applications

communication protocols

processors (CPUs)

kernel of a secure distributed operating system

compilers

safety-critical: medical systems, nuclear control

railway automated control

aerospace — attitude monitors

instrumentation systems

telephone and internet switching systems

airplane cabin communications

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any software that must be correct

programs are

commands to a computer

programs are

commands to a computer

mathematical expressions

programs are

commands to a computer → execution

mathematical expressions

programs are

commands to a computer → execution

mathematical expressions → theory of programming

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mathematical expressions → theory of programming

why theory?

programs are

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mathematical expressions → theory of programming

why theory?

formal theory

programs are

commands to a computer → execution

mathematical expressions → theory of programming

why theory?

formal theory = formalism + rules of proof, calculation, manipulation

programs are

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why theory?

theory = formalism + rules of proof, calculation, manipulation

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why theory? → proof

theory = formalism + rules of proof, calculation, manipulation

programs are

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why theory? → proof, calculation

theory = formalism + rules of proof, calculation, manipulation

programs are

commands to a computer → execution

mathematical expressions → theory of programming

why theory? → proof, calculation, precision

theory = formalism + rules of proof, calculation, manipulation

programs are

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why theory? → proof, calculation, precision, understanding

theory = formalism + rules of proof, calculation, manipulation

programs are

commands to a computer → execution

mathematical expressions → theory of programming

why theory? → proof, calculation, precision, understanding

theory = formalism + rules of proof, calculation, manipulation

formal $\neq$ careful, detailed

informal $\neq$ sloppy, sketchy

programs are

commands to a computer → execution

mathematical expressions → theory of programming

why theory? → proof, calculation, precision, understanding

theory = formalism + rules of proof, calculation, manipulation

formal ≠ careful, detailed

informal ≠ sloppy, sketchy

formal = using formulas (mathematical expressions)

informal = using a natural language (English)

start informal (with discussion)

start informal (with discussion)

end formal (with program)

start informal (with discussion)

end formal (with program)

then test, but

start informal (with discussion)

end formal (with program)

then test, but

> how do you know if the program is working?

start informal (with discussion)

end formal (with program)

then test, but

how do you know if the program is working?

what about the inputs you didn't test?

start informal (with discussion)

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how do you know if the program is working?

what about the inputs you didn't test?

proof tells whether program is correct for all inputs

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proof / verification after development

start informal (with discussion)

end formal (with program)

then test, but

  how do you know if the program is working?

  what about the inputs you didn't test?

proof tells whether program is correct for all inputs

~~proof / verification after development~~

program development, with proof at each step

start informal (with discussion)

end formal (with program)

then test, but

how do you know if the program is working?

what about the inputs you didn't test?

proof tells whether program is correct for all inputs

~~proof / verification after development~~

program development, with proof at each step

program modification, with proof

other theories

Hoare triples $P\{S\}R$ or $\{P\}S\{R\}$

other theories

Hoare triples $P\{S\}R$ or $\{P\}S\{R\}$

Dijkstra's weakest preconditions $wp(S, R)$

Vienna Development Method (VDM)

Z and B

temporal logic $\Box$ $\Diamond$

process algebras (CSP, CCS, mu-calculus, pi-calculus, ...)

event traces, interleaved histories

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model checking

other theories

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temporal logic $\square$ $\lozenge$

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exhaustive automated testing

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exhaustive automated testing

up to 10^{60} states

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event traces, interleaved histories

model checking

exhaustive automated testing

up to 10^{60} states $\approx$ 2^{200} states

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Z and B

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event traces, interleaved histories

model checking

- exhaustive automated testing
- up to 10^{60} states $\approx$ 2^{200} states $=$ 200 bits

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model checking

exhaustive automated testing

up to 10^{60} states $\approx$ 2^{200} states $=$ 200 bits $\approx$ 6 variables

other theories

Hoare triples $P\{S\}R$ or $\{P\}S\{R\}$

Dijkstra's weakest preconditions $wp(S, R)$

Vienna Development Method (VDM)

Z and B

temporal logic $\Box$ $\Diamond$

process algebras (CSP, CCS, mu-calculus, pi-calculus, ...)

