NPRG075
Learning from architecture and design

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Lectures: Monday 12:20, S7

https://d3s.mff.cuni.cz/teaching/nprg075

Design and architecture

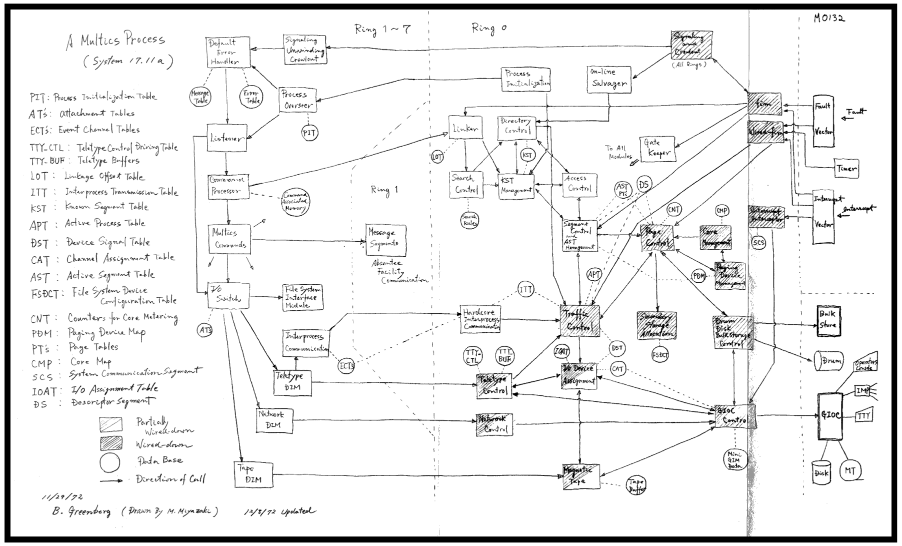
Solving complex problems

Architecture and urban planning

Understanding and solving complex problems

Organizing large number of diverse entities

Useful concepts and methodologies?



Software architecture

How to organize systems?

How can we study what organization makes sense?

How languages and tools shape organization?

How systems grow as requirements change?

Urban planning

Jacobs on cities

Problems of simplicity
Fully analyzable

Unorganized complexity
Statistically analyzable

Organized complexity
Non-reducible

Parnas on software

Analogy systems
Continuous models

Repetitive digital
Reduce via abstraction

Non-repetitive digital
Non-reducible

Design problems

Design problems are ill-defined

- Full information never available
- Cannot be exhaustively analyzed
- No correct solution may exist

BIRKHÄUSER
Nigel Cross
Designerly Ways of Knowing
Board of International Research in Design, BIRD

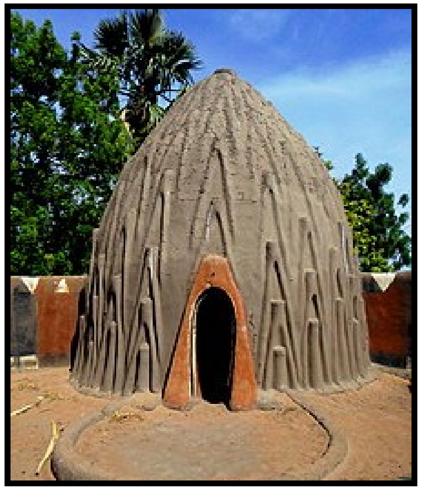
Solving design problems

- Conjectured solution reframes the problem
- Designers impose "primary generator"
- Change problem-as-given in light of solution

