

Annotated Z Bibliography

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1 Introduction

This annotated Z bibliography contains a selected list of some pertinent publications for Z users. Most of those included are readily available, either as books or in journals. A few unpublished items have been included, where they are particularly relevant and can be obtained reasonably easily.

Some references are accompanied by an annotation. This may include a contents list (of a book), a list of the titles of Z related papers (in a collection) with cross references to the full details, or a summary of the work.

2 Cross references

The bibliography in the last section lists all references in alphabetical order by author. In this section papers are arranged by subject (with authors and brief details of the subject matter), together with cross references to the full details in the bibliography.

2.1 Management, style, and method

For justifications for using formality, and quick introductions to Z, see:

- [63, 199] Cohen/McDermid. Justification of formal methods and notations
- [204] Meyer. On formalism in specifications
- [269] Spivey. Introduction to Z
- [305, 306] Wing. General introduction to formal methods including Z
- [311] Woodcock. Structuring specifications

For discussion about using formal methods in practice, see:

- [20] Barden et al. Z in practice
- [22, 45, 46, 118, 201] Barroca/McDermid, Bowen/Stavridou and Gerhart et al. Formal methods and safety-critical systems
- [116] Gerhart. Applications of formal methods
- [124, 40, 41, 42] Hall and Bowen/Hinchey. Myths and guidance about formal methods
- [319] Worden. Fermenting and distilling ideas

Educational issues are presented and discussed in:

- [68] Cooper. Educating management
- [113] Garland. Effective integration of formal methods into a professional master of software engineering course
- [252] Saiedian. The mathematics of computing
- [290] Swatman. Educating information systems professionals

Various papers describing good specification style are:

- [6] Ainsworth et al. The use of viewpoint specifications, a technique with concentrates on making large specifications more understandable
- [92] Duke. Enhancing structure
- [122, 123] Gravell. Minimization in specification/design and what makes a good specification
- [189] Macdonald. Usage and abuse

Much work has been done on attempting to integrate Z with traditional structured analysis methods. Some of this is described in:

- [14] Aujla et al. A rigorous review technique
- [55] Bryant et al. Structured methodologies and formal notations
- [90] Draper. Z and SSADM
- [83] Giovanni and Iachini. HOOD and Z
- [239, 240, 238] Polack et al. SAZ Method – Structured Analysis and Z
- [165, 166] Josephs and Redmond-Pyle. Entity-relationship models, structured methods, and Z
- [245, 246] Randell. Data Flow Diagrams and Z
- [256] Semmens and Allen. Yourdon and Z
- [257] Semmens et al. Integrated structured analysis and formal specification techniques
- [299] van Hee et al. Petri nets and Z

Other work towards the development of a ‘method’ for Z itself include:

- [20] Barden et al. Z in practice
- [127] Hall and McDermid. Towards a Z method using axiomatic specification in Z (using order sorted algebra and OBJ3 in particular)

- [219] Neilson. A rigorous development method from Z to C
- [308] Wood. A practical approach using Z and the refinement calculus
- [321] Wordsworth. Software development with Z

The application of metrics to formal specifications has been studied:

- [302, 17] Whitty and Bainbridge et al. Structural metrics for Z specifications

A formal specification in Z can be useful for deciding test cases, etc. Work on testing is reported in:

- [8, 9] Ammann and Offutt. Functional and test specifications based on the category-partition method
- [60] Carrington and Stocks. Formal methods and software testing
- [77] Cusack and Wezeman. Deriving tests for objects specified in Z
- [128] Hall. Testing with respect to formal specification
- [133] Hayes. Specification directed module testing
- [281] Stocks. Applying formal methods to software testing
- [282] Stocks and Carrington. Deriving software test cases from formal specifications
- [283, 284] Stocks and Carrington. Test templates: a specification-based testing framework and case study

2.2 Application areas

Surveys of formal methods, including Z users, are reported in:

- [15] Austin and Parkin. Formal methods: a survey
- [19] Barden et al. Use of Z (in the UK)
- [71, 72, 73, 117, 118] Craigen et al. An international survey of major industrial formal methods applications, including a number using Z

