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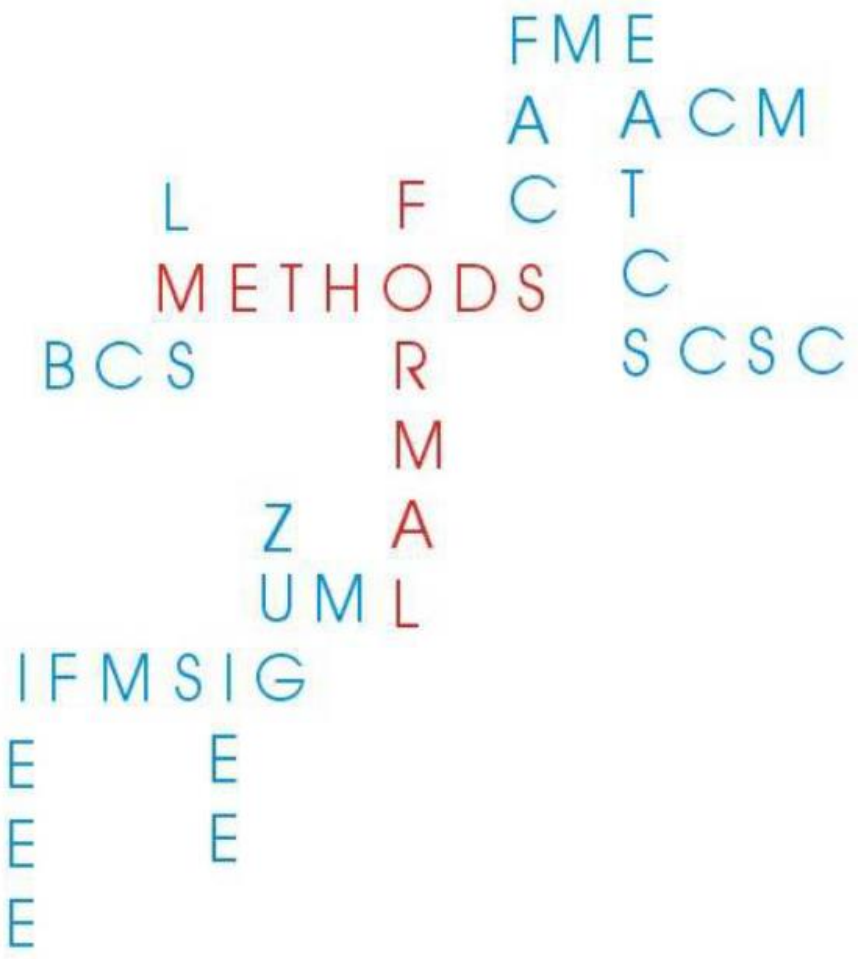
FACS ACTS



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The Newsletter of the Formal Aspects of Computing Science (FACS) Specialist Group

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About FACS FACTS

FACS FACTS (ISSN: 0950-1231) is the newsletter of the BCS Specialist Group on Formal Aspects of Computing Science (FACS). FACS FACTS is distributed in electronic form to all FACS members.

Submissions to FACS FACTS are always welcome. Please visit the newsletter area of the BCS FACS website for further details at:

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BCS-FACS websites

BCS: http://www.bcs-facs.org
LinkedIn: https://www.linkedin.com/groups/2427579/
Facebook: http://www.facebook.com/pages/BCS-FACS/120243984688255
Wikipedia: http://en.wikipedia.org/wiki/BCS-FACS

If you have any questions about BCS-FACS, please send these to Jonathan Bowen at jonathan.bowen@lsbu.ac.uk.

Editorial

Dear reader,

Welcome to Issue 2024-01 of the FACS FACTS newsletter. This is the first issue of 2024. In this issue we have the annual Chair's report from Jonathan Bowen on FACS activities over 2023 as required by the BCS; a report by Brian Monahan of the BCS FACS annual Peter Landin memorial lecture given by Edmund Robinson of Queen Mary University, London; a trip report from Jonathan Bowen on Jifeng He's 80th birthday Festschrift Symposium which took place in the Shanghai Science Hall and which Jonathan co-organised. Next there are three book reviews, the first of which from Tim Denvir covers the proceedings of that latter Jifeng He Festschrift Symposium: *Theories of Programming and Formal Methods*, LNCS 14080. The next two book reviews are in-depth, analytical accounts from Jonathan Bowen and Brian Monahan, respectively, of *The Second Law* – Resolving the Mystery of the Second Law of Thermodynamics – by Stephen Wolfram and *The Joy of Abstraction* – An Exploration of Math, Category Theory and Life – by Eugenia Cheng.

David Turner

David Turner at Strachey 100, Oxford, November 2016 (with Roger Penrose and Michael Jackson)
Photo: Jonathan Bowen

At this point, we would like to record the sad news that David Turner has died, aged 77. David was renowned for his pioneering work on functional programming, for designing and implementing the language Miranda, which employed lazy evaluation and influenced several later functional programming languages, notably Haskell. David held professorships at QMC London, University of Texas at Austin and the University of Kent; he was later a professor emeritus at the University of Kent and Middlesex University. David also worked on international standards for ALGOL 60 and ALGOL 68 as a member of IFIP WG2.1.

An obituary written by David's daughter, Sarah Nicolas, was published by *The Guardian* newspaper in November and can be accessed here. We hope to have a fuller overview of David's career and contributions from Simon Thompson in the next issue of FACS FACTS. Simon would welcome memories and input from FACS readers, including David's collaborators at Burroughs, PhD students and others, addressed to his Kent email address: s.j.thompson@kent.ac.uk

FACS-LMS Seminar, 15th January

The first FACS event of 2024 is the annual joint FACS-LMS talk on 15th January, 4–6 pm. The speaker is Lawrence Paulson, *Formalising 21st-Century Mathematics*. The talk is a webinar **(online only)** and while it is *free*, you do need to register in advance here, where fuller information can also be found.

Back Issues

Finally, just a quick word about our Back Issues (including FACS Europe and FORTEST reports) available online — these can be found and downloaded here: However, it is perhaps worth saying that, since the Back Issues are online, they are also *searchable* using Google, Bing and so on. This is quite useful if one doesn't know, for example, the exact details (e.g. year) for a particular article or event. Moreover, if one is using Google to search, then search criteria may be qualified by putting e.g. "site:bcs.org filetype:pdf facs". Then, using Google to search for "David Turner", for instance, we would have:

site:bcs.org filetype:pdf facs "David Turner"

We greatly appreciate and look forward to contributions, including comments, from you, our readers.

We hope you enjoy *FACS FACTS* issue 2024-1.

Tim Denvir
Brian Monahan

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BCS-FACS Specialist Group 2023 Chair's Report

Member Group Name:	FACS Specialist Group
Year:	2023
Report By:	Jonathan Bowen

Group Chair:	Jonathan Bowen
Group Treasurer:	John Cooke
Group Secretary:	Roger Carsley
Group Inclusion Officer:	Margaret West
Other Committee Members:	Ana Cavalcanti (*FME Liaison*), Tim Denvir (*FACS FACTS newsletter co-editor*), Brijesh Dongol (*Workshop Liaison*), Keith Lines (*Government and Standards Liaison*), Alvaro Miyazawa (*Seminar Organiser*), Brian Monahan (*FACS FACTS newsletter co-editor*), Andrei Popescu (*LMS Liaison*).