Achieving fit

Vernacular

Adaptation over generations



Modernist

Problem analysis and fresh design

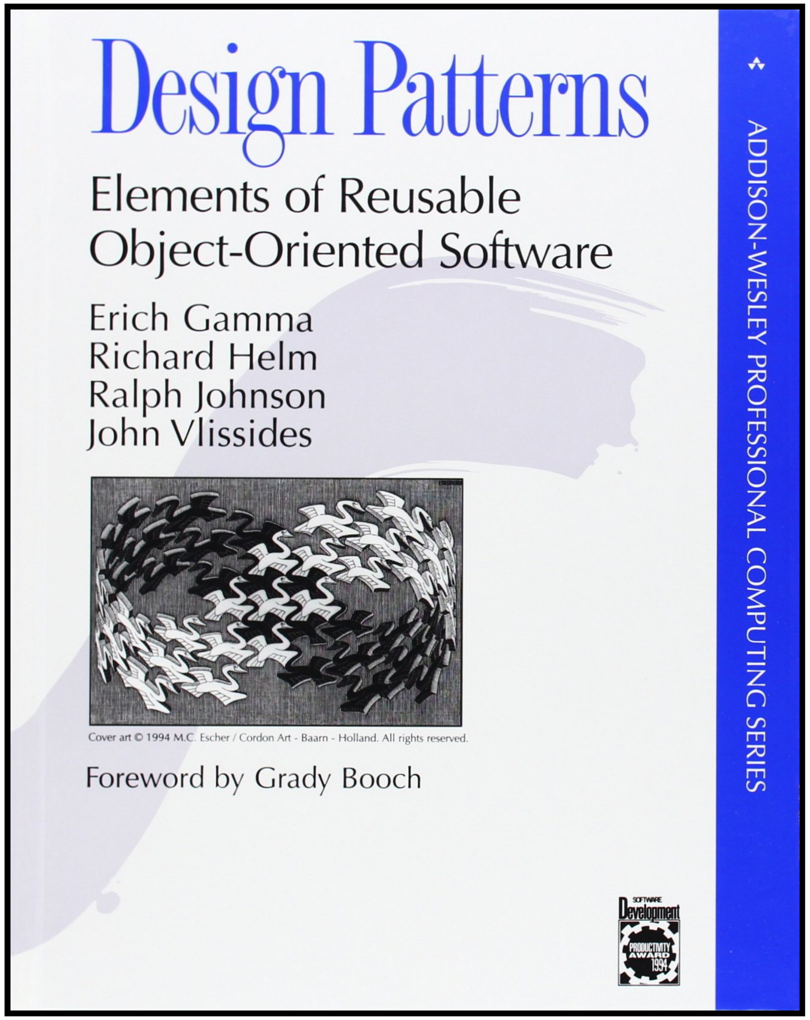
Post-modern

Prefers cleverness, humour over fit!