event traces, interleaved histories

model checking

- exhaustive automated testing
- up to 10^{60} states $\approx$ 2^{200} states $=$ 200 bits $\approx$ 6 variables
- abstraction, proof (not automated)

this theory

simpler

just binary (boolean) expressions

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more general

- includes terminating and nonterminating computation

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prerequisite

some programming, any language

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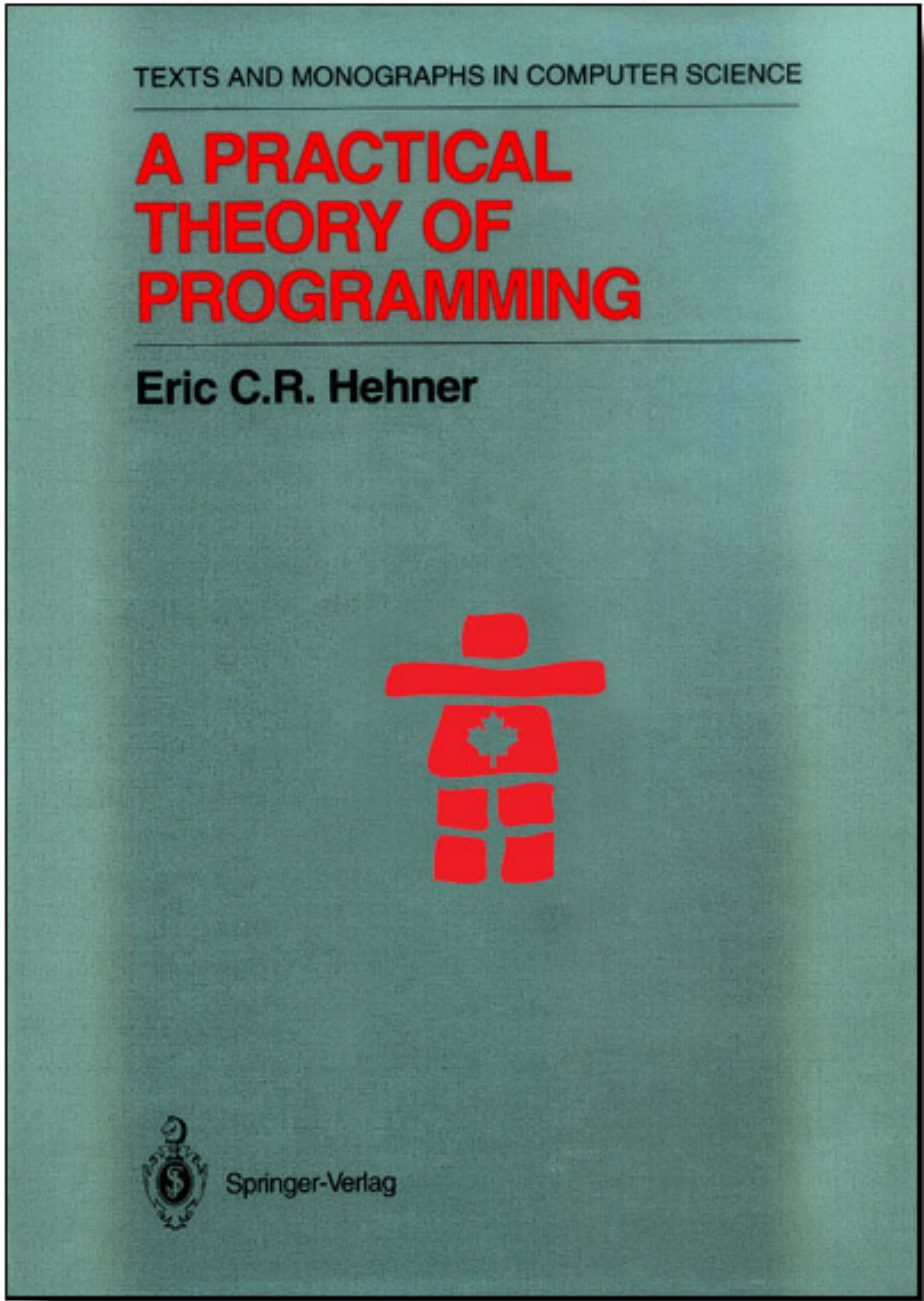
prerequisite

some programming, any language

- assignment statement, **if**-statement



TEXTBOOK

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