Successes

Success	**Additional Comments**
1. Continued evening seminars online, with recordings on YouTube	The BCS Zoom facilities and recording transfer to YouTube have widened access to FACS seminars and support for these by the BCS has improved. Thank you to Alvaro Miyazawa and the Chair for help with organising four FACS events (two each) in 2023.
2. Publication of *FACS FACTS* newsletters by BCS-FACS and *Formal Aspects of Computing* journal by ACM	We aim for two major newsletters each year, published online in PDF format. Thank you to Tim Denvir and Brian Monahan for continuing with their excellent editing of the two 2023 newsletters. Contributions by FACS members are always welcome. The associated FAC journal is now published by ACM with open access to papers. See https://dl.acm.org/journal/fac
3. Move to online and hybrid events	In 2023, two evening seminars were delivered webinars, a major 2-day Festschrift Symposium in Shanghai was made available online, and our highlight event, the Peter Landin Semantics Seminar at the BCS London office (December), is being delivered in hybrid format after the AGM.

Plans

Planned Activity	Additional Comments
1. Continued online and some hybrid events	The BCS facilities for online and hybrid talks enable these modes of delivery. Alvaro Miyazawa of the University of York is now the FACS Seminar Organiser.
2. At least two *FACS FACTS* newsletters	We aim for early and mid-year as times of publication.
3. Collaboration with related organizations such as Formal Methods Europe (FME), London Mathematical Society (LMS), and newly the Edinburgh Mathematical Society.	Our LMS Liaison Officer, Andrei Popescu is organizing a FACS/LMS talk in January 2024 by Lawrence Paulson FRS. Tim Denvir has liaised with the Edinburgh Mathematical Society on possible joint seminars in the future.

Impediments

Impediment	Description
1. Lack of volunteers to organise events	The FACS Seminar Organiser Alvaro Miyazawa and the FACS Chair Jonathan Bowen have organized two FACS events each in 2023 but there have been no other volunteers helping to organize events in 2023. Andrei Popescu (LMS Liaison) and Keith Lines are organising events in 2024.
2. Reduced BCS funding	Our funding from the BCS has been maintained for the 2023/24 financial year at a much-reduced amount as last year compared to earlier years. Thus, our pre-Covid aim of around six physical seminars per year is now realistically reduced to a maximum of two physical events per year. That said, online seminars are much more cost-neutral, so we can continue with these more easily.
3. Reduced physical meetings	The lack of physical meetings impedes networking of FACS members. On the other hand, online seminars are popular due to the reduced cost for attendees and provides a wider national and international reach.

Additional Facts and Figures

We aim for at least two *FACS FACTS* newsletters per year (we had two in 2023, in January and July). We also aim for four to six online/hybrid evening seminars per year (we had four in 2023, three online and one hybrid).

Further Comments

For the record, FACS organised the following events during 2023:

1. *Formal Development of Cyber-Physical Systems: The Event-B Approach*, by **Paulius Stankaitis**, Newcastle University, 4 April. Online event.

2. *The Independence Day of Witnessing the Correctness of Systems*, by **Claudio Menghi**, University of Bergamo, Italy, 4 July. Online event.

3. *Jifeng@80: Theories of Programming and Formal Methods*, chaired by **Jonathan Bowen et al.**, London South Bank University, 15–16 September. Festschrift Symposium held at the Shanghai Science Hall, China. Online event for FACS members.

4. *Logical Relations & Mathematical Foundations*, by **Edmund Robinson**, Queen Mary University of London, 12 December. The annual Peter Landin Semantics Seminar, in association with the FACS AGM, at the BCS London office. Hybrid event.

Thank you to all the FACS committee members for performing their various roles, as detailed above. New committee members and new ideas for activities/collaborations are very welcome, especially if interested in co-organising events.

The BCS FACS Landin Lecture 2023

Logical Relations & Mathematical Foundations

Edmund Robinson
Queen Mary, University of London

We are fortunate in continuing our tradition of having Landin seminar speakers having some form of direct connection with Peter Landin himself – and this year is certainly no exception. Edmund Robinson, our distinguished speaker, not only holds the position of Professor of Computer Science at Queen Mary, where Peter Landin himself worked but is well-known in mathematical semantics foundations, specialising in category theoretic approaches. Landin's significant contributions to programming language semantics, albeit from a more operational perspective, embraced a characteristically rigorous and unyielding mathematical stance. This is particularly so given Landin's strong advocacy of lambda calculus as a cornerstone of programming language theory and practice — something which continues to inform our understanding to this day.

Robinson began his talk by explaining that he started out at Queen Mary by jointly lecturing with Peter Landin on his programming course for a number of years. He saw at firsthand how Peter's fascination for semantics sprang from a profound curiosity about how programming languages really *ought* to work. For example, he would challenge students to practically investigate how programs worked by experimenting with notions like scope and extent, thus motivating the deeper question of when two programs should be said to be equivalent.

It is in this foundational spirit that Robinson introduced the main topic of his talk: *logical relations*. I recall hearing about logical relations as a postgrad theory student at Edinburgh in the late 1970s – early 1980s. At that stage, it was a topic shrouded in a certain amount of mystery – quickly mentioned but not discussed further in lectures. It was an active research topic back then – just as it remains so today.

Robinson opened by stating that, at its core, the notion of a logical relation between semantic spaces is really quite a simple, foundational idea. Broadly speaking, the intuition is that a logical relation is a system of (binary) relations

between semantic spaces (or models), all of which appropriately preserve some designated structures and establish correspondences between related entities.

Although simple enough to say, the following diagram, taken from Robinson's slides, helps to sharpen and focus this intuition:

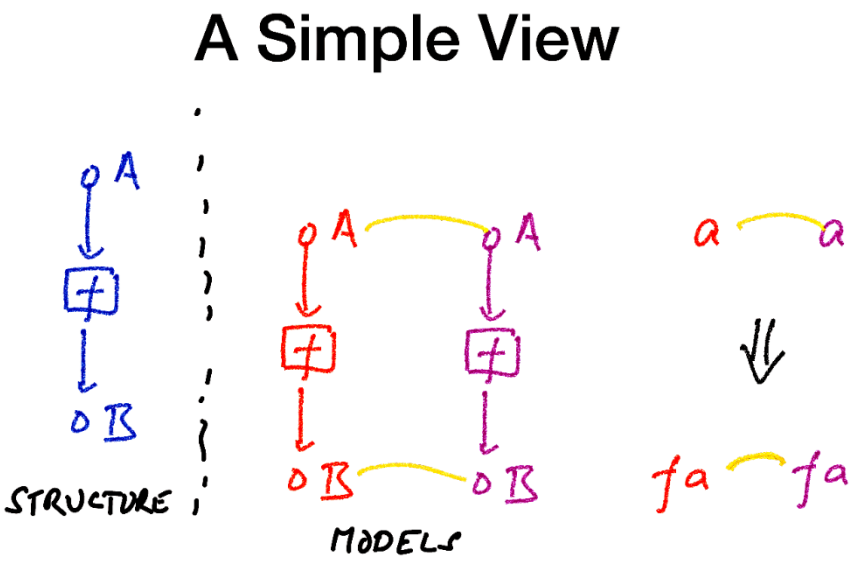

Diagram illustrating the workings of logical relations

The set-up here is that there are various types *A, B, …,* together with various operations *f, g, …,* etc. The structure on the left of the dotted line shows a typical operation (denoted by *f*) which maps type *A* to type *B.* To the right of the dotted line, two corresponding *models* (as *semantic spaces*) of this structure are given in different colours, one in **red** and the other in **purple.**

The various yellow lines then represent the logical relation itself. This associates entities not only at the type level but also at the level of points (or values) within the *corresponding* types. Thus, the logical relation links together both types and values in a way that *preserves* structure in a *coordinated* manner.

