LFCS Now and Then

Gordon Plotkin

LFCS@30
Edinburgh, April, 2016
Logic programming
Readers who take a narrow view on the automation of inductive theorem proving might be surprised that we discuss the waterfall. It is impossible, however, to build a good inductive theorem prover without considering how to transform an inductive conclusion into the hypothesis (or, alternatively, how to recognize that a legitimate induction hypothesis can dispatch a subgoal). So we take the expansive view and discuss not just the induction principle and its heuristic control, but also the waterfall architecture that is effectively an integral part of the success.

Boyer and Moore had met in August 1971, a year before the induction work started, when Boyer took up the position of a post-doctoral research fellow at the Metamathematics Unit of the University of Edinburgh. Moore was at that time starting the second year of his PhD studies in “the Unit”. Ironically, they were both from Texas and they had both come to Edinburgh from MIT. Boyer’s PhD supervisor, W. W. Bledsoe, from The University of Texas at Austin, spent 1970–71 on sabbatical at MIT, and Boyer accompanied him and completed his PhD work there. Moore got his bachelor’s degree at MIT (1966–70) before going to Edinburgh for his PhD. Being “warm blooded Texans”, they shared an office in the Metamathematics Unit at 9 Hope Park Square, Meadow Lane. The 19th century buildings at Hope Park Square were the center of Artificial Intelligence research in Britain at a time when the promise of AI were seemingly just on the horizon.

In addition to mainline work on mechanized reasoning by Rod M. Burstall, Robert A. Kowalski, Pat Hayes, Gordon Plotkin, J Strother Moore, Mike J. C. Gordon, Robert S. Boyer, and (by 1973) Robin Milner, there was work on new programming paradigms, program translation. The Metamathematics Unit of the University of Edinburgh was renamed into “Dept. of Computational Logic” in late 1971, and was absorbed into the new “Dept. of Artificial Intelligence” in Oct. 1974. It was founded and headed by Bernard Meltzer. In the early 1970s, the University of Edinburgh hosted most remarkable scientists, of which the following are relevant in our context:

<table>
<thead>
<tr>
<th>Name</th>
<th>Univ. Edinburgh time, Dept.</th>
<th>PhD year, advisor</th>
<th>life time (birth–death)</th>
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**Notes:**

- CL = Metamathematics Unit (founded and headed by Bernard Meltzer)
  (new name from late 1971 to Oct. 1974: Dept. of Computational Logic)
  (new name from Oct. 1974: Dept. of Artificial Intelligence)
- MI = Experimental Programming Unit (founded and headed by Donald Michie)
  (new name from 1966 to Oct. 1974: Dept. for Machine Intelligence and Perception)
  (new name from Oct. 1974: Machine Intelligence Unit)
- LFCS = Laboratory for Foundations of Computer Science
In this article we describe how this leap took place, and sketch the further development of automated inductive theorem proving. The work on this breakthrough in the automation of inductive theorem proving was started in September 1972, by Robert S. Boyer and J. Strother Moore, in Edinburgh, Scotland. Unlike earlier work on theorem proving, Boyer and Moore chose to make induction the focus of their work. Most of the crucial steps and their synergetic combination in the "waterfall" of their now famous theorem provers were developed in the span of a single year and implemented in their "Pure LISP Theorem Prover," presented at IJCAI in Stanford (CA) in August 1973, and documented in Moore's PhD thesis [1973], defended in November 1973.

5 See Figure 1 for the Boyer–Moore waterfall. See [Bell & Thayer, 1976] for the probably first occurrence of "waterfall" as a term in software engineering. Boyer and Moore, however, were inspired not by this metaphor from software engineering, but again by an always waterfall, as can be seen from [Boyer & Moore, 1979, p. 89]: "A good metaphor for the organization of these heuristics is an initially dry waterfall. One pours out a clause at the top. It trickles down and is split into pieces. Some pieces evaporate as they are proved. Others are further split up and simplified. Eventually at the bottom a pool of clauses forms whose conjunction suffices to prove the original formula."

6 Cf. [Boyer & Moore, 1973].

Figure 2: Robert S. Boyer (1971) (l.) and J. Strother Moore (1972?) (r.)
Bob Boyer suggested we meet for research discussions in the evening.

