Presentation: The interdisciplinary field of Logic, Language and Information

"Logic, Language and Information" (LLI henceforth) refers to an interdisciplinary field of research whose structure is based on three columns: Logic, in the broad sense, Linguistics and, Computer Science, including Artificial Intelligence. In addition, the field has been enriched by contributions from mathematicians, philosophers and other scholars interested in specific phenomena. The combination of these subjects has resulted from efforts made by many scholars working in the same direction but from different perspectives.

LLI tries to go beyond dealing with the appropriate facts from a logical, linguistic or computational point of view. Instead, it works on the interface of those three disciplines, although some others should also be taken into account. This perspective may have surfaced once the areas have achieved a specific level of development. As an illustration, van Benthem (1991) points out that the theory of types, which became a tradition in logic, found applications in computer science and played a particularly relevant role in the semantics underlying programming languages. Furthermore, the theory of categories, as long as it is a paradigm in linguistics known as categorial grammar, is also relevant in the computational processing of natural language. On the other hand, the growing concern about the foundations of the different disciplines has highlighted some other points of contact. Despite historical controversies, it is well known that computation and artificial intelligence can be based on mathematical logic (Genesereth, Nilsson 1986; Sperschneider, Antoniou 1991). Knowledge representation, for example, requires us to be familiarised with the translation of natural language sentences into formulae in a formal language, or the conceptualisation and reasoning about facts and events. At the same time, a number of works appeared on the logical foundation of categorial grammar and computability theory have provided some interesting results which would be relevant in logic (especially those regarding the decidability problem, for example). Thus, foundational works in one discipline can affect the others *ipso facto*.

Historically, logic has been a philosophical discipline far apart from mathematics for several centuries. After the XIXth Century and the incursion of the mathematical form of logic, this situation changed and logic is widely applied nowadays in philosophy, mathematics and computing. Then, a question arises: Is there any logic to be similarly applied to the three of them? If so, which are its characteristics? In fact, the application needs are different in each of those disciplines, so that to some traditional investigations we must add others in new areas of logic aimed at covering the needs of computer science. Starting from this point, Gabbay (1991) suggests the use of new logics whose characteristics seem to be very similar in logical systems applied to computing. The very notion of a logical system must be redefined. In this sense, it may be relevant to distinguish *logical systems* from *interactive reasoning systems*. The former can be defined by means of a language (more or less specific) and an operation of consequence, whose intuitive properties may be presented as a small set of structural rules, while the latter has to be considered under two different aspects: namely, a declarative-procedural and an interactive (and imperative reasoning) aspect. As an example, labelled deductive systems could be considered unifying systems in the sense that they can present and describe the different logics. Thus, not only logic is applied in computing, but some developments of computer science have somehow influenced the logical theory.

This points to the ancient topic of the relation between philosophical logic and argumentation theory, which has now been renewed as a result of the above investigations. The new logics, inspired by problems arisen in computing, try to model forms of argumentation which are not properly deductive, including common sense reasoning, abduction, etc. In general, in order to study any argumentation we must pay attention not only to the language itself, but also to language use, so that something beyond logic is necessary. Aside from discussing the exact role of logic in drawing the borderline of a theory of argumentation, the study of sound arguments –a responsibility of logic—must be deeply related to the study of all kinds of arguments. Incidentally, a theory of argumentation can be seen as a form of rhetoric (Perelman, Olbrechts-Tyteca, 1989) and, as a consequence, since pragmatics is concerned with the relation between the elements of language and its usage, as enclosed in it. In any case, it may be seen as another path to pursue other interesting problems from the LLI point of view.

Van Benthem (1991) suggests another fruitful avenue of study for LLI, which is an underlying intention in that work, namely, to achieve an understanding of the cognitive functioning of the human mind. If this is our goal, we should pay attention to natural language, perhaps the most representative expression of the human cognitive capacity. Then, we could consider the hypothesis according to which natural language is a specialized deductive system. If so, linguistic studies must be developed hand in hand with logical investigations and related topics. An interesting aspect is that any concept of consequence, and in general any logical operation, can be characterised by its properties, usually expressed through structural rules. By applying this idea of structural analysis, some linguistic operations may be taken as logical operations. This, again, shows the proximity between the related areas and that some of their topics cannot be studied independently.

Let us assume the abovementioned intention, and the special attention paid to natural language in order to work in LLI. Thus, LLI may now be related to cognitive sciences and, what is more, it can be seen as part of the cognitive sciences, since the subject matters which define its content are usually enclosed in that broader class of knowledge. In this case, its interdisciplinary character is rather obvious. *The MIT Encyclopaedia of the Cognitive Sciences* includes introductions to "Philosophy", "Neurosciences", "Computational Intelligence", "Linguistics and Language" and "Culture, Cognition, and Evolution". In that case "philosophy" should be understood as the sum of philosophical logic, philosophy of science, philosophy of language and philosophy of mind. The last introduction may suggest a kind of biological perspective, which will be dealt with below.

