Literate Software and the Drasil Framework

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Literate Software and Drasil

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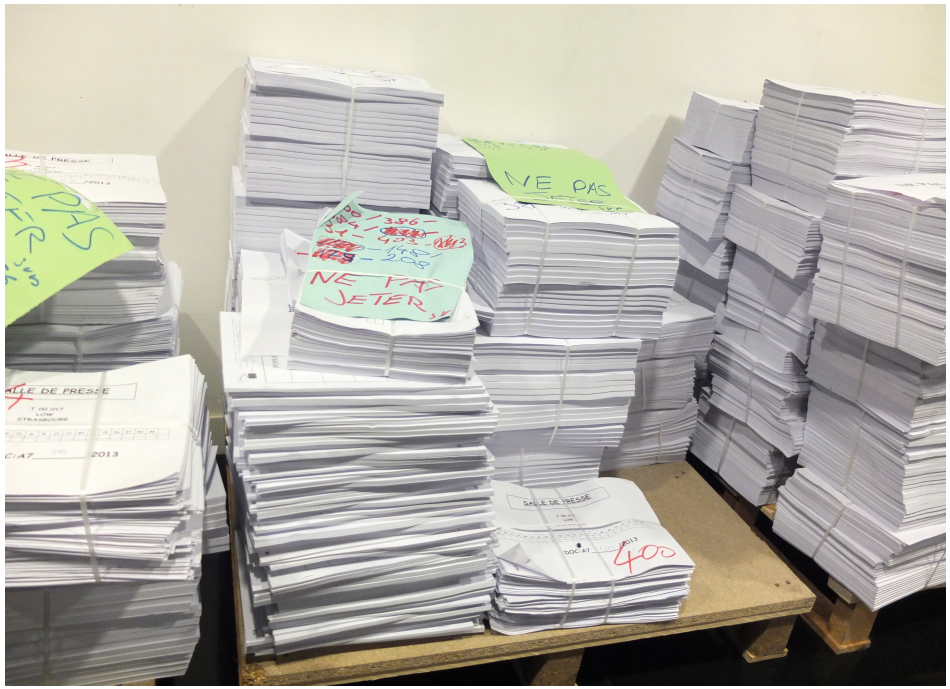
Information Duplication



- Wastes resources
- Reduces software quality

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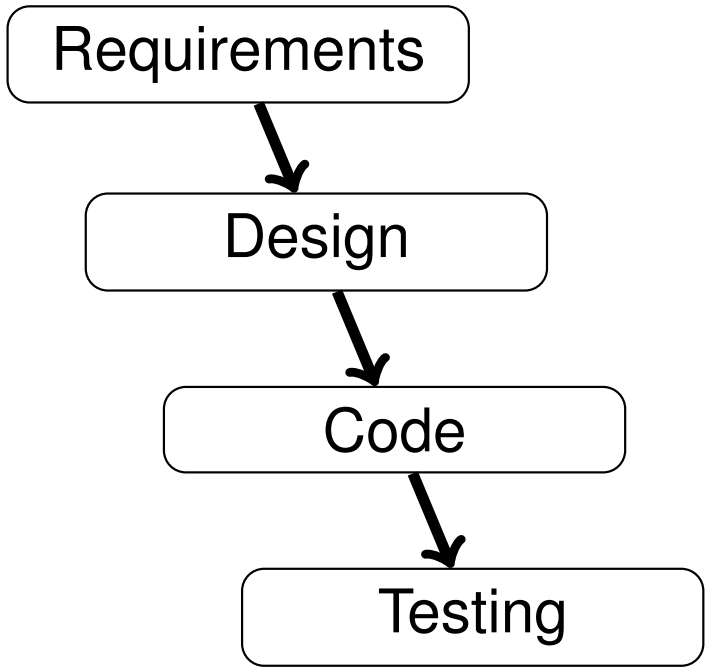
Example