One of the high profile users of Z is IBM UK Laboratories at Hursley for specification and development of the CICS transaction processing system. General descriptions of the CICS project include:

- [64] Collins et al. Introducing formal methods: the CICS experience with Z
- [147] Houston and King. CICS project report
- [228] Nix and Collins. Use of software engineering and Z in the development of CICS
- [235] Phillips. CICS experience throughout the lifecycle
- [320] Wordsworth. The CICS Application Programming Interface (API) definition

Specifying secure systems is discussed in:

- [160] Jones. Verification of critical properties
- [267] Smith and Keighley. A secure transaction mechanism (SWORD secure DBMS)

Not all Z specifications are of software systems. Much interesting and important work has been done on formally specifying hardware, including microprocessors. The Inmos T800 transputer Floating Point Unit microcode development is a major real example where formal methods have saved time by reducing the amount of testing needed.

[196, 198, 197, 261, 260] May, Shepherd et al. T800 transputer FPU development

More technical papers on hardware applications (including embedded software) are:

[21] Barrett. A floating-point number system (IEEE standard)

[29, 30, 33] Bowen. Microprocessor instruction sets (Motorola M6800 and transputer)

[81, 82, 114, 135] Delisle/Garlan and Hayes. Oscilloscopes, including reuse of specifications

[167, 168] Kemp. Viper microprocessor

[266] Smith and Duke. Cache coherence protocol (in Object-Z)

[271] Spivey. Real-time kernel

Communications systems and protocols are specified in:

[29] Bowen et al. Network services via remote procedure calls (RPC)

[57] Butler. Service extension (PABX)

[95] Duke et al. Protocol specification and verification using Z

[98] Duke et al. Object-oriented protocol specification (mobile phone system, in Object-Z)

[121] Gotzhein. Open distributed systems

[132] Haughton. Safety and liveness properties of communication protocols

[194] Mataga and Zave. Formal specification of telephone features

[236] Pilling et al. Inheritance protocols for real-time scheduling

[293] Till and Potter. Gateway functions within a communications network

[323] Zave and Jackson. Specification of switching systems (PBX)

The following papers describe the use of Z for various graphics applications, standards (especially GKS), and human computer interfaces:

[2] Abowd et al. A survey of user interface languages including Z

[10, 11] Arnold et al. Configurable models of graphics systems (GKS)

[31, 34] Bowen. Formal specification of window systems (X in particular)

[53] Brown and Bowen. An extensible input system for Unix

[88] Dix et al. Human-Computer Interaction (HCI)

[91] Duce et al. Formal specification of *Presentation Environments for Multimedia Objects* (PREMO)

[130] Harrison. Engineering human-error tolerant software

[156] Johnson. Specification and prototyping of concurrent multi-user interfaces

[157] Johnson and Harrison. Declarative graphics and dynamic interaction

[214, 215] Narayana and Dharap. Formal specification of a Look Manager and a dialog system

- [217] Nehlig and Duce. Formal specification of the GKS design primitive
- [287] Sufrin. Formal specification of a display-oriented editor
- [286, 289] Sufrin and He. Effective user interfaces and interactive processes
- [294] Took. A formal design for an autonomous display manager

An important application area for formal methods is safety-critical systems where human lives may depend on correctness of the system.

- [22, 45, 46, 118, 201] Barroca/McDermid, Bowen/Stavridou and Gerhart et al. Surveys covering formal methods and safety-critical systems
- [35, 46, 39] Bowen et al. Safety-critical systems and standards
- [173] Knight and Littlewood. Special issue of *IEEE Software* on *Safety-Critical Systems*
- [237] Place and Kang. Safety-critical software: status report and annotated bibliography

Some examples of the application of Z to safety-critical systems are:

- [152, 153, 154] Jacky. Formal specifications for a clinical cyclotron
- [172] Knight and Kienzle. Using Z to specify a safety-critical system in the medical sector
- [250] Ruddle. Specification of real-time safety-critical control systems