Bob left about 1973; Robin arrived about then.

Rod suggested we form the BBMS.

The BBMS was hosted by Rod and Sissi, and Robin and Lucy.

The meetings were (in my memory!) always packed, with people sometimes having to sit on the floor.

We discussed programming languages and their semantics and theorem proving and concurrency and anything else that interested us.

We even had an outside speaker - Adrian Bird told us about genetics at Rod’s house.

The BBMS met until sometime around 1985 (?), maybe 10 years in all,

A motivation and scientific and social basis to found LFCS.
A massive government/industry research by Japan’s MITI, to create a massively parallel “epoch-making computer" with supercomputer-like performance. Prototype machine performance between 100M and 1000 LIPS and so provide a platform for future artificial intelligence applications using concurrent logic programming (Ehud Shapiro: Concurrent Prolog).

A number of languages were developed, all with their own limitations; in particular, the committed choice feature of concurrent constraint logic programming interfered with the logical semantics of the languages.

Did not meet with commercial success (cf Lisp machines) as eventually surpassed in speed by less specialized hardware.

At the end of the ten-year period, the project had spent about $400 million at 1992 exchange rates and was terminated.
The Japanese in the 1980’s had a reputation for invincibility.

Parallel projects were set up:

1. US: the Strategic Computing Initiative; and MCC, the Microelectronics and Computer Technology Corporation.
2. UK: Alvey
3. Europe: ESPRIT, the European Strategic Program on Research in Information Technology; and the ICL-Bull-Siemens ECRC (European Computer Research Centre).
The Alvey Programme ran from 1983 to 1987. Focus areas for the Alvey Programme included:

- VLSI (very large scale integration) technology for microelectronics
- Intelligent Knowledge Based Systems (IKBS) or Artificial Intelligence (AI)
- **Software Engineering**
- Man-Machine Interface (included Natural Language Processing)
- Systems Architecture (for parallel processing)
The protagonists

Gordon Plotkin  LFCS Now and Then
ARGUMENT FOR THE LABORATORY

Alvey proposes the increased awareness, exploitation and development of formal methods in Computer Systems engineering, both hardware and software. The UK is well placed to achieve these ends, as the groundwork for such an advance has been laid by theoretical researchers in UK perhaps more than anywhere else in the world (and certainly so in proportion to the size of its research community).

In parallel with this advance, it is essential that UK maintain its leading position in theoretical research. For this purpose, we wish to argue that a centre is needed whose primary aim is to advance computation theory, now that the theory is beginning to find application and to influence design to an extent which few would have predicted even five years ago. Such a centre will certainly flourish and bear fruit in the very positive climate which now exists, provided by interplay between the intrinsic challenge of computer science as an academic subject on the one hand, and on the other hand by the demands of industry for application.
Professor Robin Milner  
Edinburgh University  
Department of Computer Science  
James Clark Maxwell Bld  
The Kings Bld  
Mayfield  
Edinburgh  
EH9 3JZ

Dear Robin

A rather belated note to thank you, Rob and Gordon for a most interesting and worthwhile day at the University last week. In particular Rob witty and myself enjoyed very much meeting your very bright team. It was a real pleasure seeing so much quality together! We were also pleased to have the opportunity to meet John Constable and do pass on to him our best wishes for a very productive stay in spite of the lack of an office.

I would like to confirm that I am very sympathetic to the proposal that was put forward for a Laboratory with the general aims that you described. We look forward to having you draft out in a little more detail the likely cost profiles and the "charter" as we discussed.

I have to say that turning the aim into a reality will not be simple and will require patience and effort from us both. On our side we will be testing out what we believe is "doable" under Alvey. We will keep in regular contact in this matter.

Again many thanks for a stimulating day and for the excellent hospitality.