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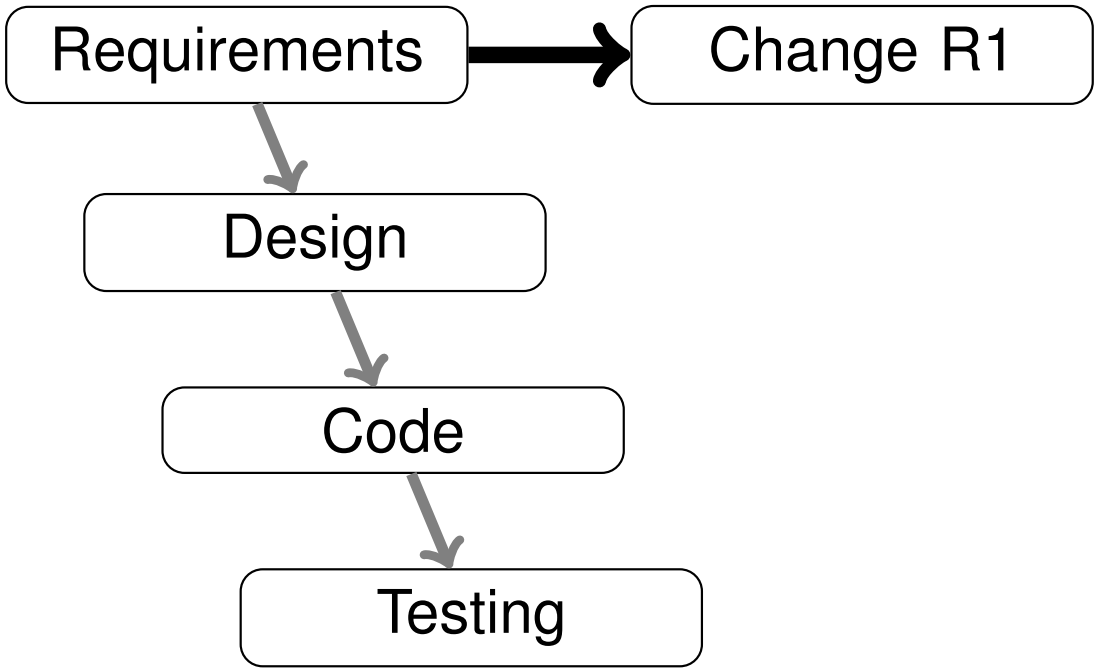
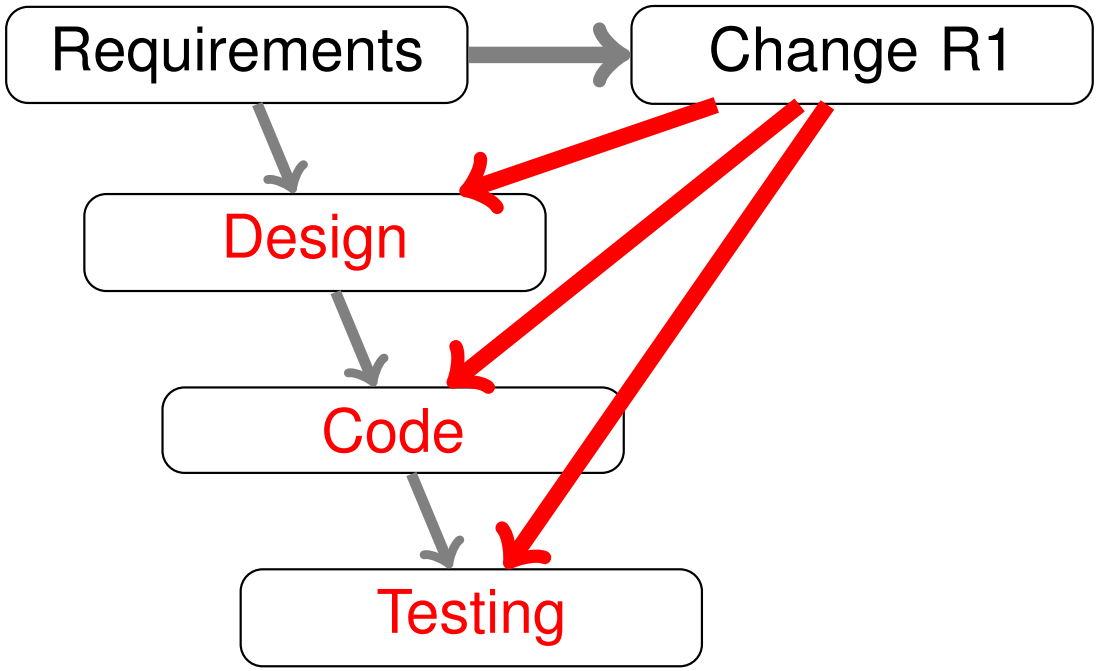