To be precise, there is no "handbook of LLI". However, van Benthem & ter Meulen (1997) could be taken as such, since "this handbook documents the main currents in contemporary research at the interface of logic and natural language, including its broader ramifications in computer science, linguistic theory and cognitive science" (van Benthem & ter Meulen, 1997, p. v). This work outlines a new map in which the scientific community could concentrate their efforts in order to face the class of problems in LLI. Even though its first part contains interesting articles concerning Montague Grammars, representing discourse in context, etc., a more basic framework is presupposed. This framework could be illustrated by replicating in a small-scale the triangle whose angles are taken by a minimal logic, at least first order classical logic and elements of its metalogic; some linguistic knowledge, like rudiments of pragmatics, syntax and semantics; and, finally, several concepts of computer science. Gamut (1991) is a good introduction with a view to draw such triangle in LLI, since it covers the angle of logic completely, and, partially, that of language.

The theory of formal languages constitutes an important part of theoretical computer science. On the whole, it has shown interest in phenomena which have been studied from other points of view, which makes it the best candidate in order to cover the last angle. In fact, "in a very true sense its role has been the same as that of philosophy with respect to science in general" (Rozenberg, G. & Salomaa, A., 1997, p. v). Following these authors, it must be pointed out that the origin of the theory of formal languages is extraordinarily varied. It may be said that it is the offspring of many parents. Pure mathematics, particularly algebra or, more precisely, the study of semigroups and monoids in group theory, should be taken into account to ascertain its paternity. Besides, classical logic, including a good amount of metalogical issues, such as results about decidability, soundness and completeness, and those related with computability theory, especially the theory of recursive functions, Turing computability and, what is more important, everything which allows us to find formal models of computing. Certainly, nobody denies the active role of linguistics in the birth of the theory of formal languages. Its origins were somehow in the application of mathematical methods to linguistic studies, as one may conclude after having a look at the main class of its topics. This formal theory includes not only a linguistic terminology (*alphabet, word, vocabulary,* etc.) but also deals with some specific matters, such as phrase structure grammars and their classifications according to the production rules; the subsequent characterisation of languages, etc; in sum, the study of grammatical structure initiated by Chomsky but now applying rigorous mathematical methods.

Many other objective data may be put forth in favour of the existence of LLI as a structured field. The *European Foundation for Logic, Language and Information* (FoLLI) has organised the now famous "summer schools", where many graduate students have taken courses to obtain a PhD degree. It also edits the prestigious *Journal of Logic, Language and Information* (JoLLI), which is one of the best references to know the relevant LLI research lines, and it participate as an institution in the organisation of the most important events in the area (workshops, seminars, etc.). Along with JoLLI, we should also mention those journals whose scope includes matters that belong to the LLI field, but since they are well known, we omit them for simplicity. As for its extension, in brief, the field is settled enough in Europe, where there are important institutions and groups that focus their efforts on LLI, such as the Institute for Logic, Language and

Computation in Amsterdam, the Interest Group in Propositional and Predicate Logic in London, the Institut de Recherche en Informatique in Toulouse, etc. Something similar can be said with respect to USA., where the Center for the Study of Language and Information should be underlined. In Spain, LLI began its development several years ago. There is an Institute of Logic, Cognition, Language and Information at the University of the Basque Country and an Institute for Logic, Language and Information has recently been founded at the University of Seville (Nepomuceno, Quesada, Salguero, 2000). There are groups working on interesting topics that may contribute to develop the field (philosophy of language and logic and philosophy of mind at the University of Granada, cognitive sciences and philosophy of mind at the University of Malaga, theory of formal languages at the Rovira I Virgili University, etc.). Finally, some projects of research have been focused on the logical study of information (Manzano, 2000).

Our choice

Whatever our choice, it would necessarily be limited, not only for limitations of space, but also because choosing among a great amount of topics cannot be totally objective. In fact, despite not ponder able circumstances, the last selection of articles shows our personal preferences, although they can be minimally justified. Let us get on with it.

The structure of the volume is predetermined from the purpose we have in mind for it. This has been partially covered in the previous paragraphs. If our aim had only been to draw the borders of LLI, then some representative works from each pair of concepts or matters, then connected so as to define the content of LLI, would have been enough. Possible pairs of concepts might have been logic-linguistics, logic-computer science, linguistics-computer science, and, perhaps, philosophy (of mind, language or science)-logic and mathematics-linguistics. However, it is also interesting to convey not only old topics but also new ones or even aspects of them that, so to speak, belong unequivocally to the field. If not literally, both possibilities have somehow been considered in order to make the final decision. In fact, a mere repetition of matters and themes would have made any work like that unnecessary, but the incorporation of new topics, or new perspectives of any of the related matters, justifies this volume and other publications in the future.