Other papers describing a variety of applications using Z include:

- [1] Abowd et al. Software architectures
- [32] Bowen. A text formatting tool
- [36, 178] Bowen, Lano and Breuer. Reverse engineering
- [54] Brownbridge. CASE toolset (for SSADM)
- [56] Butcher. A behavioural semantics for Linda-2
- [70] Craig. Specification of advanced AI architectures
- [78, 79] de Barros and Harper. Formal specification and derivation of relational database applications
- [104] Fenton and Mole. Flowgraph transformation
- [209] Morgan and Sufrin. Specification of the Unix filing system
- [216] Nash. Large systems
- [248] Reizer et al. Requirements specification of a proposed POSIX standard
- [276] Stepney. High integrity compilation
- [288] Sufrin. A Z model of the Unix make utility
- [315] Woodcock et al. Formal specification of the UK Defence Standard 00-56
- [325] Zhang and Hitchcock. Designing knowledge-based systems and information systems

2.3 Textbooks on Z

- [86] Diller. Z: an introduction to formal methods (2nd edition)

- [139] Hayes et al. Specification case studies (the first book on Z, now in its 2nd edition, containing an excellent selection of example Z specifications)
- [149] Imperato. An introduction to Z
- [150] Ince. An introduction to discrete mathematics and formal system specification (2nd edition)
- [183] Lightfoot. Formal specification using Z
- [202] McMorran and Powell. Z guide for beginners.
- [229] Norcliffe and Slater. Mathematics of software construction
- [241] Potter, Sinclair and Till. An introduction to formal specification and Z (a popular first textbook on Z)
- [247] Ratcliff. Introducing specification using Z
- [317] Woodcock and Loomes. Software engineering mathematics
- [321] Wordsworth. Software development with Z

A video course is also available [230, 231].

2.4 Language details

Z's syntax, semantics and mathematical toolkit are being internationally standardized under ISO/IEC JTC1/SC22. A draft version of the standard is available:

- [52] Brien and Nicholls. Z Base Standard, version 1.0

The definition of the Z syntax and mathematical toolkit used by many practitioners is:

- [273] Spivey. Z reference manual (2nd edition)

More technical works describing Z's formal semantics are:

- [298] Diepen and van Hee. The link between Z and the relational algebra
- [112] Gardiner et al. A simpler semantics
- [268] Spivey. Understanding Z
- [274] Spivey and Sufrin. Type inference

Z is often compared and contrasted with VDM (Vienna Development Method). The following papers show the cross-fertilization and comparisons between the two:

- [26] Bera. Structuring for the VDM specification language, in response to the Z schema notation
- [119] Gilmore. Correctness-oriented approaches to software development in which the Z, VDM and algebraic styles are compared
- [138] Hayes. A comparative case study of VDM and Z
- [141] Hayes et al. Understanding the differences between VDM and Z
- [184, 185] Lindsay. A VDM perspective on reasoning about Z specifications and transferring VDM verification techniques to Z

- [186] Lindsay and van Keulen. Case studies in the verification of specifications in VDM and Z
- [206] Monahan and Shaw. Model-based specifications, including a discussion of the respective trade-offs in specification between Z and VDM

Reasoning about Z specifications is addressed in:

- [208] Morgan and Sanders. Laws of the Logical Calculi
- [309] Woodcock. Calculating properties (preconditions)
- [314, 193] Woodcock/Brien and Martin. \mathcal{W} , a logic for Z.