Robinson then gave a useful non-programming example by way of illustration. This built upon well-known ideas familiar to students of abstract algebra — particularly, the mathematical theory of groups (c.f. the study of symmetry). The elegant point made here by Robinson was to show how, in this situation, the well-

known notion of a *group homomorphism* between groups corresponds *exactly* to this notion of a logical relation between groups. This albeit straightforward example illustrates a couple of important aspects – firstly, that logical relations can be thought of as a *generalisation* of the well-known algebraic concept of homomorphisms – and secondly, it shows that logical relations between models could be *asymmetric*, meaning that they do not necessarily represent *equivalences* between models. Logical relations represent a foundational means of exploring non-trivial relationships between semantic spaces.

There is a long history of ideas contributing to notions of logical relation in semantics, with Robinson highlighting the independent work of Gordon Plotkin (lambda-definability for both the type-free and typed lambda calculus), Robert Milne (relations between programming language implementations), as well as Mike Gordon (unpublished contributions), all in and around 1973–74.

Intriguingly, Robinson showed briefly that the notion of logical relation is general enough to have use in both algebraic and coalgebraic contexts. As seen later, this meant that logical relations could be applied in characterising and defining many bisimulation equivalences – contexts that typically involve coalgebraic techniques.

From a more computational point of view, this mathematical perspective helps provide a response to this important motivating question asked by Robinson:

What happens if we use different models; do we get the same results?

Of course, this all depends upon what is meant by "different" and "the same" — which logical relations help to clarify. This question naturally stimulated the following consideration, at least for me: in the context of programming languages and compiler correctness, all correct compilers naturally, by definition, conform to the accepted standard semantics of the implemented language. However, *any* compiler/interpreter for a given programming language could equally be regarded as providing a semantic interpretation in its own right, meaning that compiler implementations that happen to conform to the standard semantics of the language should also produce conforming output code whenever given the same valid program.

Following Milne, the logical relations approach suggests that there should be corresponding relationships between output code produced by conforming compilers, for each valid program. When that is not the case, that means there is a valid program whose compiled outputs do not correspond to each other and therefore indicating that at least one of the compilers does not conform to the

standard semantics – mind you, it could also be that neither do! The latitude offered by logical relations specifically being relations, as opposed to functions, could also accommodate the sophisticated data representation and instruction scheduling choices commonly used in compilers (c.f. optimisation).

The final segment of Robinson's talk focused on recent research published in 2022[1] by Robinson and colleagues concerning the nature of process bisimulation equivalence. It is well-known that there is a considerable plethora of such bisimulation equivalences. This important work shows how the different ways that state transition systems are modelled in turn give rise to the appropriate bisimulation equivalences in a natural, standard way, by deriving them in terms of logical relations. This approach has successfully characterised strong bisimulation, weak bisimulation, and branching bisimulation of processes, among others. Tackling probabilistic bisimulation involves further challenges to this approach and forms a part of ongoing research.

Robinson concluded his excellent talk with a humorous anecdote related to Peter Landin. The departmental student teaching rooms used to be known as the "Bancroft Teaching Rooms" in honour of Francis Bancroft, a 17th-century educational benefactor. However, these rooms were located opposite the much larger and grander Francis Bancroft Building, in the Faculty of Humanities and Social Sciences. Many an undergraduate Computer Science student could find themselves wandering around there, trying forlornly to find their tutorial! Finally, it was decided to rename the departmental teaching rooms to the "Peter Landin Teaching Rooms" to clearly disambiguate the very different underlying semantics of the situation – something that Peter Landin would surely have approved of!

There was clearly a lot of material to be covered here, but unfortunately, not all of it could be presented in the time available. Nevertheless, the talk shone considerable light on what logical relations are mathematically and their fundamental role in unpacking the complex mathematical structures found in theoretical computer science, such as those involved in modelling concurrency.

The slides and YouTube video for the talk may be found here.

Brian Monahan
(Photo: courtesy of Jonathan Bowen)

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[1] Hermida, Claudio, Uday Reddy, Edmund Robinson, and Alessio Santamaria. "Bisimulation as a logical relation." Mathematical Structures in Computer Science 32, no. 4 (2022): 442-471.

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Hermida, Claudio, Uday S. Reddy, and Edmund P. Robinson. "*Deriving logical relations from Interpretations of Predicate Logic.*" Electronic Notes in Theoretical Computer Science 347 (2019): 241-259.

Hermida, Claudio, Uday Reddy, Edmund Robinson, and Alessio Santamaria. "*Bisimulation as a logical relation.*" Mathematical Structures in Computer Science 32, no. 4 (2022): 442-471.

Trip report: Jifeng He's 80th birthday Festschrift Symposium

Jonathan P. Bowen

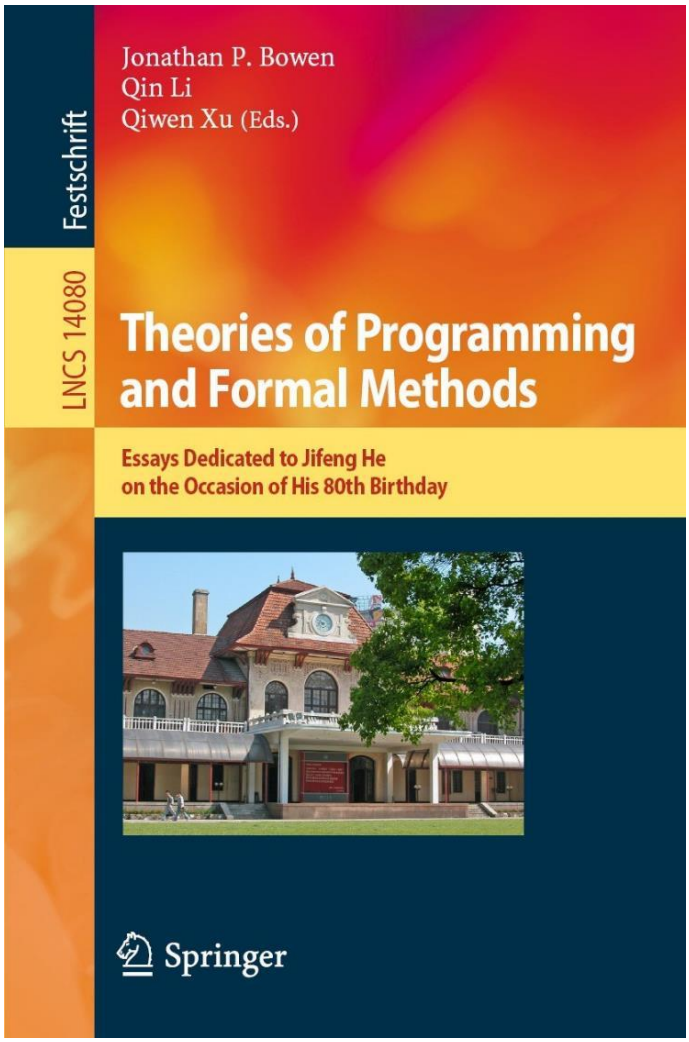
In September 2023, I co-organized and attended the "Jifeng@80" Festschrift Symposium to celebrate the 80th birthday of Prof. Jifeng He at the Shanghai Science Hall, as announced in the last *FACS FACTS* newsletter (Bowen, 2023). Jifeng He has been an important contributor to the field of formal methods, especially in collaboration with Tony Hoare. We provided a brief biography in the previous article, based on that in Bowen & Zhu (2023), followed by a list of presentations, most with associated papers in Bowen et al. (2023). The symposium was held in hybrid mode. FACS members were able to register for online access to the symposium. Those attending in person were there by invitation. A group photograph was taken in front of the main entrance of the Symposium venue (see below).