Yours sincerely

DAVID TALBOT
Professor A J R G Milner
Department of Computer Science
James Clerk Maxwell Building
Mayfield Road

Dear Professor Milner,

I had a most useful discussion with Mr Oakley on Friday as a consequence of which I am prepared to permit your proposal to establish a Laboratory for Foundations of Computer Science to be forwarded to the Alvey Directorate. In so doing I have to say that we cannot, at this stage, have high expectations of funding the capital aspects of the project, and it may well be that a number of the recurrent items will need to be met in part by the University. I have in mind particular items 17, 18, 19, 23, and 24, as well as the maintenance costs of the proposed building, i.e. items 7-10. These are all areas which I am continuing to explore on behalf of all our Alvey projects with Oakley, the UGC, and possibly Ministers. Nevertheless, the Directorate would like to see your ideas without, of course, any commitment at this stage on either side to funding.

Yours sincerely,

[Signature]

5 November 1984
14 May 1985

Professor A J R C Milner
Department of Computer Science
James Clerk Maxwell Building
The King's Buildings
Mayfield Road

Dear Milner,

Thank you for your further letter of 10 May. I think that I need rather firmer evidence about what additional accommodation will be made available to Computer Science before I can authorise action on the post of Assistant Director. I have, accordingly, written to the Dean on this matter and enclose a copy of my letter.

Yours sincerely,

JHB
George Cleland
YEAR ONE:

- Formally found the Laboratory.
- Become acquainted with all current details of Laboratory planning, with the University administrative staff, and with Alvey Directorate.
- Coordinate recruiting and accommodation of Research staff.
- Coordinate recruiting and accommodation of Support staff.
- Form financial plan for Laboratory development.
- Launch fund-raising exercise for permanent Laboratory building.
- Initiate Industrial Membership scheme.
- Tour Industry and elsewhere to explain and publicize the Laboratory.
- Arrange visiting Industrial Scientist programme.
- Plan programme of short courses for Industry.
- Establish regular communication with Industry, particularly Member Companies.
- Explore with SERC the continued funding of the Laboratory after Alvey.
INaugural Lecture

17th January 1986

"Is computing an experimental science?"

Robin Milner
We are beginning an ambitious programme of research into the Foundations of Computer Science. This isn't to say that we are beginning to study the theory of computation; this has been going on fruitfully for many years. Nevertheless, the particular programme which we have put forward is a new kind of exercise. What makes it new is a central commitment to a double thesis: that the design of computing systems can only properly succeed if it is well grounded in theory, and that the important concepts in a theory can only emerge through protracted exposure to application.
Laboratory for Foundations of Computer Science

A large research group within the C.S. Department

Some 60 members:
- 10 academic staff
- 14 post doc. research fellows
- 25 students
+ support staff
+ visiting researchers.

Extensive funding from
SERC
Alvey
ESPRIT
**Foundations Laboratory: Purpose**

**Main Purpose:**
- Fundamental research in computation theory (40%)
- To be made accessible by defining and implementing formal analytic tools (30%)

These will help to achieve the **Supporting Purposes:**

1. Technology transfer to, and feedback from, industry (15%)
2. Education, including short courses for industry (15%)
The research concerns in LFCS.

- Hardware Design
- Mathematical Theories
- Formal Specifications
- Proof Engineering
- Logical Framework
- Concurrent Systems

A programming metalanguage: ML (functional programming)
TWO EXAMPLES

VIPER (at RSRE Malvern)
First formally verified microprocessor (at least in Europe)
The verification followed methods which began in Edinburgh

COMMUNICATIONS PROTOCOLS
LOTOS
A calculus for describing and analysing communication disciplines based on a theory of communicating systems created here
Lab Director Bob Taylor held periodic informal meetings in the “beanbag” conference room where CSL staff presented new ideas. Members received frank and sometimes brutal feedback from their colleagues.
LFCS social-intellectual life

- Lab lunch
- Seminars
- Clubs: Concurrency; Semantics; ML...
- Away days
- Directors’ meetings
LABORATORY FOR FOUNDATIONS OF COMPUTER SCIENCE

presents

FUNCTIONAL PROGRAMMING IN STANDARD ML
Part 1: Introduction to the Core Language (2 days)
Part 2: Introduction to ML Modules (3 days)

Prepared and presented by

Dave Barry, Kevin Mitchell, Robin Milner,
Nick Rohlwell, Don Sannella and Made Toft