Design patterns

Learning from architecture

Design patterns

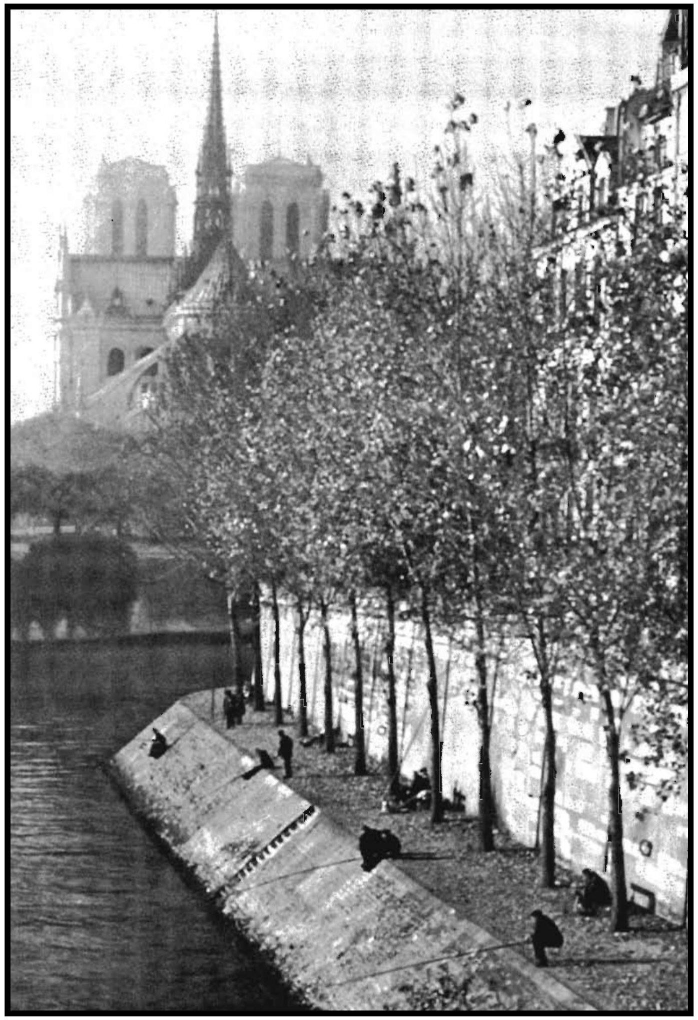

Design Patterns
Elements of Reusable Object-Oriented Software
Erich Gamma
Richard Helm
Ralph Johnson
John Vlissides
Cover art © 1994 M.C. Escher / Cordon Art - Baarn - Holland. All rights reserved.
Foreword by Grady Booch
ADDISON-WESLEY PROFESSIONAL COMPUTING SERIES
SOFTWARE Development PRODUCTIVITY AWARD 1994

Based on Christopher Alexander's work on architecture

Useful but criticized

Missing the point of Alexander's work

Workarounds for coding in a poor language



Quality without name

A system has it when it is true to its inner forces, when it is free from contradictions

Each "living" pattern resolves a system of forces. When all forces are resolved, the quality appears.

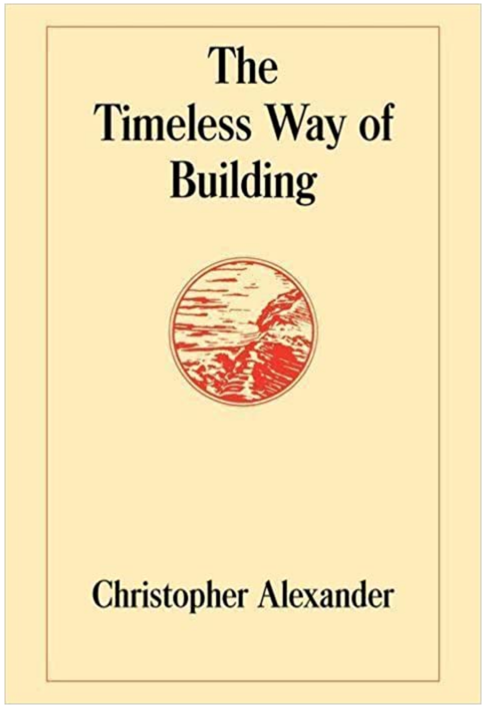
Why is it hard?

Vernacular method

- Shared language lost from community
- Complexity of problems has grown
- Community cannot build a skyscraper

Modernist method

- Cannot perfectly analyze problem
- Always misses some important detail
- Keeps reinventing imperfect forms



Quality

How is this about programming?

- Think about programmer thinking and coding
- Programming systems, not languages
- Need to resolve complex systems of forces
- Patterns to capture approaches that work

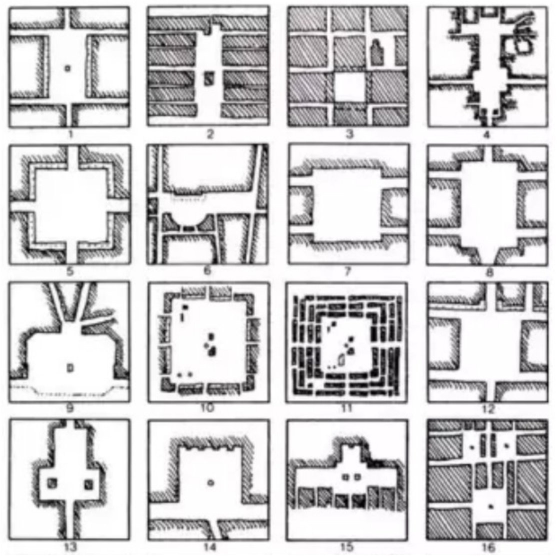
Achieving fit

Design pattern

- Context, problem, forces, solution
- Resolves interconnected forces
- Works as a solution template

Pattern language

- Ordered sequence of patterns
- Can be followed step-by-step
- Ideally shared and agreed on