Work on refining Z-like specifications towards an implementation (see also section 2.5) includes:

- [21] Barrett. Refinement from Z to microcode via Occam
- [16] Bailes and Duke. Class refinement
- [23] Baumann. Z and natural semantics programming language theory for algorithm refinement
- [85, 86] Diller. Hoare logic and Part II: *Methods of Reasoning*
- [107, 108, 109] Fidge. Real-time refinement and program development
- [119] Gilmore. Correctness-oriented approaches to software development (Z, VDM and algebraic styles are compared)
- [144] He et al. Foundations for data refinement
- [155] Jacob. Varieties of refinement
- [163] Josephs. Data refinement calculation for Z specifications
- [171] King and Sørensen. Specification and design of a library system
- [177, 180] Lano and Haughton. Reasoning and refinement in object-oriented specification languages
- [190, 191, 192] Mahoney/Hayes et al. Timed refinement
- [218, 219] Neilson. Hierarchical refinement of Z specifications and a rigorous development method from Z to C
- [258] Sennett. Using refinement to convince (pattern matching in ML)
- [259] Sennett. Demonstrating the compliance of Ada programs with Z specifications
- [289] Sufrin and He. Specification, analysis and refinement of interactive processes
- [304] Whysall and McDermid. Object-oriented specification and refinement
- [307] Wood. Software refinery
- [312] Woodcock. Implementing promoted operations in Z
- [318] Woodcock and Morgan. Refinement of state-based concurrent systems
- [321] Wordsworth. Software development with Z

The ‘refinement calculus’ approach to refinement is espoused in:

- [170] King. Z and the refinement calculus
- [207] Morgan. A standard student textbook (2nd edition)
- [210] Morgan and Vickers. Collected research papers
- [308] Wood. A practical approach using Z and the refinement calculus

The related B-Method, with associated B-Tool, B-Toolkit and Abstract Machine Notation (AMN), have been developed by Abrial et al., also the progenator of Z:

- [3, 4, 5] Abrial. The B-Tool, B-Method and forthcoming B-Book
- [80] Dehbonei and Mejia. Use of B in the railways signalling industry
- [87] Diller and Docherty. A comparison of Z and Abstract Machine Notation
- [220, 221] Neilson and Prasad. ZedB (a prototype B-based proof tool)
- [249] Ritchie et al. Experiences in using the Abstract Machine Notation in a GKS graphics standard case study
- [285] Storey and Haughton. A strategy for the production of verifiable code using the B-Method

Execution of formal specifications is a subject of perennial debate. See:

- [140] Hayes and Jones. Specifications are not (necessarily) executable

A retort may be found in:

- [111] Fuchs. Specifications are (preferably) executable

Animating Z specifications is discussed in:

- [51] Breuer and Bowen. Correct executable semantics for Z using abstract interpretation, including an informal taxonomy of approaches
- [84] Dick et al. Computer aided transformation of Z into Prolog
- [86] Diller. Part IV: *Specification Animation* (using Miranda)
- [89] Doma and Nicholl. EZ: automatic prototyping
- [120] Goodman. Animating Z specifications in Haskell using a monad
- [131] Hasselbring. Animation of Object-Z specifications with a set-oriented prototyping language
- [158] Johnson and Sanders. Functional implementations (Z to Miranda)
- [187] Love. Animating Z specifications in SQL
- [280] Stepney and Lord. An access control system (Z to Prolog)
- [296] Valentine. Z^- , an executable subset of Z
- [300] West and Eaglestone. Two approaches to animation (Z to Prolog)

Specific language features are addressed in:

- [13, 263] Arthan and Smith. Free types in Z (including recursion)
- [134] Hayes. A generalization of bags
- [136] Hayes. Interpretations of schema operators
- [137] Hayes. Multi-relations in Z (a cross between multi-sets and binary relations)
- [188] Lupton. Promotion and forward simulation
- [209] Morgan and Sufrin. Schema framing
- [310, 312] Woodcock. Proof rules for promotion and implementing promoted operations

Some research has been undertaken in using and adapting Z to model concurrent systems:

- [66] Coombes and McDermid. Specifying distributed real-time systems
- [101, 102] Evans. Visualising, specifying and verifying concurrent systems using Z
- [156] Johnson. Applying temporal logic to support the specification and prototyping of concurrent multi-user interfaces
- [175] Lamport. TLZ: Temporal Logic of Actions (TLA) and Z
- [215] Narayana and Dharap. Invariant properties in a dialog system
- [255] Schuman et al. Object-oriented process specification

In particular, there has been some work on combining Z and CSP (Communicating Sequential Processes), a formal process model with associated algebra for concurrent systems:

- [24] Benjamin. A message passing system: an example of combining CSP and Z
- [164] Josephs. Theoretical work on a state-based approach to communicating processes
- [318] Woodcock and Morgan. Refinement of state-based concurrent systems

Researchers have also considered modelling and reasoning about real-time systems, for example, by combining temporal logic with Z.

