knowledge. For relevance presupposes an answer to “relevant to what,” and this “what” is nothing but the correct solution; but we do *not* know the solution, so that we have to construct several hypotheses (as regards what the solution is like). Moreover, we can neither construct hypotheses in a vacuum; we’ve got to work out on some background. For instance, you may notice that “this case somehow resembles that case,” or “this is the same type of event as that.” Such perception of resemblance may be a good starting point.

Holmes also emphasizes the importance of imagination.

> “See the value of imagination,” said Holmes. “It is the one quality which Gregory lacks. We imagined what might have happened, acted upon the supposition, and find ourselves justified.” (Silver Blaze, 344)
>
> “I have devised seven different explanations, each of which would cover the facts as far as we know them. But which of these is correct can only be determined by the fresh information which we shall no doubt find waiting for us.” (The Adventure of the Copper Beeches,” 323)

That is, without the power of imagination you cannot devise hypotheses. And Holmes boasts of his own ability to devise hypotheses. Further, he clearly suggests that fresh facts can be predicted by such hypotheses; whether or not such facts can be found is, of course, a matter of investigation. Notice that this cycle of “from a hypothesis, new predictions, and empirical confirmation” is exactly similar to scientific investigations.

Now, the point of Holmes' metaphor of a little attic seems to be this. Imagination is important, all right, but without well-prepared background knowledge, it is hard to come up with *promising* hypotheses. You may easily ignore small points, or details, which may well be relevant to the given case. Thus Holmes' pet subject:

> "A certain selection and discretion must be used in producing a realistic effect," remarked Holmes. "This is wanting in the police report, where more stress is laid, perhaps, upon the platitudes of the magistrate than upon the details, which to an observer contain the vital essence of the whole matter. Depend upon it, there is nothing so unnatural as the commonplace." (A Case of Identity, 191)
>
> "It was most suggestive," said Holmes. "It has long been an axiom of mine that the little things are infinitely the most important." (A Case of Identity, 194)

You've got to be able to see the *peculiarities* of the given case, and for this, your assortment of tools in your "attic" must be systematic and fine, and even maniac. On such background knowledge, it is *more probable* that you can devise a promising hypothesis for given cases. And, "promising" in this case means that such hypotheses are *more probable* than others to succeed!

9. A model of probabilistic inferences

In order to get into the nature of the Sherlockian probabilistic reasoning, let's begin with a simpler model, which became prevalent in the 19^{th} century, thanks to contributions by Pierre-Simon Laplace (1749-1827, French mathematician and physicist), de Morgan, and Jevons. Suppose here are three urns containing black and white balls; they all contain the same number of balls, say 5, but you cannot see the inside. You are told in advance, that urn 1 contains 4 black and 1 white, urn 2 contains 3 black and 2 white, and urn 3 contains 2 black and 3 white. Suppose one urn was chosen at random (you cannot tell which urn it is, since the outward appearance is the same for all urns), and your job is to tell, based on experiments, which urn it is. All you are allowed is to draw one ball, record its color, and then return it back into the urn and shuffle. You may make this experiment any number of times, until you think you can give an answer.

With this simple model, you can grasp the essential feature of probabilistic inferences. You have only three hypotheses to test, i.e.,

H1: this urn is urn 1 containing 4 black

H2: this urn is urn 2 containing 3 black

H3: this urn is urn 3 containing 2 black.

And since the urn was chosen at random, each hypothesis is equally likely. That is, before you begin your experiment, the probability that any hypothesis is true is 1/3 (since the probabilities must add up to 1). And notice that, *given any hypothesis*, you can tell the probability of any outcome. For instance, on hypothesis H1, the probability that a black ball is drawn on any trial is 4/5; likewise, the probability that black is drawn on any two consecutive trials is $4/5 \times 4/5$, or 16/25. In mathematical symbols, we can write P(outcome, H1) = 16/25, for instance.