Group photograph of attendees at the Jifeng@80 Festschrift Symposium.
Centre front row: Zhiming Liu, Andrew Butterfield, Jifeng He, Jonathan Bowen, and Bill Roscoe.
Centre second row behind Jifeng: Huibiao Zhu and Dines Bjørner.

Jifeng@80 Festschrift Symposium

The 80th birthday Festschrift symposium for Prof. Jifeng He ("Jifeng@80") was held during 15–16 September 2023, at the Shanghai Science Hall in Shanghai, China (see photograph on the front cover of the proceedings below). This historic venue was built in the early 20th century within the French Concession area of Shanghai,

previously as a school and for other purposes. In the 1950s, it became the Science Hall, and the facility has since been extended with newer buildings for scientific meetings and related activities. The site is a hidden gem in Shanghai, away from the street with a lawn and garden opposite it. The building is so historic that no Wi-Fi is available! The Symposium was still held in hybrid mode using Zoom, all the computer equipment, video cameras, and networking facilities needed being installed from scratch, with remarkably few technical issues.



The front cover of the Festschrift proceedings, including a view of the Shanghai Science Hall where the Symposium was held.

A Festschrift volume has appeared in the Springer Lecture Notes in Computing Science series (LNCS 14080), containing papers relevant to formal methods by colleagues of Jifeng He, many of whom have been coauthors of academic papers with him (Bowen et al., 2023). This proceedings is a follow-on volume to that associated with Jifeng He's 70th birthday Festschrift Symposium (Liu et al., 2013).

A review of the proceedings by Tim Denvir can be found elsewhere in this issue of the *FACS FACTS* newsletter.

A recorded video presentation by Jonathan Bowen at Jifeng's birthday party in Shanghai before the Symposium, from 11 Keble Road, the location of the Programming Research Group in Oxford.

Reviewing of papers was undertaken by authors and external international researchers. The latter is now required by Springer even for Festschrift volumes. Countries represented included Austria, Australia, Brazil, China, Denmark, France, Germany, India, Ireland, New Zealand, South Africa, the United Kingdom, and the United States.

Festschrift Symposium presentations

In the initial session of the Festschrift Symposium, three talks presented aspects of Jifeng He's contributions to computer science. Jifeng provided an opening address, including his recent interest in Artificial Intelligence and how formal methods could be used in this field. The first main presentation provided a lifetime overview of Jifeng's research contributions, especially regarding formal methods, especially at Oxford University's Programming Research Group in collaboration with Tony Hoare. The following two talks provided more information with respect to developments in UTP (Unifying Theories of Programming) and rCOS (refinement calculus of object systems), two approaches for which Jifeng provided foundational underpinning. Jifeng's book on UTP with Tony Hoare is his magnum opus (Hoare & He, 1998; Bowen, 2020) and has been highly influential, initiating a subfield of formal methods and its own regular series of conferences. In the subsequent sessions were presentations by colleagues and coauthors with Jifeng while he was at the University of Oxford and

also on the European ProCoS project on Provably Correct Systems during this time, where Jifeng especially contributed to provably correct program compilation (He et al.,1993; He, 1994; He & Bowen, 1994). There were also presentations by colleagues of Jifeng from China, Europe, and the United States. The final talk before Jifeng's closing words related to his roadmap for UTP in the future.

The audience at the Symposium. Front row: Dines Bjørner, Bill Roscoe, Emil Vassev, Jifeng He, Zhiming Liu, Andrew Butterfield, Kelly He, during the talk by Jonathan Bowen.

The following presentations have mostly been published in the Festschrift proceedings (Bowen et al., 2023), except where starred. Main presenters are underlined in the author lists below.

Day 1 – Friday, 15 September 2023

Opening address *
Jifeng He

Jifeng He's research influence

(Chair: Qin Li)

Jifeng He at Oxford and Beyond: An Appreciation
Jonathan Bowen and Huibiao Zhu

UTP, Circus, and Isabelle †
Jim Woodcock, Ana Cavalcanti, Simon Foster, Marcel Oliveira, Augusto Sampaio, and Frank Zeyda

Linking Formal Methods in Software Development – A Reflection on the Development of rCOS
Zhiming Liu

Oxford colleagues

(Chair: Andrew Butterfield)

Consciousness by Degree ‡
Yifeng Chen and Jeff Sanders

Specifying and Reasoning about Shared-Variable Concurrency †
Ian J. Hayes, Cliff B. Jones, and Larissa A. Meinicke

The Consensus Machine: Formalising Consensus in the Presence of Malign Agents
Bill Roscoe, Pedro Antonino, and Jonathan Lawrence

ProCoS and other colleagues

(Chair: Jonathan Bowen)

Domain Modelling: A Foundation for Software Development
Dines Bjørner

Logical Algorithmics * †
Moshe Vardi

Additional tributes * ‡
Bernard Sufrin, including messages from Tony Hoare, Jeremy Jacob, and Carroll Morgan.