Example



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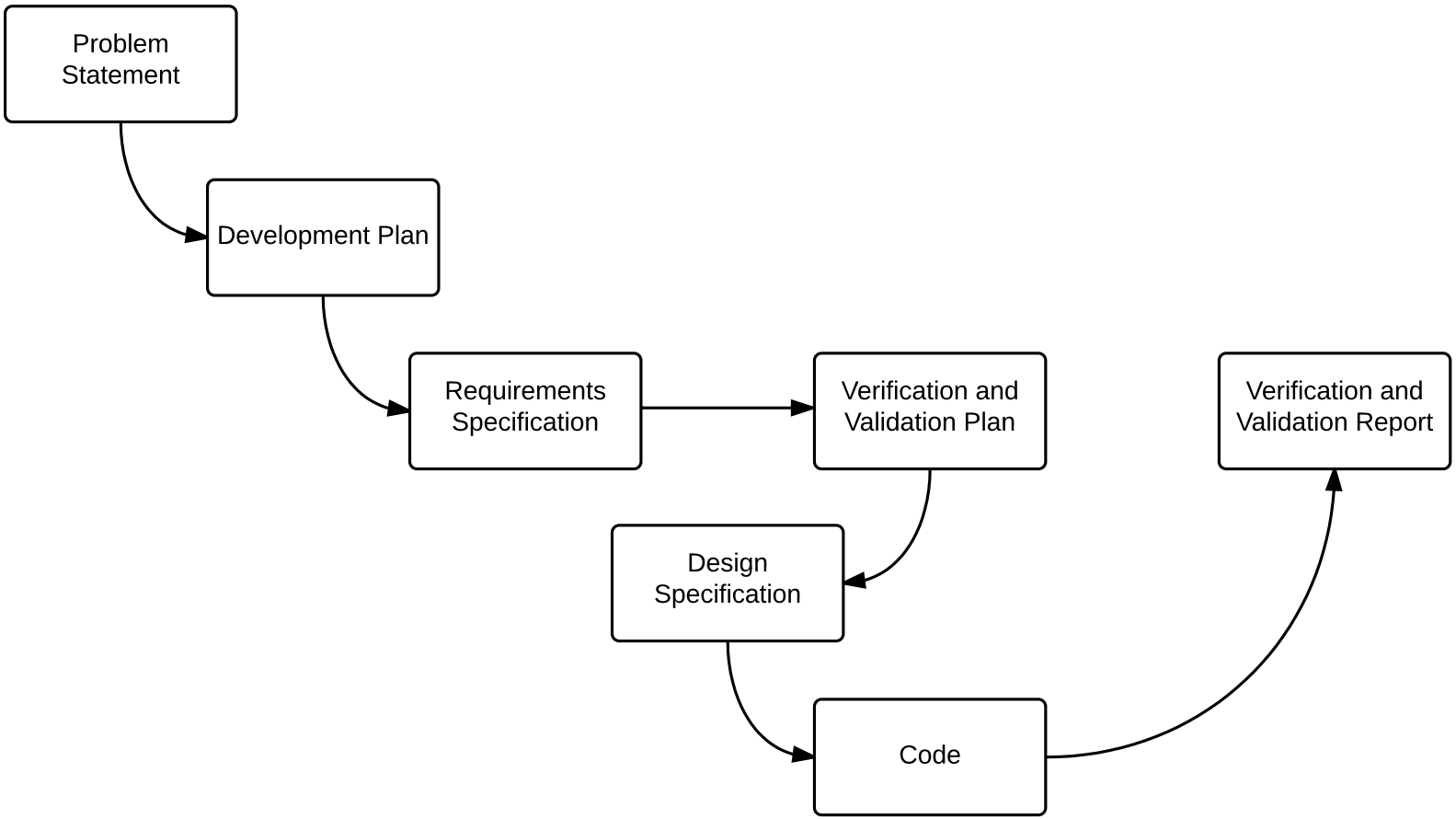
Rational Design Process



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Reduced Software Qualities

- Maintainability
- Traceability
- Verifiability
- Reproducibility

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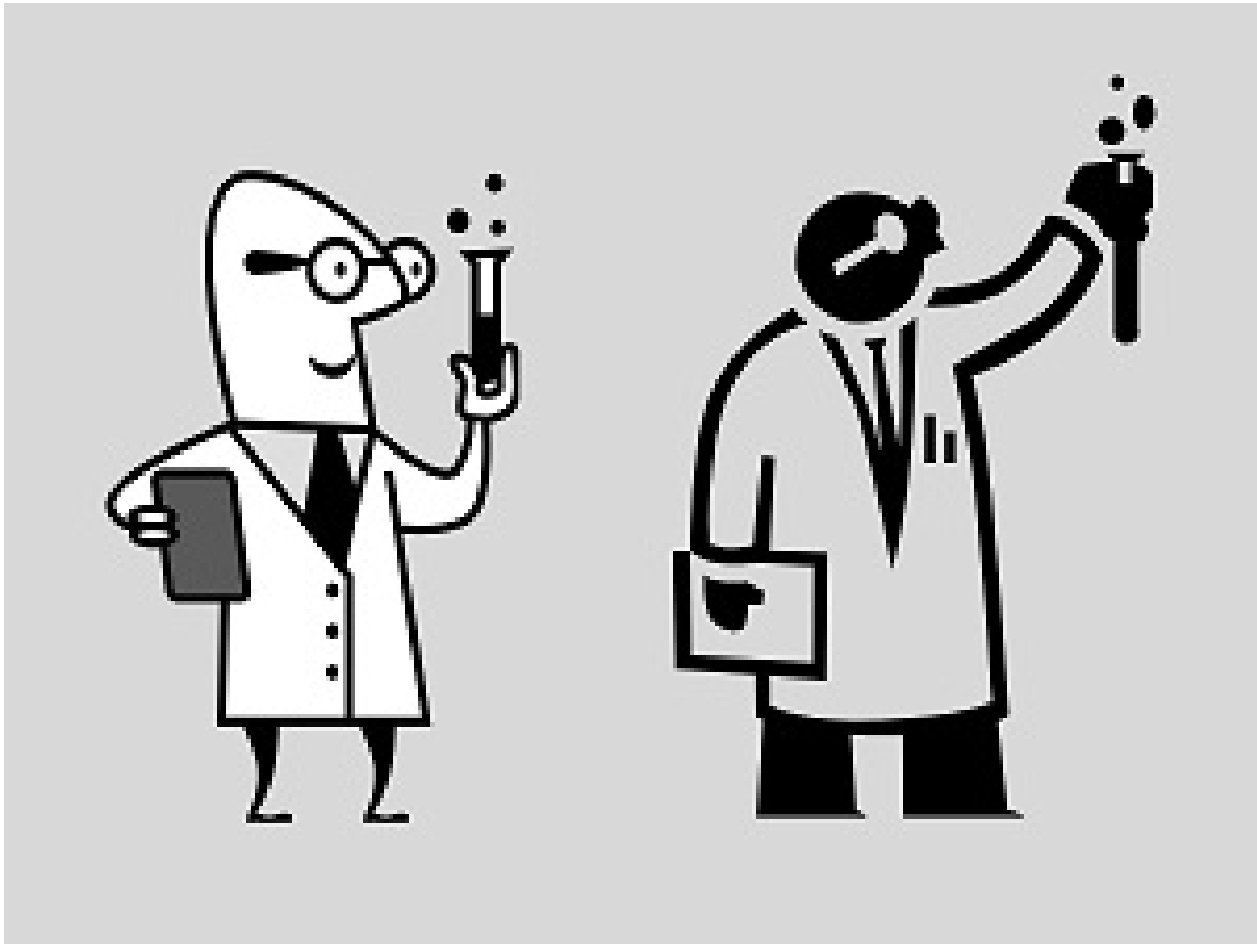
Reproducibility