- [66] Coombes and McDermid. Specifying temporal requirements for distributed real-time systems
- [99] Duke and Smith. Temporal logic and Z specifications
- [100] Engel. Specifying real-time systems with Z and the Duration Calculus
- [105] Fergus and Ince. Model logic and Z specifications item[[106]] Fidge. Specification and verification of real-time behaviour using Z and RTL
- [107, 108, 109] Fidge. Real-time refinement and program development
- [143] He Jifeng et al. Provably correct systems, including the use of Duration Calculus with schemas for structuring
- [156] Johnson. Applying temporal logic to support the specification and prototyping of concurrent multi-user interfaces
- [175] Lamport. TLZ: Temporal Logic of Actions (TLA) and Z
- [190, 191, 192] Mahoney/Hayes et al. Timed refinement
- [215] Narayana and Dharap. Invariant properties in a dialog system using Z and temporal logic
- [236] Pilling et al. Inheritance protocols for real-time scheduling
- [250] Ruddle. Specification of real-time safety-critical control systems
- [264] Smith. An object-oriented approach including a formalization of temporal logic history invariants

2.5 Conferences proceedings

Regular Z User Meetings are organized by the Z User Group and have had published proceedings since the 4th meeting:

- [222] Nicholls. 4th Z User Meeting, Oxford, 1989
- [224] Nicholls. 5th Z User Meeting, Oxford, 1990
- [226] Nicholls. 6th Z User Meeting, York, 1991
- [44] Bowen and Nicholls. 7th Z User Meeting, London, 1992
- [38] Bowen and Hall. 8th Z User Meeting, Cambridge, 1994
- [43] Bowen and Hinchey. 9th Z User Meeting, Limerick, 1995

The annual Refinement Workshop is organized by BCS-FACS. Papers cover a variety of refinement techniques from specification to code, and include some Z examples.

- [200] McDermid. 1st Refinement Workshop, York, 1988
- [211] Morgan and Woodcock. 3rd Refinement Workshop, Hursley, 1990
- [212] Morris and Shaw. 4th Refinement Workshop, Cambridge, 1991
- [160] Jones et al. 5th refinement Workshop, London, 1992
- [292] Till. 6th refinement Workshop, London, 1994

FME Symposia are held every 18 months, organized by Formal Methods Europe. These grew out of the the later VDM-Europe conferences which included papers on Z:

- [28] Bloomfield et al. VDM'88, Dublin
- [27] Bjørner et al. VDM'90, Kiel
- [242, 243] Prehn and Toetenel. VDM'91, Noordwijkerhout
- [316] Woodcock and Larsen. FME'93, Odense
- [213] Naftalin et al. FME'94, Barcelona

2.6 Tools

The ZIP Project tools catalogue lists some tools that support formatting, checking and proof of Z specifications:

- [234] Parker. Z tools catalogue

Details of individual tools may be found in:

- [12] Arthan. A proof tool based on HOL which grew into ProofPower (see below)
- [37] Bowen and Gordon. Z and HOL (a tool based on higher order logic)
- [110] Flynn et al. Formaliser (editor and type-checker)
- [161] Jones. ICL ProofPower (a commercial tool based on HOL)
- [162, 295] Jordan et al. CADiZ (formatter and type-checker)
- [220, 221] Neilson and Prasad. ZedB (a prototype B-based schema expansion and precondition calculator tool)

- [251] Saaltink. Z and EVES (a tool based on ZF set theory)
- [272] Spivey. *fUZZ* (a commercial \LaTeX formatter and type-checker, 2nd edition)
- [322] Xiaoping Jia. ZTC (a freely available type-checker)