Day 2 – Saturday, 16 September 2023

Chinese and European colleagues

(Chair: Qiwen Xu)

Characterizations of Parallel Real-Time Workloads
Xu Jiang, Jinghao Sun, and Wang Yi

Towards Efficient Data-flow Test Data Generation
Ting Su, Chengyu Zhang, Yichen Yan, Lingling Fan, Yang Liu, and Zhendong Su

Assume-Guarantee Reasoning for Additive Hybrid Behaviour †
Pieter J. L. Cuijpers, Jonas Hansen, and Kim G. Larsen

European colleagues

(Chair: Ting Su)

Time: It is only Logical!
Frédéric Mallet

Applying Formal Verification to an Open-Source Real-Time Operating System
Andrew Butterfield and Frédéric Tuong

KnowLang – A Formal Specification Model for Self-Adaptive Systems
Mike Hinchey and Emil Vassev

Conclusion and the Future Roadmap

(Chair: Dines Bjørner)

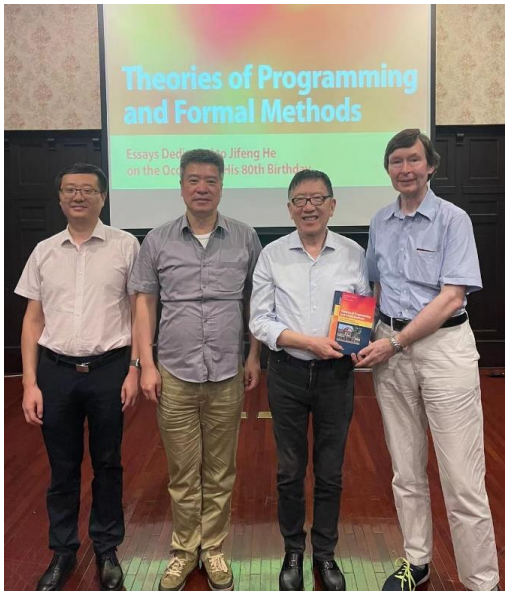
Concurrent Hyperproperties †
Bernd Finkbeiner and Ernst-Rüdiger Olderog

A Coq Implementation of the Program Algebra in Jifeng He's New Roadmap for Linking Theories of Programming
Rundong Mu and Qin Li

Closing address *
Jifeng He

* Not in the proceedings. † Online presentation. ‡ Video presentation.

A video recording and the slides for the talk by Jonathan Bowen and Huibiao Zhu are available online, linked from the information on the BCS-FACS web page for the event (BCS-FACS, 2023).

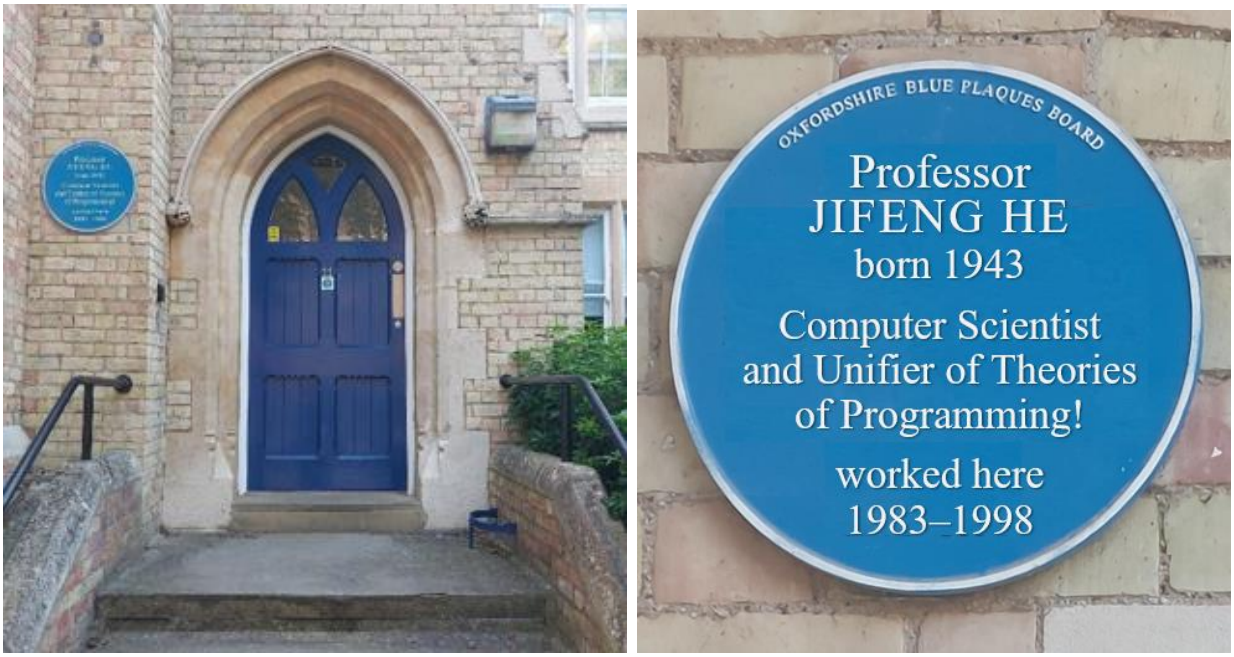
Left: Presentation of "The Silent Traveller in Oxford" by Chiang Yee from Jonathan Bowen to Jifeng.
Right: Presentation of the Symposium proceedings by the editors, Qin Li, Qiwen Xu, and Jonathan Bowen, to Jifeng.

A selection of speakers. Left to right:
Jifeng He, Ting Su, Frédéric Mallet, Andrew Butterfield,
Emil Vassev, Qin Li, Dines Bjørner, Jifeng He (with Ernst-Rüdiger Olderog on screen).

Conclusion

The above talks were presented during the hybrid Festschrift Symposium for Jifeng He's 80th birthday, held during 15–16 September 2023. Associated activities included a Symposium dinner on the evening of the first day, an evening boat trip along the Bund at the end of the second day, and a trip to Tongli, a historic town nicknamed the "Venice of the East" due to its canals, on the day after the Symposium.

A number of Chinese connections in Oxford were noted in the first presentation of the Symposium after Jifeng's address. The poet, author, painter, and calligrapher Chiang Yee (1903–1977) stayed in Oxford during the mid-20th century and wrote of his experiences in a book, "*The Silent Traveller in Oxford*" (Yee, 1944). A copy of the book was presented to Jifeng on the first day of the Symposium (see above). Yee has a blue plaque on the house where he lived in North Oxford. Another blue plaque can be found in Keble Road, a few doors down from 11 Keble Road where Jifeng worked while in Oxford. This is for James Legge (1876–1897), a missionary in China, sinologist, translator of Chinese classic literature, and the first Professor of Chinese at Oxford University. With these existing Chinese connections, the presentation concluded with the suggestion that there should be a blue plaque for Jifeng at 11 Keble Road in due course (see below). That said, the house was once the home of William Archibald Spooner (1844–1930), Warden of New College in Oxford and famed for his "spoonerisms", so there may be some competition for blue plaques on the building!



Suggested blue plaque for Jifeng at 11 Keble Road, Oxford!

Acknowledgement

Thank you to Kelly He for providing many of the photographs from Shanghai. Jonathan Bowen provided the photographs of individual speakers and those of Keble Road in Oxford.