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Scope

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Scope

Limited to well-understood domains.

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Scope

Limited to well-understood domains.

Specifically targeting Scientific Computing (SC)

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Scope

Limited to well-understood domains.

Why SC?

- Rich, well-understood background
- SC Developers lack software engineering background

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Goals and Objectives

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Goals and Objectives

Simplify the development process for SC developers

- Create better software artifacts
- Lower the long term cost of updating/maintaining software
- Improve reproducibility

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Goals and Objectives

Create a tool to facilitate a knowledge-based approach

- Create better software artifacts
  - Ensure consistency
- Lower the long term cost of updating/maintaining software
  - Automate creation of software artifacts
- Improve reproducibility

Current State of SC Software Development

- Emphasis on science, not software development [15]
- Rigid, process-heavy approaches are considered unfavourable [4]

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Problems in SC Software Development

- Not enough knowledge reuse
  - Ex. 37 of 52 triangular mesh generators implemented the same triangulation algorithm [26]
- Lack of understanding of software testing [23]
- Very limited tool use (especially version control [42])

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Literate Programming (LP)

- Shifts focus to explain (to humans) what the computer should do [17]
- Algorithms are broken down into *chunks* [12]
- Chunks are ordered to promote understanding
- Many tools for (or inspired by) LP

Advantages of LP

- Increases understandability
- More consistent documentation and code [35]
- Code is more maintainable [29]
- Code can be automatically incorporated into documentation
- Documentation and code are updated simultaneously

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Drawbacks of LP

- Not yet mainstream
- One-source, one document
- Code-centric

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Literate Software Development (LSD)

Combination of LP and Box Structures designed to address:

- Specifying interfaces between modules
- Decomposing boxes
- Implementing designs
- Lack of tool support

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Literate Software Development (LSD)

Combination of LP and Box Structures designed to address:

- Specifying interfaces between modules
- Decomposing boxes
- Implementing designs
- Lack of tool support

LSD's framework *WebBox* addressed the above, but remains primarily code-focused.

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Reproducible Research (RR)

Reproduction can be nearly impossible without the original author's help [11] due to undocumented :

- Assumptions
- Modifications
- Hacks

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Reproducible Research (RR)

Compendia [9] provide a means of encapsulating:

- Research reports
- Data
- Code
- ...

Compendia are intended for use in peer review.