These probabilities calculated from each hypothesis, together with the actual outcome of your experiment (that is, the "result" in Holmes' sense), enables you to know the probability of each *hypothesis*, *given the outcome*, written in symbols, P(H1, outcome). Notice the order of the hypothesis and the outcome is reversed, so this probability was called "inverse probability" in the 19th century.

I ventured to write mathematical symbols, in order to make clear the parallelism of these expressions and Holmes' distinction between "reasoning forward" (synthetic) and "reasoning backward" (analytic). Reasoning forward, in terms of probabilities, e.g., P(outcome, H1) is straightforward and easy. But reasoning backward (again in terms of probabilities) is more complicated. Although I will skip its mathematical proof, the inverse probability of each hypothesis is proportional to the probability given to the outcome according to each hypothesis. This can be better understood with the aid of the following Table, which is calculated when the outcome is "black and black". The inverse probabilities are shown in bold face letters.

The initial probability of each hypothesis	The probability of the outcome on each hypothesis	The probability of each hypothesis, given the outcome
1/3	16/25	**16/29**
1/3	9/25	**9/29**
1/3	4/25	**4/29**

Table 2. Inverse Probabilities

The Table clearly shows the effect of the experiment. Before the experiment, each hypothesis was equally likely, but after two trials with the result "black and black," the probabilities changed, according to the probability each hypothesis gave to the result; and, at this stage, the most likely candidate is H1, its probability exceeding 1/2. Thus, although there still remains uncertainty, something like "elimination" is going on. After several trials, you will surely say, "Now I am confident that the urn has such-and-such constitution"; and this is nothing but probabilistic elimination of *unlikely* hypotheses!

With this preparation, I will now claim that the major part of Holmes' reasoning consists of such probabilistic elimination, that is, reasoning backward in terms of probabilities.

10. "Balance probabilities and choose the most likely"

As I have told in section 1, I rediscovered Sherlock Holmes in 1987, and one of the most striking statements by Holmes was found in *The Hound of the Baskervilles*:

> "We are coming now rather into the region of guesswork," said Dr. Mortimer.
>
> "Say, rather, into the region where we balance probabilities and choose the most likely. It is the scientific use of the imagination, but we have always some material basis on which to start our speculation." (The Hound of the Baskervilles, 687)

The second statement is of course by Holmes, and this clearly confirms my claim made at the end of the last section. Of course, Holmes' reasoning should be far more complicated than the simple model of probabilistic inference explained in the last section, but the overall character of the reasoning, characterized by Holmes himself, is exactly the same. Moreover, it must be emphasized that Holmes refers to probabilistic or statistical inferences many times, and such a statement as the above one is not exceptional, but fits in with many other statements in his stories. I will show this in the rest of this section.

First, Holmes, as well as many scientists in the 19th century, was impressed by the statistical regularities, even in the field where as to individual cases, any predictions or regularities seem impossible.

> "Winwood Reade is good upon the subject," said Holmes. "He remarks that, while the individual man is an insoluble enigma, in the aggregate he becomes a mathematical certainty. You can, for example, never foretell what any one man will do, but you can say with precision what an average number will be up to. Individuals vary, but percentages remain constant. So says the statistician." (Sign of Four, 137)

Winwood Reade worked as a government agent in Accra (west Africa), and even Darwin corresponded with him; and Reade became a good writer. But my point here is this: the importance of statistical regularities was pointed out by many scientists from the 18th century and especially in the 19th century, and then through many books of popular writers, such as Reade, many people became aware of it. A "logician", like Holmes, was among the first to utilize this sort of knowledge.