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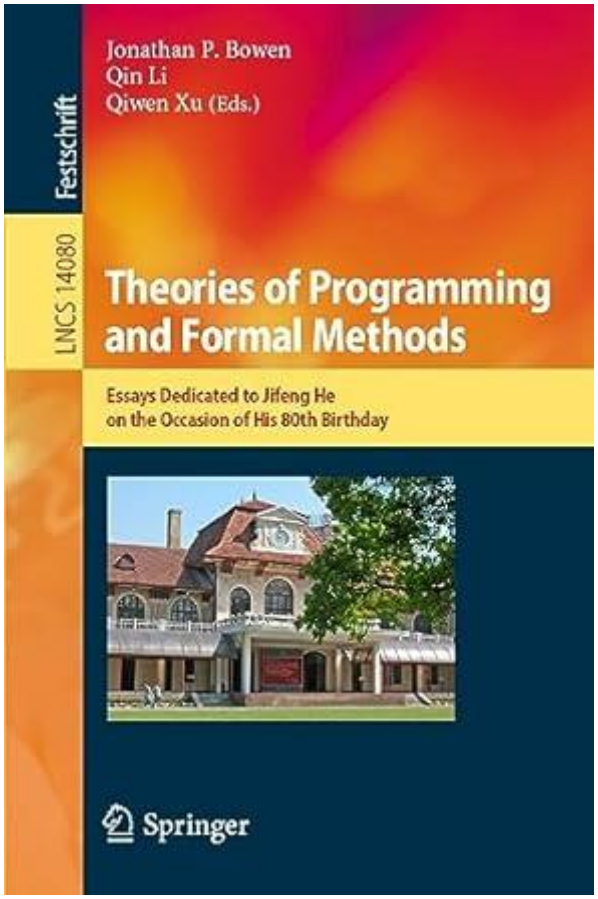
Book review:
Theories of Programming and Formal Methods

Essays Dedicated to Jifeng He on the Occasion of His 80th Birthday

Reviewed by Tim Denvir



Theories of Programming and Formal Methods: Essays Dedicated to Jifeng He on the Occasion of His 80th Birthday,
Editors: *Jonathan P. Bowen*, London South Bank University, UK; *Qiwen Xu*, University of Macau, China; *Qin Li*, East China Normal University, Shanghai, China, LNCS 14080, 2023, 739pp,
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The 80th birthday Festschrift symposium for Prof. Jifeng He (Jifeng@80) was held in September 2023, at the Shanghai Science Hall in Shanghai, China. This Festschrift volume contains papers in the broad area of formal methods by colleagues of Jifeng He, many of whom have been co-authors of academic papers with him. The volume starts with an appreciation by Jonathan Bowen and Huibiao Zhu under the heading of **Jifeng He's Research Influence**: *Jifeng He at Oxford and Beyond*, and follows with two more papers under the same heading. Then come twelve more papers under further headings: **Oxford Colleagues** (3), **ProCos Colleagues** (2), **Chinese Colleagues** (2), **European Colleagues** (4), and finally, **The Future Roadmap** (1). There are forty authors in all. The full list of papers with their authors' details, abstracts and references can be found at the web page above. Each paper can be bought in downloadable pdf format for £19.95, and the whole book for £47.99 in pdf or £59.99 as a softcover.

Many of the papers express personal appreciation for Jifeng He as a colleague, with words such as "Respect", "Friendship", "Mentor", "Inspiration", "Influence". There are also specific tributes, references to collaborative work, praise for his contributions especially to UTP: "Seminal work", "his will to build in Shanghai a

research centre of excellence for trustworthy systems". At least one paper is a specific follow-up to some of Jifeng He's work.

This would be an enjoyable book to possess. I could list all the papers with details of their authors, keywords, abstracts etc., but that would make this review tediously long and all that information is easily available via the concise Springer web page above. Instead I give a flavour of the volume by listing a number of the topics covered, but is by no means complete.

The Introduction by Jonathan Bowen and Huibiao Zhu makes passing reference to AI, the ProCoS project, compiler design, the SAFEMOS project, Unifying Theories of Programming (UTP), Verilog, Duration Calculus (DC), rCOS (refinement calculus of object systems), Unification of CSP and CCS, and Hybrid modelling language (HRML). The other two papers under the heading of **Jifeng He's Research Influence** make more specific references to Circus (Z, CSP, guarded commands, refinement calculus), UTP, Isabelle, the COMPASS project, rCOS, Unified Modelling Language (UML), and Institutions.

Papers under the heading, **Oxford Colleagues**, refer to Consciousness by Degree – formal modelling of awareness, AI, shared variable concurrency, rely-guarantee, refinement calculus, linear temporal logic, State Machines, Process algebras, blockchain, CSP, and Haskell.

Under the heading, **ProCoS Colleagues,** papers refer to Domain modelling, Requirements, Hyperproperties, concurrent traces, Petri Nets, non-determinism, and partially ordered multisets (pomsets).

Under **Chinese Colleagues** papers refer to real-time embedded systems, Dataflow Testing, Symbolic Execution, Model Checking, and Genetic Algorithms.

Under **European Colleagues** papers refer to Assume-Guarantee, Hybrid Automata, Timed Automata, Resource Hybrid Automata, Logical Time, Logical Clocks, Cyber-Physical Systems, UML, Denotational Semantics, XML, Operational Semantics, Clock-Labelled Transition Systems, UTP, Model checking, Promela/SPIN, Test Generation, Real-Time Operating Systems, Knowledge Representation and Reasoning (KnowLang), self-adaptive systems, Knowledge Base, Robotic intelligence, ontologies.

The final single paper under the heading **Future Roadmap** refers to Coq, UTP, Program algebra, Refinement, Indeterminacy.

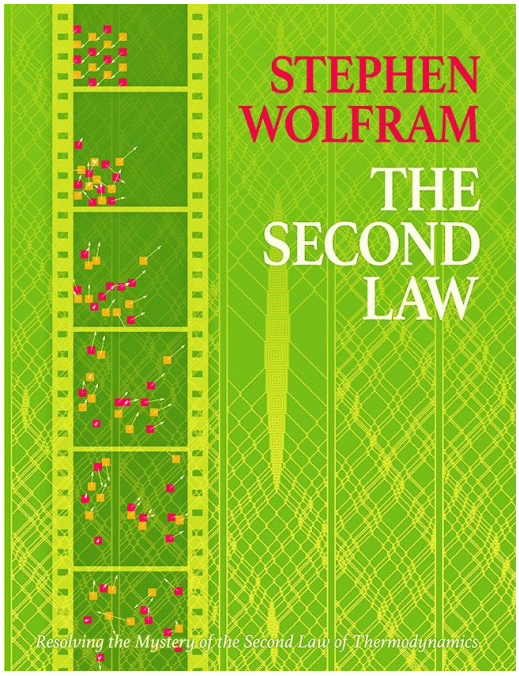
Two papers appealed to me personally. But I insist that this preference is entirely idiosyncratic and is in no way a judgement in comparison with other papers. The first is *Consciousness by Degree by* Yifeng Chen and J. W. Sanders. This paper attempts to give a formal model of consciousness and awareness, of "agents ranging from humans and other animals through cells to organisations and software, (e.g. AIs)". As one might expect, I think their approach would be characterised philosophically as "behaviourist". But I was struck by the novelty of this topic. The second paper is *Time: It is only Logical!* by Frédéric Mallet. This paper seeks to promote logical time to a first-class aspect of the semantics of concurrent and synchronous systems.