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Approach

Knowledge Based Approach

Knowledge Capture

- Expand chunks
- Specification level encapsulation
- Easy to transform

Knowledge Based Approach

Artifact Generation

- Automatic updating
- Traceability & maintainability
- Reproducibility

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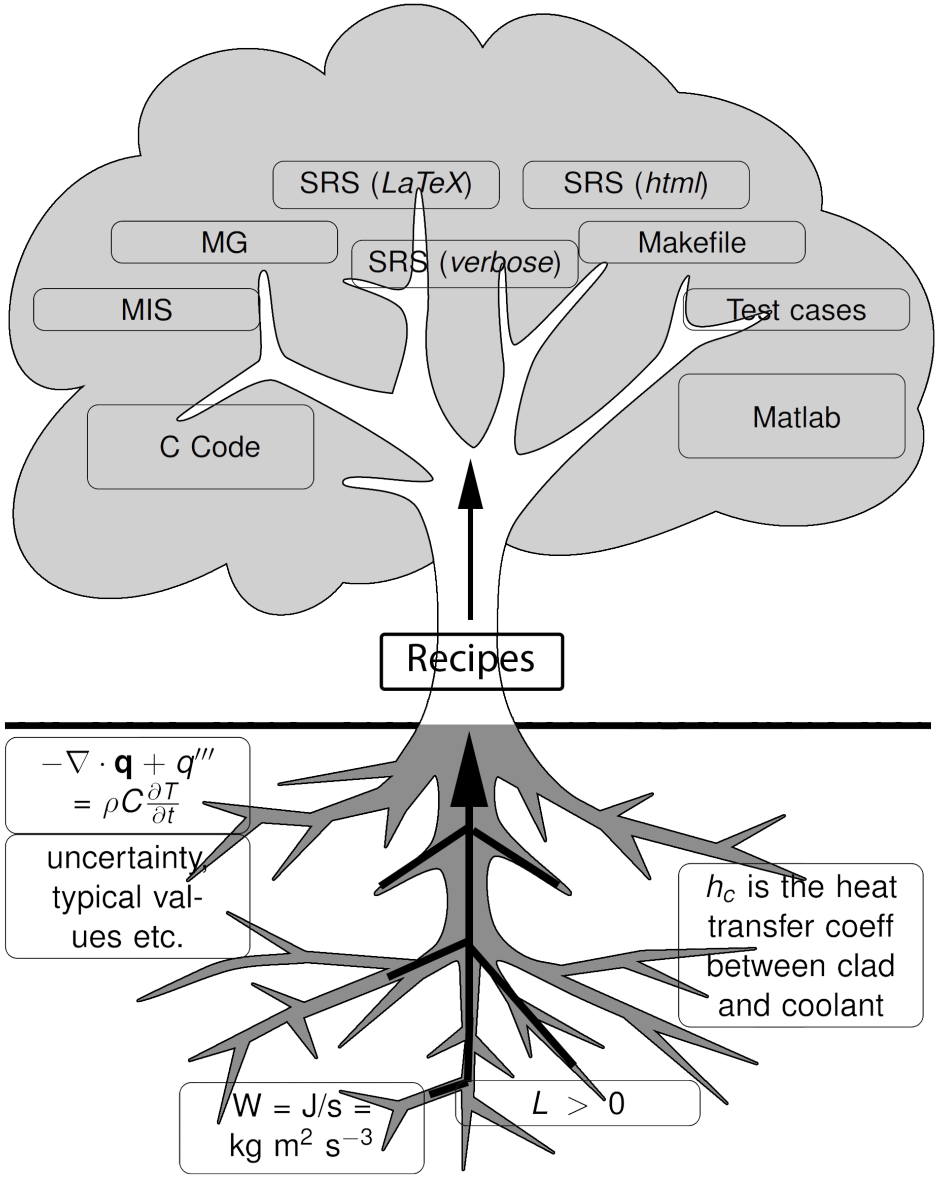
Knowledge Based Approach



Knowledge Based Approach

Artifact Generation

- Automatic updating
- Traceability & maintainability
- Reproducibility

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Knowledge Based Approach

Drasil Framework

- Practical, example-driven approach
- Small case studies to start
- Larger case studies in progress

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The Drasil Framework

Design

Drasil is currently being implemented as a combination of six eDSLs:

- Expression
- Expression Layout
- Document Layout
- C Representation
- LaTeX Representation
- HTML Representation