Degrees of publicness

Context: Where people want to live is different

Forces: Some want to live where the action is, some in more isolation

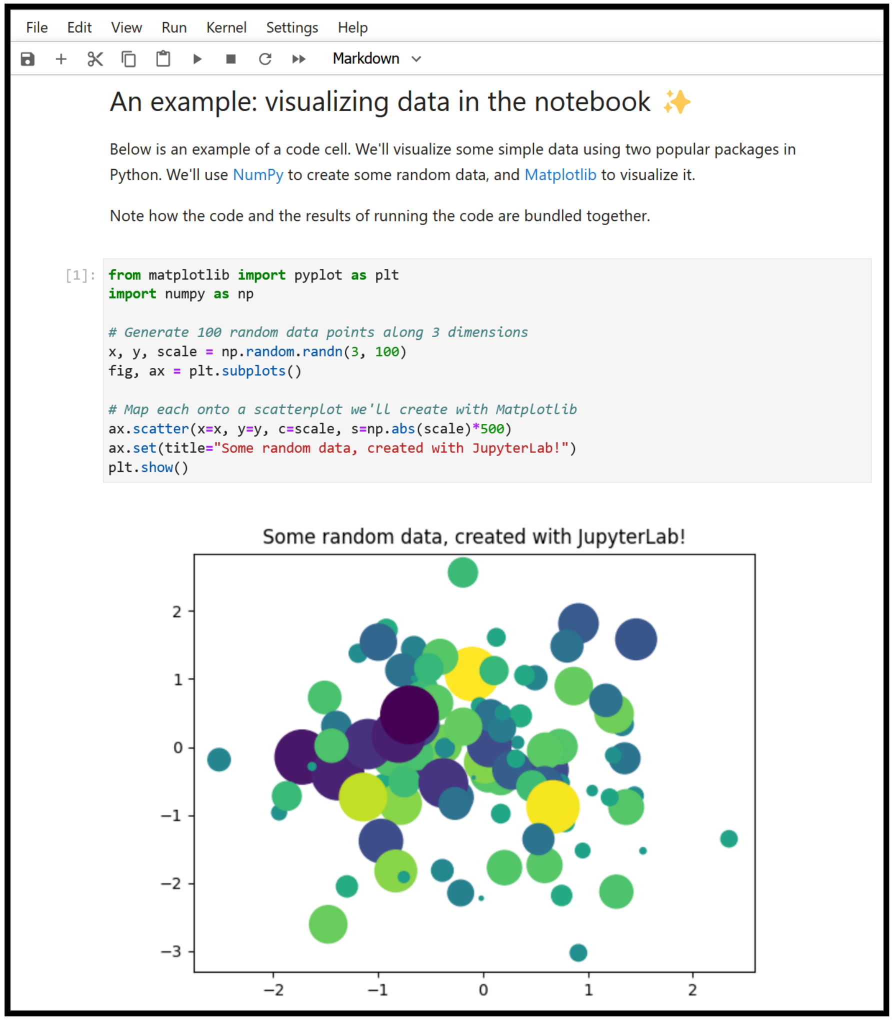
Problem: How to organize a cluster of homes?

Solution: Distinguish private homes, public homes and in-between

Notebook systems

Designing a complex system

Notebook systems



An example: visualizing data in the notebook ✨

Below is an example of a code cell. We'll visualize some simple data using two popular packages in Python. We'll use NumPy to create some random data, and Matplotlib to visualize it.

Note how the code and the results of running the code are bundled together.

```
[1]: from matplotlib import pyplot as plt
     import numpy as np

     # Generate 100 random data points along 3 dimensions
     x, y, scale = np.random.randn(3, 100)
     fig, ax = plt.subplots()

     # Map each onto a scatterplot we'll create with Matplotlib
     ax.scatter(x=x, y=y, c=scale, s=np.abs(scale)*500)
     ax.set(title="Some random data, created with JupyterLab!")
     plt.show()
```

Literate programming environment - code, outputs, comments

Used for exploration, scientific tasks, data science, learning

How to design exploration environment?

