Humboldt Professor Hannes Leitgeb intends to push mathematics deep into the domain of philosophy. His goal is to uncover the logical rules that govern the workings of the brain. This makes him a valued partner for neuroscientists.

Insights: Professor Leitgeb, in Britain in 2007 you won an important prize for your research, and the jury's citation was unusually effusive. It singled out your ability to express a vague philosophical discussion in the form of a precise mathematical problem, and in this way, to solve the problem. Is contemporary philosophy marked by a new yearning for clarity?

Leitgeb: No, the quest for clarity is a constant in philosophy. The classical Greek philosophers like Plato and Aristotle always tried to pose philosophical questions as clearly as possible, to dissect and discuss them and, if at all possible, to answer them. If ever a philosopher deliberately set out to be obscure he or she would be a bad philosopher. Today we apply a different set of tools, including mathematical methods, to refine the definitions of terms and formulate our hypotheses and arguments unambiguously. Attaining deep insights in philosophy is like peering into water. If the water is clear, one can see farther.

Using mathematical models to test philosophical propositions – is this the preserve of a small group of logicians or does it represent the future of philosophy as a whole?

Leitgeb: As far as I am concerned it indeed represents the future of the discipline, or at least one aspect of it. It’s not a panacea for every problem in philosophy, but an important approach. Many philosophers, especially the younger ones, already employ mathematical methods. Logic, being highly formalized, is particularly amenable to such methods. Logic deals with the derivation and validity of conclusions, which are expressed in symbols, just as quantities are expressed as variables in mathematics. Furthermore, mathematical methods have become standard tools in the philosophy of science, which is concerned with the rational reconstruction of scientific practice. But they are also applied to problems in epistemology, metaphysics, philosophy of language and, to some degree, even in ethics.
You began your career in Salzburg, where you obtained your doctorate and were on the teaching staff. You then went to Stanford University for a year and later spent five years at Bristol University. How would you characterize the English tradition in your discipline?

_Leitgeb:_ Philosophy in the UK and the US has traditionally tended toward the analytical approach, after the model of the exact sciences. But this characterization of philosophy being analytical or not is no longer very relevant. In any case, the important distinction for me is whether philosophy is good or bad.

How would you define “bad philosophy”?  
_Leitgeb:_ If a philosopher formulates propositions in an obscure way – and further probing fails to lead to greater precision – one begins to suspect that there is not much behind them, and that the obscurity might be deliberate. That would be bad philosophy. Simply proposing a thesis without any supporting arguments is also bad philosophy. These are quite elementary faults. A scientist would cite similar things to characterize bad science. Then there is honest, sustainable philosophy that is not particularly stimulating. This is work that is methodologically flawless, but bad in the sense that it fails to open up any new or exciting vistas for philosophical research.

Looking at the history of 19th and 20th century European philosophy, one would have to say that much of it would not meet your criteria – the work of the anti-rationalists, for instance, or the deconstructionists. Great names like Friedrich Nietzsche, Martin Heidegger, Jacques Derrida – none of them up to scratch?
Leitgeb: I wouldn’t describe anyone as a habitually bad philosopher, but particular contributions can certainly be regarded as failures. Derrida is a case in point. There are texts by him which I’m not sure say anything at all.

Getting back to your biography for a moment, what was it that attracted you to Bristol? What sort of profile does philosophy have there?

Leitgeb: When I moved to Bristol in 2005 a new Department was being formed, staffed by young and intellectually agile people. And within a short time, the university there had become the best academic setting for logic, philosophy of science and philosophy of mathematics in the UK.

From there you could have chosen to go to any of several renowned universities in the US. Why did you come to Munich instead?

Leitgeb: One important reason was, of course, the Humboldt Professorship. It gives me the opportunity to build up a Center for Mathematical Philosophy here and attract outstanding talents to Munich. The LMU Faculty of Philosophy is the largest in Germany and has a splendid tradition in logic and philosophy of science. The University not only gave the idea of the Center its full support, it also offered it a long-term perspective, assuming that everything develops favorably. In Stanford or the other universities that offered me a professorship, I would have been able to focus on my own research, which is also nice, but not quite the same.

Part of the rationale for your Humboldt Professorship was that you should connect philosophy with theoretical informatics and neuroscience. How do you see the links between them?