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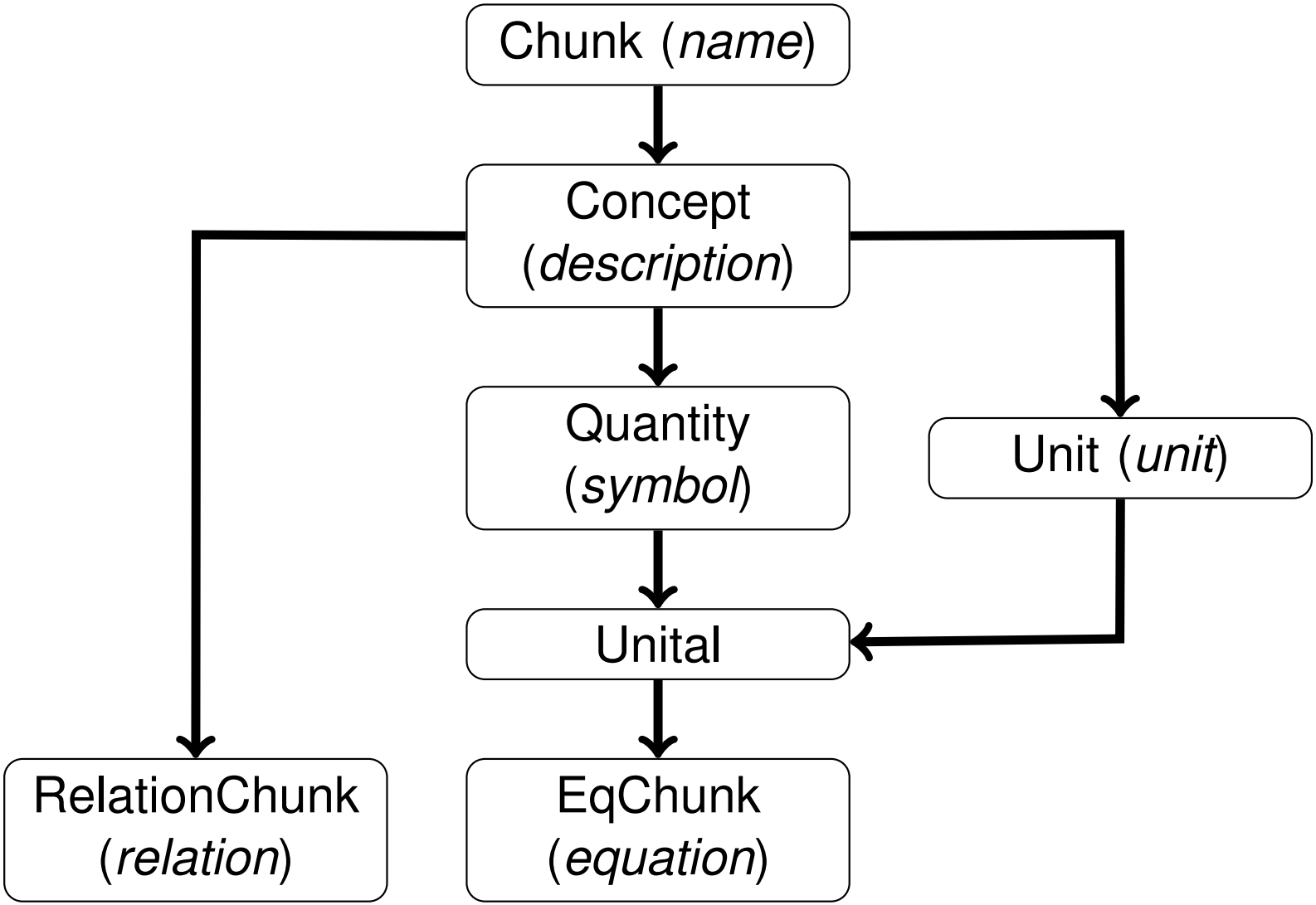
Chunks



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Example – Fuel Pin SRS

Original SRS from LaTeX
SRS from Generated LaTeX
Generated HTML SRS

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Example – Recipes

```
vars :: [EqChunk]
vars = [h_g, h_c]

s1, s2, s3, s4 :: LayoutObj
s1 = table_of_units si_units
s2 = table_of_symbols vars
s3 = Section 0 (S "Data Definitions") $ map (Definition . Data) vars
s4 = Section 0 (S "Code — Test") $ map (CodeBlock . toCode CLang Calc) [h_c]

srs :: Quantity s => [s] -> String -> [LayoutObj] -> Document
srs ls author body =
  Document ((S "SRS for ") :+:
    (foldr1 (:+:) (intersperse (S " and ") (map (\x -> U $ x ^. symbol) ls))))
    (S author) body

srsBody,lpmBody :: Document
srsBody = srs vars "Spencer Smith" [s1, s2, s3, s4]

lpmBody = Document ((S "Literate Programmer's Manual for ") :+:
  (foldr1 (:+:) (intersperse (S " and ") (map (\x -> U $ x ^. symbol) vars))))
  (S "Spencer Smith") [l1]

l1 :: LayoutObj
l1 = Paragraph (
```

...

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Example – Recipes

```
-- Standard code to make a table of units
-- First true example of a (small!) recipe.
module Example.Drasil.Units(table_of_units) where

import Control.Lens ((^.))
import Data.Char (toLower)

import Language.Drasil

table_of_units :: Unit s => [s] -> LayoutObj
table_of_units u = Section 0 (S "Table of Units") [s1_intro, s1_table u]

s1_intro :: LayoutObj
s1_intro = Paragraph
  (S "Throughout this document SI (Syst" :+: (F Grave 'e') :+:
   S "me International d'Unit" :+: (F Acute 'e') :+:
   S "s) is employed as the unit system." :+:
   S " In addition to the basic units, several derived units are" :+:
   S " employed as described below. For each unit, the symbol is" :+:
   S " given followed by a description of the unit with the SI" :+:
   S " name in parentheses.")

s1_table :: Unit s => [s] -> LayoutObj
s1_table u = Table [S "Symbol", S "Description"] (mkTable
  [(\x -> Sy (x ^. unit)),
   (\x -> (x ^. descr) :+: S (" (" ++ map toLower (x ^. name) ++ ")"))
  ] u)
  (S "Table of Units") False
```