As I have already noted, one can find a comprehensive list of all the papers with details of their authors, affiliations, keywords and abstracts on this succinctly presented Springer web page: https://doi.org/10.1007/978-3-031-40436-8

Book review: *The Second Law*

Resolving the Mystery of the Second Law of Thermodynamics

Reviewed by Jonathan P. Bowen



The Second Law — *Resolving the Mystery of the Second Law of Thermodynamics* by Stephen Wolfram, Wolfram Media, Inc., 2023, 584pp
ISBN 978-1579550837

"One of the advantages of being disorderly is that one is constantly making exciting discoveries."
— A. A. Milne (1882–1956)

As an engineering science undergraduate, I studied thermodynamics. This field has several general laws associated with it, but the Second Law of Thermodynamics has gained a mythic status. It can be formulated in several ways. In the study of engineering, the emphasis was that *entropy* is always increasing. This can also be seen in terms of increasing *chaos*, and I can attest to this in the state of my office, despite occasional efforts by me to reverse the Second Law. That said, the quotation by A. A. Milne above certainly reinforces one of the benefits of such "organization"!

A previous article in *FACS FACTS* (Bowen, 2023) reviewed the book *Twenty Years of A New Kind of Science* by Stephen Wolfram (2022), surveying two decades since the publication of the book *A New Kind of Science* (Wolfram, 2002). The book under review here (Wolfram, 2023) considers an important physical law from various aspects, both traditional and computational. The latter has been of special interest to Wolfram during his career (Wolfram, 2019). All these books are published by Wolfram's own publishing arm, Wolfram Media, a benefit of running a successful business such as Wolfram Research, which has produced mathematical software-based products including Mathematica and the search facility WolframAlpha.

For those not familiar with the laws of thermodynamics, the First Law formulated the law of conservation of energy in thermodynamic processes. In a system with internal energy U, from all work done W, and the amount of heat Q supplied (or withdrawn), the change of internal energy is $\Delta U = Q - W$. The Second Law has been

formulated in several different ways. One form states that heat always flows from hotter to colder regions of physical matter. Another formulation, useful in the engineering of heat engines, is that not all heat can be converted to work within a thermodynamic cyclic process. There are also Zeroth Law, established later in the 1930s, concerning a definition of temperature independent of entropy, and the Third Law, stating that the entropy of a closed system at thermodynamic equilibrium tends towards a constant value as the temperature approaches absolute zero. However, the book under review concentrates on the Second Law, arguably the most famous of these laws.

Overall, this book is relevant to those interested in the laws of the physical world. However, this book specifically takes a computational view of the Second Law. It is divided into three major parts. The first part considers the computation foundations of the Second Law. The second part explores Wolfram's own half-century journey of consideration about the Second Law. The third part covers a more extensive history of the Second Law by way of background, taking a more physical view. One could argue that these parts should be in the reverse order, but perhaps that is deliberate given the nature of the Second Law. Further to these three major parts, the book also includes an annotated bibliography, some selected papers by Wolfram, some relevant excerpts from Wolfram's book, *A New Kind of Science* (Wolfram, 2002), and an index.

The first part of the book starts by observing the mystery surrounding the Second Law. Wolfram notes the three important area of physics – general relativity, quantum mechanics, and statistical mechanics – with the Second Law applying in the last of these domains. He considers the Second Law in relation to his long-time study of cellular automata, where seemingly random and complex patterns emerge from simple rules. Formal methodists may be especially attracted to the section entitled "*Towards a Formal Proof of the Second Law*". Wolfram formulates the issue in terms of the state of the system S, an "observer function" Θ, and an "evolution function" Ξ. The Second Law can then be formalized as an inequality: $\Theta[\Xi[S]] \geq \Theta[S]$. This style of relation will be familiar with respect to "refinement" in a formal methods context. The Second Law means that randomness increases as the system evolves. The repeated application of the Ξ function could be in terms of a cellular automaton or a Turing machine, in a computational context. Ξ may consist of multiple individual steps ξ applied t times (i.e., $\Xi = \xi^t$). The observer function is an abstraction function in a formal methods context. It needs to simplify the model of the real system, but the simplification must incorporate the important relevant features of the system under observation. This is always an engineering judgement, requiring domain expertise. With simple models (e.g., a

finite automaton), proofs may be possible, but in most real systems, it is intractable. Perhaps systems amenable to model checking would be suitable for exhibiting entropy properties in the context of the Second Law.

Not considered explicitly in this book, but of interest to the formal methods community, is the concept of "chaos" (or "*CHAOS*") in a formal language such as Tony Hoare's CSP (Communicating Sequential Processes), useful for descriptions of concurrent systems (Hoare, 1985). It is considered as the most non-deterministic (or "chaotic") process. One could contemplate the rules of refinement gradually leading to *CHAOS* in every parallel process over time as a model of the Second Law with the system of processes under consideration (or even the universe) eventually reaching the most chaotic state. The "divergences" of every "trace" of *CHAOS* (in the CSP sense) leads to *CHAOS*. Hoare (1985, p. 129) notes:

> *"It is a shame to devote so much attention to divergence, when divergence is always something we do* not *want. Unfortunately, it seems to be an inevitable consequence of an efficient or even computable method of implementation."*

This comment has resonances with the Second Law in a computational context. Increasing entropy is something that one tries to avoid when designing systems but is inevitable in the wider context of the physical world due to the Second Law.

The second part of the book charts Wolfram's personal progress in understanding the Second Law over half a century. It includes consideration of the Second Law from the perspective of Wolfram's 2002 book *A New Kind of Science* (Wolfram, 2002). In the context of cellular automata, many rules lead to apparent randomness, but some lead to interesting patterns. This seeming anomaly with respect to the Second Law is explored by Wolfram. Since the publication of his 2002 book, he has established a "Physics Project", exploring the possibility of a fundamental theory for physics. The Second Law has been an important part of this quest.

The third part of the book presents a more general history of the Second Law. Over the years, it has been formulated in different ways, typically of practical use by engineers considering thermodynamic properties of systems under design. This part of the book includes extracts from relevant historical publications. It presents the contributions of many scientists and engineers. These include Nicolas Carnot (1796–1832, known for the Carnot cycle for heat engines), James Clerk Maxwell (1831–1879, better known for Maxwell's equations concerning electromagnetism and electrical circuits – on which modern computers are based),

and William Kelvin (1824–1907, known for mathematical analysis of electricity as well as formulating the First Law and Second Law), among others. Sadly, one result of the Second Law is that perpetual motion machines are not possible! The Second Law is generally considered to be axiomatic. However, Max Plank (1858–1947) produced a 1903 *Treatise on Thermodynamics*, including a chapter rather misleadingly entitled "Proof", justified by the fact that nobody has ever managed to create a perpetual motion machine. This has some similarities with the issue of $P \neq NP$, which can be linked to the Second Law through Wolfram's concept of "computational irreducibility" (Wolfram, 2002). This relates to the problem that when modelling a complex physical system, it cannot necessarily predict what will happen in practice. Only an actual experiment can do this. The computational view of the Second Law has developed more recently, and it is this aspect that is likely to be of most interest to formal methodists and more generally computer scientists.

The final parts of the book include an annotated bibliography, some earlier publications by Wolfram from the 1980s onwards, excepts from Wolfram (2002) relevant to this current book, and an index. Overall, this book is highly discursive. Some parts will resonate with those working in the area of formal methods, although much of the book is more relevant to physics and engineering in general. However, this sets the computational aspects of the Second Law in context. Most with an interest in formal methods and theoretical computer science will probably find something of interest in the book but may prefer to dip into it rather than reading it cover to cover. I certainly found interesting resonances with formal methods ideas within the book. I am not sure if the book resolves the mystery of the Second Law of Thermodynamics as its subtitle intimates, but it certainly presents an interesting journey towards this end.