Although it may look like a subtle distinction, another reason can be called upon. As it has been suggested above, the ongoing concerns focus on the "interfaces" between some disciplines rather than about such disciplines independently considered. To study them, we could break those interfaces down into others that might be easier and could offer an explanation of the former. So, we might pay attention to the interface between philosophy of mind and philosophy of language, logic and computability theory, logic and semantics, and so on. To be precise, we would like to underline what elements of philosophy of mind, among others, are unique in defining the still embryonic LLI field, since, dealing with products of mind, many developments in logical theory have been obtained which serve as the basis for other works into LLI. However, their relevance with respect to the conception of mind or vice versa, even the relations between logic and psychology, are not so clear. Often, in order to depart from

LLI, we may observe an appeal to philosophy of mind although specific works about such a subject are rarely enclosed in more extensive works devoted to our interdisciplinary field. With a view to break this habit, this volume includes *Conceptions of the mind… that do not loose sight of logic* by J. J. Acero, who studies, shortly against his will because of the limit imposed, the relations between conceptions of mind and logic, covering an edge usually left aside.

There is no doubt about the productive interrelation between linguistics and computer science. Nowadays it is easy to find expressions like "computational linguistics", "computational semantics", "natural language processing", "automated translation", etc., which denote lines of investigation in linguistics characterised by the use of computing as a tool, with a view not only to apply linguistic knowledge but also to work in a theoretical direction. In fact, in spite of philosophical concerns about the problem of meaning, with its long historic tradition, an exact understanding of it needs to take into account the results in such areas. As it is well known, logic is also a powerful tool that, together with computing, has promoted and intensified the interest in the related interfaces. Of course these are commonly considered an important part of LLI studies. *Computational semantics* by P, Blackburn and J. Bos has helped cover the need of a relevant example where linguistics (semantics), logic and computer science are working as interconnected disciplines.

Descriptive Complexity Theory by, J. Flum deals with a series of results that constitute the core of the theory of the same name. If we wish to have access to the way in which logic and computer science relate to each other, we should pay attention to the foundations of the latter by means of classical logic. In fact, logic can be a mathematical way of expressing problems, provided that a logic is defined as a language over a given vocabulary and a relation between some structures and the sentences of such language and, according to its expressive power, it can describe a complexity class. So, there could be a back and forth relation between logic and this part of theory of computability, with ramifications in the theory of formal languages. As the author says "the descriptive characterizations allow to convert problems, methods and results of computational complexity theory into logic and vice versa, thus widening the methodological possibilities for both sides". This article is a good sample of that area.

We have previously mentioned the possibility of introducing a biological perspective in LLI studies. Several alternatives exist, such as to study the human languages from a biological perspective, to pay attention to genetic algorithms, to look for analogies between human languages and animal forms of communication, etc. Some of them may be productive but others have little interest. Whatever the case may be, another point of view may be necessary, since we have constantly appealed to the interface between different disciplines. The thing is that new topics of any of the matters that give content to LLI should be brought in, not only to develop new aspects of interrelation with others, but to avoid being far from what can become the paradigm accepted by the scientific community in the future. Although it is rather audacious to foretell the course which knowledge will take, we may venture to say that biology will be the paradigmatic science in the XXIst Century, replacing physics, which inspired a lot of methodological investigations through the XIXth and XXth centuries. That is to say, a revived Vienna Circle, for example, would take biology as the model to make abstract general methods for scientific research and achieve his ideal of a unified science. Nevertheless, biology, because of its object and methods, is not the same at this moment. We cannot forget that at present we are in the information society, in a global world, very different from a world in the past that remained in part unexplored, and that biological disciplines have incorporated not only technical progress but also mathematical methods beyond the mere classifications.

The new point of view should bring biological issues closer to others which are relevant in LLI. Such is the case of the last two contributions: *Networks of Evolutionary Processors: A Survey*, by C. Martin and V. Mitrana, and *Recent Computability Models Inspired from Biology: DNA and Membrane Computing*, by Gh. Pãun and M. J. Pérez. Both present very novel proposals, instead of a more revisionist point of view that would be typical in papers that draw the limits of a field. Each of them introduces new models of computation that are inspired not just in biology, but in nature itself. After all, nature has been performing computations for millions of years and the results are well known, so it should be able to teach us something about computation. Networks of evolutionary processors and DNA and membranes computing could be used to solve some sorts of problems. The described computational processes can be seen as biological processes. In fact, biological notions such as mutations, selection process, chromosomes, etc. are also used in this context. Thus, this kind of work serve as a good illustration of methodological symbiosis between biological science and computability theory, which will give new perspectives in LLI and will have repercussions in the methodology and philosophy of science.

In conclusion, the papers in this volume provide a panoramic view of LLI that should be considered as complementary to the more known one. So, a balance between bringing papers to draw the LLI border and bringing new themes for widening the field has been obtained. Whatever the case, it is more interesting to read the papers than continuing to speak about them. All that remains is for us to thank all authors, who, from the beginning, accepted to participate in this project despite their occupations. Thanks to *Theoria* for the opportunity of having an entire section to make the LLI field better known. Finally, we cannot forget the help of F.J. Salguero, J.F. Quesada and M. C. Hernández and J.G. Amores, on elaborating the project, sending correspondence, organising papers, etc. and the patience of Iñaki who had to face up to endless technical details.

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Diciembre de 2002

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