Example – Chunks

```
-- {----------- Begin tau_c -----------}

tau_c :: VarChunk
tau_c = makeVC "tau_c" "clad thickness" ((Special Tau_L) `sub` lC)

-- {----------- Begin h_c -----------}

h_c_eq :: Expr
h_c_eq = 2 * (C k_c) * (C h_b) / (2 * (C k_c) + (C tau_c) * (C h_b))

h_c :: EqChunk
h_c = fromEqn "h_c" (S
  "convective heat transfer coefficient between clad and coolant")
  (lH `sub` lC) heat_transfer h_c_eq

-- {----------- Begin h_g -----------}

h_g_eq :: Expr
h_g_eq = (2*(C k_c)*(C h_p)) / (2*(C k_c)+((C tau_c)*(C h_p)))

h_g :: EqChunk
h_g = fromEqn "h_g" (S
  "effective heat transfer coefficient between clad and fuel surface")
  (lH `sub` lG) heat_transfer h_g_eq
```

Example – Common Knowledge

```
metre, second, kelvin, mole, kilogram, ampere, candela :: FundUnit
metre    = fund "Metre"    "length (metre)"                "m"
second   = fund "Second"   "time (second)"                 "s"
kelvin   = fund "Kelvin"   "temperature (kelvin)"          "K"
mole     = fund "Mole"     "amount of substance (mole)"    "mol"
kilogram = fund "Kilogram" "mass (kilogram)"               "kg"
ampere   = fund "Ampere"   "electric current (ampere)"     "A"
candela  = fund "Candela"  "luminous intensity (candela)" "cd"
```

Impressions

Advantages to a knowledge-based approach using Drasil:

1. No inconsistencies inter-/intra-artifact
2. Full traceability
3. Automatic update propagation
4. Reusable knowledge
5. Pervasive bugs

Impressions

Disadvantages:

1. No local hacks
2. Creating common knowledge is difficult
3. Large short-term investment

Next Steps

Planned features:

- More types of information (i.e. physical constraints & reasonable values)
- Generate test cases from constraints
- More output languages (MATLAB)
- More artifact types
- Different document views
- External syntax

References I

[1] Karen S. Ackroyd, Steve H. Kinder, Geoff R. Mant, Mike C. Miller, Christine A. Ramsdale, and Paul C. Stephenson. Scientific software development at a research facility. *IEEE Software*, 25(4):44–51, July/August 2008.

[2] Shereef Abu Al-Maati and Abdul Aziz Boujarwah. Literate software development. *Journal of Computing Sciences in Colleges*, 18(2):278–289, 2002.

[3] Jacques Carette. Gaussian elimination: a case study in efficient genericity with metaocaml. *Science of Computer Programming*, 62(1):3–24, 2006.

References II

[4] Jeffrey C. Carver, Richard P. Kendall, Susan E. Squires, and Douglass E. Post. Software development environments for scientific and engineering software: A series of case studies. In *ICSE '07: Proceedings of the 29th international conference on Software Engineering*, pages 550–559, Washington, DC, USA, 2007. IEEE Computer Society.

[5] Michael Deck. Cleanroom and object-oriented software engineering: A unique synergy. In *Proceedings of the Eighth Annual Software Technology Conference, Salt Lake City, USA*, 1996.

[6] Steve M. Easterbrook and Timothy C. Johns. Engineering the software for understanding climate change. *Comuting in Science & Engineering*, 11(6):65–74, November/December 2009.

References III

[7] Matthew Flatt, Eli Barzilay, and Robert Bruce Findler. Scribble: Closing the book on ad hoc documentation tools. In *ACM Sigplan Notices*, volume 44, pages 109–120. ACM, 2009.

[8] Peter Fritzson, Johan Gunnarsson, and Mats Jirstrand. Mathmodelica-an extensible modeling and simulation environment with integrated graphics and literate programming. In *2nd International Modelica Conference, March 18-19, Munich, Germany*, 2002.

[9] Robert Gentleman and Duncan Temple Lang. Statistical analyses and reproducible research. *Journal of Computational and Graphical Statistics*, 2012.

[10] Marco S Hyman. Literate c++. *COMP. LANG.*, 7(7):67–82, 1990.

References IV

[11] Cezar Ionescu and Patrik Jansson. Dependently-Typed Programming in Scientific Computing — Examples from Economic Modelling. In *Revised Selected Papers of the 24th International Symposium on Implementation and Application of Functional Languages*, volume 8241 of *Lecture Notes in Computer Science*, pages 140–156. Springer International Publishing, 2012.

[12] Andrew Johnson and Brad Johnson. Literate programming using `noweb`. *Linux Journal*, 42:64–69, October 1997.

[13] Diane Kelly. Industrial scientific software: A set of interviews on software development. In *Proceedings of the 2013 Conference of the Center for Advanced Studies on Collaborative Research*, CASCON '13, pages 299–310, Riverton, NJ, USA, 2013. IBM Corp.

References V

[14] Diane Kelly. Scientific software development viewed as knowledge acquisition: Towards understanding the development of risk-averse scientific software. *Journal of Systems and Software*, 109:50–61, 2015.

[15] Diane F. Kelly. A software chasm: Software engineering and scientific computing. *IEEE Softw.*, 24(6):120–119, 2007.

[16] Oleg Kiselyov, Kedar N Swadi, and Walid Taha. A methodology for generating verified combinatorial circuits. In *Proceedings of the 4th ACM international conference on Embedded software*, pages 249–258. ACM, 2004.