2.7 Object-Oriented Approaches

There has been much work recently to enhance Z with some of the structuring ideas from object-orientation. Overviews and comparisons can be found in:

- [58] Carrington. ZOOM workshop report
- [181] Lano and Haughton. Object-oriented specification case studies, many using extensions to Z
- [278, 279] Stepney et al. Collected papers and a survey on object-orientation in Z

Object-Z is the best-documented and probably most widely used object-oriented extension to Z. The definitive description of the language is:

- [97] Duke et al. Version 1 of Object-Z

Other Object-Z papers include:

- [59] Carrington et al. Object-Z: an object-oriented extension to Z
- [91] Duce et al. Formal specification of *Presentation Environments for Multimedia Objects* (PREMO)
- [93] Duke and Duke. Towards a semantics
- [94] Duke and Duke. Aspects of object-oriented specification (card game example)
- [98] Duke et al. Object-oriented protocol specification (mobile phone system)
- [131] Hasselbring. Animation with a set-oriented prototyping language
- [244] Rafsanjani and Colwill. From Object-Z to C++
- [266] Smith and Duke. Cache coherence protocol

Descriptions of other object-oriented approaches in conjunction with Z may be found in:

- [7] Alencar and Goguen. OOZE: an object-oriented Z environment
- [62] Chan and Trinder. An object-oriented data model supporting multi-methods, multiple inheritance, and static type-checking
- [75] Cusack. Inheritance in object-oriented Z
- [125, 126] Hall. A specification calculus for object-oriented systems and class hierarchies in Z
- [129] Hammond. Producing Z specifications from object-oriented analysis
- [176, 179, 36] Lano/Haughton et al. Z^{++} : an object-orientated extension to Z
- [195] Maung and Howse. Hyper-Z: a new approach to object-orientation
- [203] Meira and Cavalcanti. MooZ: Modular object-oriented Z specifications
- [254, 255] Schuman, Pitt et al. Object-oriented subsystem and process specification
- [301] Wezeman and Judge. Z for managed objects
- [303, 304] Whysall and McDermid. Object-oriented specification and refinement

3 On-line information

The BIB_TE_X source for this bibliography and related information is available on-line via the World-Wide Web under the following URL (Uniform Resource Locator):

<http://www.comlab.ox.ac.uk/archive/z/bib.html>

The bibliography is searchable. The user may provide a regular expression or select from a number of predefined keywords. Hyperlinks are included to documents that can be accessed on-line.

4 Acknowledgements

We would like to thank all those who suggested references for inclusion in this bibliography. It has been adapted from the ZIP project bibliography [277], the on-line Z bibliography held at the Oxford University Computing Laboratory [47], including more recent additions.

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5 Bibliography

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- [2] G. D. Abowd, J. P. Bowen, A. J. Dix, M. D. Harrison, and R. Took. User interface languages: A survey of existing methods. Technical Report PRG-TR-5-89, Oxford University Computing Laboratory, Wolfson Building, Parks Road, Oxford, UK, October 1989.
- [3] J-R. Abrial. The B tool. In Bloomfield et al. [28], pages 86–87.
- [4] J-R. Abrial. The B method for large software, specification, design and coding (abstract). In Prehn and Toetenel [243], pages 398–405. Volume 2: Tutorials.
- [5] J.-R. Abrial. *The B-Book*. Cambridge University Press, 1995. To appear.
Contents: Mathematical reasoning; Set notation; Mathematical objects; Introduction to abstract machines; Formal definition of abstract machines; Theory of abstract machines; Construction large abstract machines; Example of abstract machines; Sequencing and loop; Programming examples; Refinement; Construction large software systems; Example of refinement;
Appendices: Summary of the most current notations; Syntax; Definitions; Visibility rules; Rules and axioms; Proof obligations.