Leitgeb: In the context of the Excellence Initiative, LMU established a Graduate School in Neurosciences which has close contacts with philosophy; faculty colleagues of mine teach courses there. The University also founded the Munich Center for Neurosciences and I am a member of its steering committee. We are in the process of hiring a Professor of Neurophilosophy. What makes all these activities so interesting for me is that part of my research is devoted to the logical description of neural nets. Neural nets are greatly simplified and idealized abstract models of brain subsystems. In this context, “abstract” means that they can easily be described in mathematical terms. As I have already shown, the dynamics of such neural nets can be captured in the language of formal logic. If one does this properly, one can discern from the structure of a net how it draws logical inferences, and demonstrate that it performs this task in exactly the same way as we humans reach conclusions about the world around us. The question I would now like to pose is whether learning processes in neural nets can also be described in similar logical terms.

Your own intellectual predecessors include the founders of Logical Empiricism, who together formed the so-called Vienna Circle. You have done much to rekindle interest in the work of
Rudolf Carnap, for instance. But Carnap’s “Logical Structure of the World”, which is one of your cardinal references, is generally regarded as a failed undertaking. Would you say it is ready for revival?

Leitgeb: Actually all of Carnap’s books may be rated as failures. Anyone who formulates his theories as clearly and in such detail as he did makes it easy for critics to pick out the weaker points. But Carnap’s failures were always accompanied by philosophical advances – from his first great book “The Logical Structure of the World”, in 1928, right down to his late work. A revival of interest in his ideas set in during the 1980s, when American philosophers opened a new perspective on the contributions of the Logical Empiricists. Up to that point no one had really noticed that Carnap comes from the classical German tradition and was actually a Neo-Kantian. One can now interpret Logical Positivism as a response to the recognition that advances in natural science had rendered some of Kant’s central postulates untenable.

Can you illustrate that by an example?

Leitgeb: For Kant, space is Euclidean; it is the three-dimensional space that we perceive with our senses. Since then physicists have discovered that physical space does not obey all of the axioms of classical Euclidean geometry. Obviously, this must have repercussions for Kant’s assumptions. One can therefore ask how much of Kant’s original construct can be salvaged, and this is where Logical Empiricism comes in. In his doctoral dissertation Carnap already distinguished between different types of space: the space we perceive, a kind of psychological space; physical space, which must be explored by experiments; and mathematical spaces, the abstract entities that mathematicians investigate. All of these satisfy different logical and mathematical laws. In Kant’s work all of these spaces are collapsed into one. But Carnapian ideas are also in vogue in other areas of philosophy.
Where, for instance?

Leitgeb: In metaphysics we have a new buzzword, meta-ontology. Metaphysics or ontology is concerned with the basic structure of reality: what fundamental entities are there and how can one classify them? A typical Carnapian strategy is to say that one can think of the world as being structured in quite different ways, in terms of objects and their properties, but also in terms of states of affairs – as, for example, Ludwig Wittgenstein does in his “Tractatus logico-philosophicus” – and so on. Each of these views generates its own vocabulary and logical system. For Carnap all such systems, perhaps one might even call them ontologies, are valid. Each can be used for different purposes, but none is the sole true ontology.

You propose that logic and mathematics can be used to describe processes in the brain, although, so far, this approach works only in extremely restricted cases. Does this not rule out the possibility that brain functions might a priori depend on non-logical procedures?

Leitgeb: In principle, the fact that it is not yet clear whether or not my results for highly idealized neural nets also hold for more realistic models does not worry neuroscientists very much. Scientists have always employed idealized models. The important point lies elsewhere. In philosophy and ontology we traditionally deal with normative questions like ‘How should we reason?’ Logic does not provide us with empirical laws, it shows us how one may reason one’s way to a logical conclusion. Where the brain behaves irrationally, it will be inaccessible to the descriptive methods that I bring to bear upon it. I am interested in a brain that works rationally.

What about the contributions of computer experts?

Leitgeb: I follow their field closely. A short while ago I gave a lecture to bioinformatics specialists about a much discussed problem in epistemology, namely how one transforms statistical data into qualitative statements. I have developed a theory about this, and I intend to write a short book about it. Ask a meteorologist whether it’s going to rain tomorrow, and he will give you a probability of rain, say 90%, based on quantitative observations of the atmosphere. But you want to know whether you will need an umbrella. Should you expect it to rain or not? To decide, you must convert the meteorologist’s statistical estimate into a qualitative statement using logical inferences. Bioinformaticians are confronted with very similar problems. They assemble reams of data about the genome, but they need to combine the data in sensible ways so as to come up with qualitative assertions. We want to ask whether one can apply the new logical theory to problems in bioinformatics. If the answer is yes, that could be the beginning of a larger collaborative research endeavor.

Do you already have concrete plans for cooperative projects?