[17] D. E. Knuth. Literate programming. *The Computer Journal*, 27(2):97–111, 1984.

References VI

[18] Jeffrey Kotula. Source code documentation: an engineering deliverable. In *tools*, page 505. IEEE, 2000.

[19] Friedrich Leisch. Sweave: Dynamic generation of statistical reports using literate data analysis. In *Compstat*, pages 575–580. Springer, 2002.

[20] Russell V Lenth. Statweave users' manual. *URL http://www. stat. uiowa. edu/˜ rlenth/StatWeave*, 2009.

[21] Russell V Lenth, Søren Højsgaard, et al. Sasweave: Literate programming using sas. *Journal of Statistical Software*, 19(8):1–20, 2007.

[22] Anders Logg, Kent-Andre Mardal, and Garth Wells. *Automated solution of differential equations by the finite element method: The FEniCS book*, volume 84. Springer Science & Business Media, 2012.

References VII

[23] Zeeya Merali. Computational science: ...error. *Nature*, 467:775–777, 2010.

[24] Harlan D Mills, Richard C Linger, and Alan R Hevner. Principles of information systems analysis and design. 1986.

[25] Nedialko S. Nedialkov. VNODE-LP — a validated solver for initial value problems in ordinary differential equations. Technical Report CAS-06-06-NN, Department of Computing and Software, McMaster University, 1280 Main Street West, Hamilton, Ontario, L8S 4K1, 2006.

[26] Steven J. Owen. A survey of unstructured mesh generation technology. In *INTERNATIONAL MESHING ROUNDTABLE*, pages 239–267, 1998.

References VIII

[27] Matthew Patrick, James Elderfield, Richard OJH Stutt, Andrew Rice, and Christopher A Gilligan. Software testing in a scientific research group. 2015.

[28] Matt Pharr and Greg Humphreys. *Physically Based Rendering: From Theory to Implementation*. Morgan Kaufmann Publishers Inc., San Francisco, CA, USA, 2004.

[29] Vreda Pieterse, Derrick G. Kourie, and Andrew Boake. A case for contemporary literate programming. In *Proceedings of the 2004 Annual Research Conference of the South African Institute of Computer Scientists and Information Technologists on IT Research in Developing Countries*, SAICSIT '04, pages 2–9, Republic of South Africa, 2004. South African Institute for Computer Scientists and Information Technologists.

References IX

[30] Markus Püschel, José MF Moura, Jeremy R Johnson, David Padua, Manuela M Veloso, Bryan W Singer, Jianxin Xiong, Franz Franchetti, Aca Gačic, Yevgen Voronenko, et al. Spiral: Code generation for dsp transforms. *Proceedings of the IEEE*, 93(2):232–275, 2005.

[31] Norman Ramsey. Literate programming simplified. *IEEE software*, 11(5):97, 1994.

[32] Patrick J. Roache. *Verification and Validation in Computational Science and Engineering*. Hermosa Publishers, Albuquerque, New Mexico, 1998.

[33] Eric Schulte, Dan Davison, Thomas Dye, Carsten Dominik, et al. A multi-language computing environment for literate programming and reproducible research. *Journal of Statistical Software*, 46(3):1–24, 2012.

References X

[34] Judith Segal. When software engineers met research scientists: A case study. *Empirical Software Engineering*, 10(4):517–536, October 2005.

[35] Stephen Shum and Curtis Cook. Aops: an abstraction-oriented programming system for literate programming. *Software Engineering Journal*, 8(3):113–120, 1993.

[36] Volker Simonis. Progdoc–a program documentation system. *Lecture Notes in Computer Science*, 2890:9–12, 2001.

[37] Spencer Smith and Nirmitha Koothoor. A document driven method for certifying scientific computing software used in nuclear safety analysis. *Nuclear Engineering and Technology*, Accepted, 2016. 42 pp.

References XI

[38] Spencer Smith, Yue Sun, and Jacques Carette. Comparing psychometrics software development between CRAN and other communities. Technical Report CAS-15-01-SS, McMaster University, January 2015. 43 pp.

[39] Spencer Smith, Yue Sun, and Jacques Carette. Statistical software for psychology: Comparing development practices between CRAN and other communities. *Software Quality Journal*, Submitted December 2015. 33 pp.

[40] W. Spencer Smith, Nirmitha Koothoor, and Nedialko Nedialkov. Document driven certification of computational science and engineering software. In *Proceedings of the First International Workshop on Software Engineering for High Performance Computing in Computational Science and*

References XII

Engineering (SE-HPCCE), page [8 p.], November 2013.

[41] Harold Thimbleby. Experiences of 'literate programming'using cweb (a variant of knuth's web). *The Computer Journal*, 29(3):201–211, 1986.

[42] Gregory V. Wilson. Where's the real bottleneck in scientific computing? Scientists would do well to pick some tools widely used in the software industry. *American Scientist*, 94(1), 2006.