- [6] M. Ainsworth, A. H. Cruikchank, P. J. L. Wallis, and L. J. Groves. Viewpoint specification and Z. *Information and Software Technology*, 36(1):43–51, 1994.
- [7] A. J. Alencar and J. A. Goguen. OOZE: An object-oriented Z environment. In P. America, editor, *Proc. ECOOP'91 European Conference on Object-Oriented Programming*, volume 512 of *Lecture Notes in Computer Science*, pages 180–199. Springer-Verlag, 1991.
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- [9] P. Ammann and J. Offutt. Using formal methods to mechanize category-partition testing. Technical Report ISSE-TR-93-105, Department of Information & Software Systems Engineering, George Mason University, USA, September 1993.
- [10] D. B. Arnold, D. A. Duce, and G. J. Reynolds. An approach to the formal specification of configurable models of graphics systems. In G. Maréchal, editor, *Proc. EUROGRAPHICS'87, European Computer Graphics Conference and Exhibition*, pages 439–463. Elsevier Science Publishers (North-Holland), 1987.
The paper describes a general framework for the formal specification of modular graphics systems, illustrated by an example taken from the Graphical Kernel System (GKS) standard.
- [11] D. B. Arnold and G. J. Reynolds. Configuring graphics systems components. *IEE/BCS Software Engineering Journal*, 3(6):248–256, November 1988.
- [12] R. D. Arthan. Formal specification of a proof tool. In Prehn and Toetenel [242], pages 356–370. Volume 1: Conference Contributions.
- [13] R. D. Arthan. On free type definitions in Z. In Nicholls [226], pages 40–58.
- [14] S. Aujla, A. Bryant, and L. Semmens. A rigorous review technique: Using formal notations within conventional development methods. In *Proc. 1993 Software Engineering Standards Symposium*, pages 247–255. IEEE Computer Society Press, 1993.
- [15] S. Austin and G. I. Parkin. Formal methods: A survey. Technical report, National Physical Laboratory, Queens Road, Teddington, Middlesex, TW11 0LW, UK, March 1993.
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- [17] J. Bainbridge, R. W. Whitty, and J. B. Wordsworth. Obtaining structural metrics of Z specifications for systems development. In Nicholls [224], pages 269–281.

- [18] R. Barden and S. Stepney. Support for using Z. In Bowen and Nicholls [44], pages 255–280.
- [19] R. Barden, S. Stepney, and D. Cooper. The use of Z. In Nicholls [226], pages 99–124.
- [20] R. Barden, S. Stepney, and D. Cooper. *Z in Practice*. BCS Practitioner Series. Prentice Hall, 1994.
- [21] G. Barrett. Formal methods applied to a floating-point number system. *IEEE Transactions on Software Engineering*, 15(5):611–621, May 1989.
- This paper presents a formalization of the IEEE standard for binary floating-point arithmetic in Z. The formal specification is refined into four components. The procedures presented form the basis for the floating-point unit of the Inmos IMS T800 transputer. This work resulted in a joint UK Queen’s Award for Technological Achievement for Inmos Ltd and the Oxford University Computing Laboratory in 1990. It was estimated that the approach saved a year in development time compared to traditional methods.
- [22] L. M. Barroca and J. A. McDermid. Formal methods: Use and relevance for the development of safety-critical systems. *The Computer Journal*, 35(6):579–599, December 1992.
- [23] P. Baumann. Z and natural semantics. In Bowen and Hall [38], pages 168–184.
- [24] M. Benjamin. A message passing system: An example of combining CSP and Z. In Nicholls [222], pages 221–228.
- [25] M. Benveniste. Writing operational semantics in Z: A structural approach. In Prehn and Toetenel [242], pages 164–188. Volume 1: Conference Contributions.
- [26] S. Bera. Structuring for the VDM specification language. In Bloomfield et al. [28], pages 2–25.
- [27] D. Bjørner, C. A. R. Hoare, and H. Langmaack, editors. *VDM and Z – Formal Methods in Software Development*, volume 428 of *Lecture Notes in Computer Science*. VDM-Europe, Springer-Verlag, 1990.
- The 3rd VDM-Europe Symposium was held at Kiel, Germany, 17–21 April 1990. A significant number of papers concerned with Z were presented [61, 93, 114, 83, 121, 125, 170, 253, 275, 298, 318].
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