The course will take place on

Monday 19th and Tuesday 20th June (Part 1)
Wednesday 21st to Friday 23rd June 1989 (Part 2)

in the Department of Computer Science,
University of Edinburgh

Standard ML won the 1987
British Computer Society Award
for Technical Achievement
Laboratory for Foundations of Computer Science

presents

Algebraic Specifications in Theory and Practice

A three-day course prepared and given by

Don Sannella and Andrzej Tarlecki

The course will take place from

Monday 11th to Thursday 14th September 1989

in the James Clerk Maxwell Building
on the King’s Building’s Campus of the University of Edinburgh
LFCS
Laboratory for Foundations of Computer Science
Department of Computer Science - University of Edinburgh

EDINBURGH UNIVERSITY
POSTGRADUATE EXAMINATION QUESTIONS
IN
COMPUTATION THEORY

1978 - 1988

LFCS Report Series
ECS-LFCS-88-64
(also published as CSR-376-88)

SEPTEMBER 1988

LFCS
Department of Computer Science
University of Edinburgh
The King's Buildings
Edinburgh EH9 3JZ

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Edinburgh University Postgraduate Exam Questions in Computation Theory

- For more than 10 years, an informal course of lectures and seminars in Computation Theory has been offered to first-year PG students. This course is designed to give a suitable grounding for research in this area as well as a survey of current research topics. It is divided into three broad sections: Complexity, Programming Methodology and Semantics.

- Every year in May there is an informal three-day open-book examination on the material taught in the course. This report contains all of the questions which have appeared on these examinations since the course began.
<table>
<thead>
<tr>
<th>Name</th>
<th>Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Robin Milner</td>
<td>1986 – 1989</td>
</tr>
<tr>
<td>Rod Burstall</td>
<td>1992 – 1996</td>
</tr>
<tr>
<td>Don Sannella</td>
<td>1996 – 1999</td>
</tr>
<tr>
<td>Samson Abramsky</td>
<td>1999 – 2001</td>
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<tr>
<td>Colin Stirling</td>
<td>2001 – 2004</td>
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<tr>
<td>Julian Bradfield</td>
<td>2004 – 2008</td>
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<tr>
<td>Phil Wadler</td>
<td>2008 – 2011</td>
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<tr>
<td>Jane Hillston</td>
<td>2011 – 2015</td>
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<td>Stephen Gilmore + Don Sannella</td>
<td>2015 – present</td>
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</tbody>
</table>
Stuart Anderson
Myrto Arapinis
David Aspinall
Luca Bortolussi
Julian Bradfield
Peter Buneman
James Cheney
Mary Cryan
Vincent Danos
Kousha Etessami
Wenfei Fan
Michael Fourman
Stephen Gilmore
Andrew Gordon
Chris Heunen
Jane Hillston
Paul Jackson
Kyriakos Kalorkoti
Elham Kashefi
Aggelos Kiayias
Leonid Libkin
John Longley
Richard Mayr
Gordon Plotkin
Ajitha Rajan
Don Sannella
Ian Stark
Perdita Stevens
Colin Stirling
Stratis Viglas
Philip Wadler
Petros Walden
Lab lunch

LFCS Seminars

Groups/seminars: PEPA club; Security seminars; PL Thursday group; category theory (with math);....

Away days (Jane Hillston)

Friday afternoon cake.
From a lab to an institute, among other institutes.
From a tight focus to a many-splendoured thing.
Continuation of old topics, often with new twists, and changes of emphasis, e.g., mobile computing, web programming, performance and spatial modelling.
Wonderful gain of many others: e.g., software engineering, algorithms and complexity, automata theory, games, automated verification, databases, systems and synthetic biology, quantum computing, networks, security and cryptography.
Loss of some things: educational outreach to industry, integrated approach to our PhD students.
From a small group to almost a department (cf Cornell).
From a CS context to a hugely-varied Informatics one.
with rich opportunities for interaction and growth: e.g., machine learning, big data, theorem proving, systems.
From a CS context to a University one: e.g., biology (modelling and learning), mathematics (optimisation), economics (games), sociology (security).
What is LFCS to you?