Leitgeb: We have to start small, with collaborative supervision of doctoral theses. Some doctoral candidates at the Graduate School will work on philosophical problems. The learning process is one possible topic. What changes occur in the brain when one learns on the
basis of assimilated data? Actually, neural nets may provide a link between the viewpoints of the logician and the neuroscientist. The nets are simple enough to be analytically tractable, and they can be described by formal logic. So I have an approach which one can apply to insights we have already obtained concerning the derivation of inferences during the learning process. I already have the outline of a strategy for doing this in my desk-drawer, but it will take time to build up a group that can turn it into a reality.

You maintain that the brain works logically, using ordered procedures that can be described by formal logic. Nietzsche, on the other hand, was convinced that it works with metaphors and images, in conceptual leaps – and basically non-logically. Which is it, then?

Leitgeb: It depends on what one means by logic. Up until the early 19th century, logic essentially meant the simple kind used by Aristotle. But this is completely inadequate if one wants to understand how people actually reason. The first real revolution here came at the end of the 19th century with Gottlob Frege, and later Bertrand Russell. Since then it has been possible to reconstruct the logical chains of reasoning used by mathematicians. Now logic is learning how to model everyday reasoning processes and those used in the empirical sciences. That is the second revolution, and it transcends the boundaries of classical mathematical logic. To a certain extent, everyday reasoning is based on imaginative leaps, but that doesn’t mean that these are necessarily irrational.

How do you mean?

Leitgeb: The classical example is the following. If I say there’s a bird outside, you will automatically conclude that there is something outside that can fly. But strictly speaking, my statement did not contain enough information to warrant that conclusion. For I could have said: ‘By the way, there’s a bird outside, a penguin.’ In other words, you overinterpreted
the information I gave you by tacking on a likely supposition – what’s known in English as “jumping to conclusions.” You risk having to withdraw your conclusion if it turns out to be incompatible with new information. This is a situation one never comes across in mathematics. A valid proof remains valid even if you introduce further assumptions. The phenomenon of jumping to conclusions is perhaps not so very remote from your invocation of Nietzsche. There was a time when everyone assumed that it had nothing to do with logic, but we now know that this is not the case. One can symbolically encode everyday chains of inference. They involve logical, rule-based systems that can be implemented on a computer. And that is logic in its broader, modern sense.

Is this not a case of introducing uncertainty into logic in order to salvage logic itself?

Leitgeb: Not to salvage logic. The uncertainty is a given, but not necessarily an illogical, element. Another example would be that of the vague term. In mathematics every expression is precisely defined. A natural number less than 7? Only 6, 5, 4, 3, 2 or 1 will fit the bill. Distinctions are not always as sharp in everyday, natural language. What is a pile? A few grains of sand doesn’t qualify, but a few shovels worth certainly does. The boundary lies somewhere between the two but no one can say exactly where. This also holds for objects, the Sun for instance. The Sun is a ball of hot gases, without a sharp boundary. It doesn’t matter whether or not one includes the very last particle, it is still possible to draw reasonable inferences about the properties of a pile of things or of the Sun. So we can engage in reasoning even in the presence of uncertainty. We just need good theories.

Why are you so intent on retaining this rational foundation? Is your ultimate goal perhaps the construction of a basis for a rational ethics? Is your research also motivated by such an ethical impulse?

Leitgeb: Good question. For a start, I myself hardly work in ethics at all. I have published a single paper on the subject. But I do believe that people possess a fundamental core of rationality. I would never countenance the notion that irrationality is at the heart of what it is to be human.

Over the course of the 20th century, natural sciences have taken over from the humanities as the dominant source of interpretative models of the world. One has the feeling that you are trying to redress this affront. ‘Look here, we still have the crucial set of terms with which to describe the world. We can tell you how things really work.’ Is philosophy the ultimate science of all sciences?

Leitgeb: Personally I don’t regard this situation as an affront at all. I do think, however, that we philosophers have something to say to scientists. It is not the case that the philosopher must always be straining to catch up, and could never dare to suggest that it might be better if the scientists did things differently. Sometimes we are ahead of the natural scientists or the informatics experts. Long before they discovered the “jumping to conclusions”
strategy to enable computers to draw reasonable conclusions in normal situations, philosophers of language had taken the phenomenon into account in their attempts to understand the logical structure of “if-then” statements. The logic of vague terms is also a field that philosophers had explored long before Fuzzy Logic came along, which allowed technological systems to deal with hazily defined expressions. Philosophy has good grounds for self-assurance – but no claim to hegemony.

Translated by Paul Hardy