Next, we have to notice that Holmes sometimes uses technical words of probability theory. Just before the preceding quotation, Holmes talks with Watson as follows:

> "We have no right to take anything for granted," Holmes answered. "It is certainly ten to one that they go downstream, but we cannot be certain. From this point we can see the entrance of the yard, and they can hardly see us. It will be a clear night and plenty of light. We must stay where we are. See how the folk swarm over yonder in the gaslight."
>
> "They are coming from work in the yard."
>
> "Dirty-looking rascals, but I suppose every one has some little immortal spark concealed about him. You would not think it, to look at them. There is no *a priori* probability about it. A strange enigma is man!" (Sign of Four, 137)

Do you know the word "*a priori* probability"? It is a technical word, and it usually means "the probability of a hypothesis, *before* we begin experiments"; in our simple model of section 9, an urn was chosen at random so that the probability of H1 was 1/3, and this is an *a priori* probability. In contrast to this, the probability of any hypothesis after some outcome was obtained is called "*a posteriori* probability." In the ordinary English, this distinction is, of course, "prior vs. posterior."

Further, we should notice the overall tone of Holmes' statements. He is thinking in terms of probabilities, e.g., "ten to one," and he is saying, in effect, we should not disregard even a small probability ("We have no right to take anything for granted"). But, of course, *after* we have accumulated *enough* evidence, and one hypothesis was sufficiently confirmed by that evidence, we are entitled to conclude, despite a tiny uncertainty, that hypothesis is true. This is to "balance probabilities and choose the most likely."

Finally, I have to point out that Holmes himself was quite clear about this feature of his inferences. Not only was he a master of probabilistic reasoning, but he was also a theorist ("logician") who was able to analyze the process of such reasoning.

> "It has been a case for intellectual deduction, but when this original intellectual deduction is confirmed point by point by quite a number of independent incidents, then the subjective becomes objective and we can say confidently that we have reached our goal." (The Adventure of the Sussex Vampire, 1042)

11. The Last Bow

In this paper, I have tried to show that Sherlock Holmes was a good logician, according to the standard of the 19th century, both in his character and knowledge (sections 2 and 3). Holmes, in all probability, knew William Stanley Jevons' clarification of deductive reasoning in terms of "logical alphabets" (section 4).

And in view of his use of "analytic-synthetic" distinction and "analytic reasoning," I have argued that Holmes knew rather well philosophy too, as far as logic and methodology are concerned (section 5). Further, I have argued that Holmes introduced new twists (presumably, following Jevons) into analytic reasoning: application to reasoning as regards causal sequences, and probabilistic elimination of hypotheses (sections 6 and 7).

Also, in this context, I have clarified the significance of Holmes' metaphor of the "little attic": without fine assortment in your brain, it is hard to devise promising hypotheses (section 8).

Finally, presenting a simple model of probabilistic inference, which became prevalent in the 19th century (section 9), I have claimed that the essence of Holmes' reasoning consists of probabilistic inferences, "balance probabilities and choose the most likely," which is nothing but probabilistic elimination of hypotheses in the light of evidence. I have also pointed out that my claim fits in well with the text of Holmes stories (section 10).

As I have said in section 1, I came to this view in 1988, and my book on Holmes was published in Japanese (Uchii 1988). In this book, I analyzed various aspects of Holmes' reasoning, in addition to the essential claims presented in this paper.

References

De Morgan, A. (1847) *Formal Logic*

Descartes, R. (1637) *Discourse on Method*

Jevons, William Stanley. (1874) *The Principles of Science*, Macmillan.

Laplace, P.-S. (1814) *Philosophical Essay on Probabilities*

The Penguin Complete Sherlock Holmes, 1981 (originally, Doubleday & Co., 1930)

Uchii, Soshichi (1988) *Sherlock Holmes' Theory of Reasoning* (in Japanese). Tokyo: Kodansha.

Uchii, Soshichi (1998) "Sherlock Holmes and Probabilistic Induction," PITT-PHIL-SCI00000167 (originally a presentation made in 1991 at Center for Philosophy of Science, University of Pittsburgh), http://philsci-archive.pitt.edu/. Also in my website: http://www1.kcn.ne.jp/~h-uchii/Holmes/