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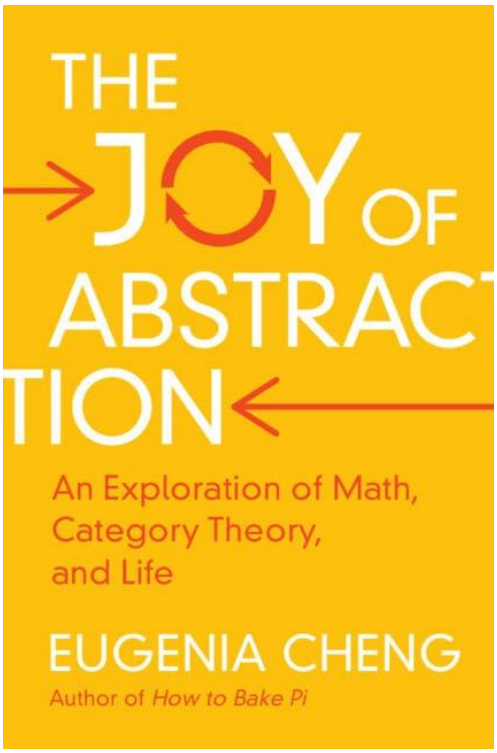
Book review: *The Joy of Abstraction*

An Exploration of Math, Category Theory and Life

Reviewed by Brian Monahan



The Joy of Abstraction by Eugenia Cheng, Cambridge University Press, 2022, 438pp, ISBN 978-1-108-47722-2

This book is really quite unusual – unexpected, certainly, at least to me. From a quick inspection, one might note that there is a fair bit of actual maths in it, which is a little bit odd for most books written for a broad science audience. For example, perhaps you recall Stephen Hawking's "A Brief History of Time" famously with its one, solitary equation ($E = mc^2$)? The second hint that this book isn't a standard run-of-the-mill exposition lies in its subtitle:

An Exploration of Math, Category Theory and Life.

It turns out to be quite an accurate description of the tone and content of the book. This really is a popular science book written about some of the most abstract mathematics available, category theory – and yet it is also so much more than that!

Usually, when a popular science book claims to tackle some topic, like for example, cosmology, genetics, or climate change, there seem to be a couple of common ways that this might go. One way is for the author, typically a subject expert, to write a fairly dry technical exposition of how the subject really should have developed in their opinion, often focusing upon their personal hobby horses along the way. A second common approach is for the author, typically a science journalist, to quickly define a few core technical terms to help the reader gain some familiarity (and establish bragging rights) but only to rapidly transition into taking a more historical, human-interest-based approach, focusing upon the leading personalities in the field and their journey, rather than what the field is actually about.

This book takes neither of those routes particularly. Instead, the first few chapters present a fairly gentle introduction to what maths[2], abstraction, patterns and so forth are all about. For my money, chapter two concerning abstraction is beautifully written and quite masterful – I think it's worth getting hold of this book, just to read that one chapter! Of course, the excellent quality of the writing should safely compel you to read the rest as well.

It is not until chapter 8 that the discussion of category theory itself (or "the mathematics of mathematics", as Eugenia Cheng says in chapter one) really gets going, with the definition of what a category is. However, even by that stage, plenty of maths has already been carefully and skilfully introduced and discussed, all to help develop and present the appropriate context. Given the overall intended audience, even that pace of progress is perhaps somewhat audacious! In this way, Part One of the book covers the whys and wherefores of category theory; this is completed in chapter 13 which gives a large number of more traditional mathematical examples from algebra and topology.

The second half of the book, Part Two, focuses on the "doing" of category theory itself, where the first four chapters 14 to 17 consider some basic architectural concepts such as the role of isomorphisms, introducing monic and epic morphisms to illustrate "element-free" definitions, the importance of universal properties, and finally, duality in categories by reversing the direction of morphisms. The next four chapters introduce several classical categorical concepts such as products and coproducts, pullbacks and pushouts, functors, and, last but certainly not least, natural transformations. Finally, the last two chapters complete Part Two with firstly, a discussion of the "Yoneda lemma", one of the jewels of category theory and, lastly, in chapter 24, a brief but fascinating introduction to higher-dimensional category theory – a topic of ongoing mathematical research forming the subject of Eugenia Cheng's own PhD research study at Cambridge under Martin Hyland[3]. The book ends with an epilogue about "Thinking categorically", various appendices and an index.

Notably, the book contains many surprising examples, quite a few *not* drawn from advanced maths, but instead from real-life situations, ranging from matters of social justice to healthcare (Covid-19) and even route planning. One of the

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[2] I say "maths" here, rather than "math"!

[3] Martin Hyland is mentioned in the Winter 1996 issues of *FACS Europe*: https://www.bcs.org/media/4997/facs-europe-winter-96.pdf

more vivid and memorable examples illustrates the concept of *pullbacks* in the category **Set.** This boils down to sets of pairs of items, each having a common property. In this case, the pullback forms a set of paired trousers and shirts, with each pair of items having the same colour! Once seen, that is hard to forget. This book not only properly teaches some category theory, but also manages to throw light on how we live!

Before closing, it is perhaps worth saying that although the book excels at being a primer in basic category theory, there is inevitably quite a bit of the subject that could not be covered here. For instance, topics that often arise within a computing science context, but are not tackled here, include *cartesian-closed categories* (c.f. λ-calculus), *adjunctions* and *monads*. However, that said, there are other places where further insight can be found – for example, consult the Bibliography below, particularly the (online) books by Leinster and also the material by Milewski.

From a programming and software development perspective, the book's overall take on abstraction and the importance of adopting a principled approach to structure and the benefits (in terms of integrity) that this brings should give strong encouragement to those pursuing such approaches, even though the book doesn't directly address programming and software development issues explicitly.

On a more personal note, while reflecting upon the nature of abstraction, this led me to wonder how programming is all about taking abstractions at some level and then somehow making them sufficiently concrete and definite so that they can be *realised* and implemented in machine terms – a process that some call *reification*. I do like the idea that programming can in a sense be thought of as a "weak inverse" (an adjunction even?) to the business of finding and using abstractions!

So, to sum up, the book provides many valuable insights into how abstraction itself works, and how this can help refine and guide our thinking. It especially reveals deep aspects of the creative "doing" of mathematics by describing many of the core inner workings of the categorical approach. If nothing else, this is an interesting and fascinating read about a much-misunderstood subject that will surely pay dividends for anyone who wishes to study it. Every FACS FACTS reader would do well to consider taking this wonderful book seriously!

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[4] Most of these entries have been taken from the book itself.

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If you have suggestions for future FACS seminar speakers or other events, especially if you are willing to help with co-organisation or even give a talk, please contact Alvaro on Alvaro.Miyazawa@york.ac.uk.

Events Venue (unless otherwise specified):

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Please revisit this site for updates as and when further events are confirmed.

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