Demo

Using F# in a notebook system

Case study: Notebooks

Notebooks for data science

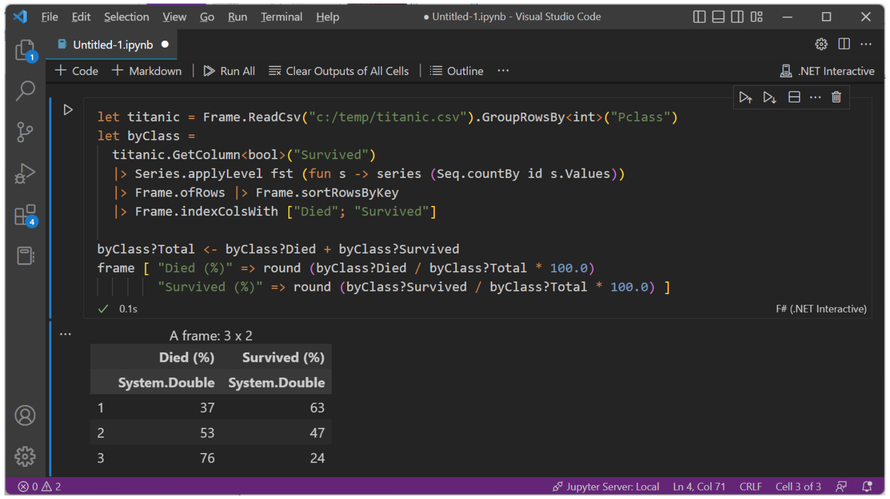
- Use by FT journalists for article
- Start with "Eurostat exports data"
- tinyurl.com/nprg075-ft

Design questions

- What are the specific forces?
- How are they reflected in the notebooks?
- Which are poorly resolved?

Pattern languages

Designing exploration tools


File Edit Selection View Go Run Terminal Help
● Untitled-1.ipynb - Visual Studio Code
Untitled-1.ipynb
+ Code + Markdown Run All Clear Outputs of All Cells Outline
.NET Interactive
F# (.NET Interactive)
Jupyter Server: Local Ln 4, Col 71 CRLF Cell 3 of 3

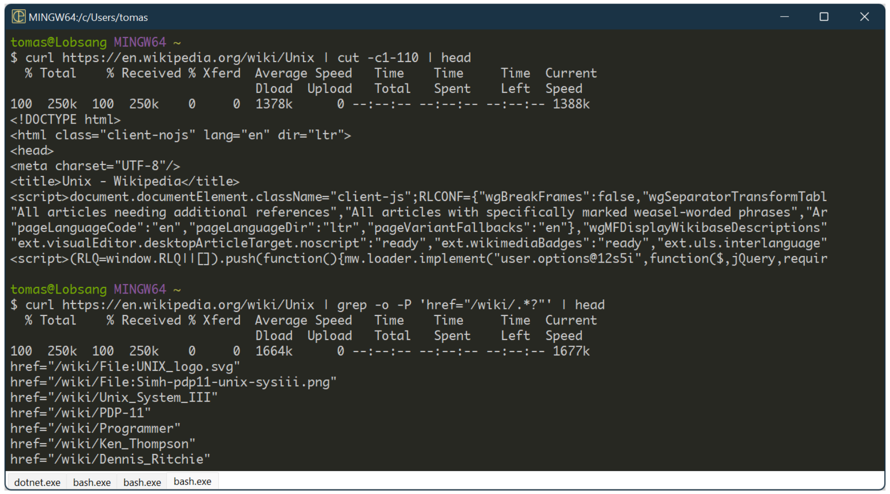
```
let titanic = Frame.ReadCsv("c:/temp/titanic.csv").GroupRowsBy<int>("Pclass")
let byClass =
  titanic.GetColumn<bool>("Survived")
   |> Series.applyLevel fst (fun s -> series (Seq.countBy id s.Values))
   |> Frame.ofRows |> Frame.sortRowsByKey
   |> Frame.indexColsWith ["Died"; "Survived"]

byClass?Total <- byClass?Died + byClass?Survived
frame [ "Died (%)" => round (byClass?Died / byClass?Total * 100.0)
        "Survived (%)" => round (byClass?Survived / byClass?Total * 100.0) ]
```

✓ 0.1s

A frame: 3 x 2

	Died (%)	Survived (%)
	System.Double	System.Double
1	37	63
2	53	47
3	76	24



```
tomas@Lobsang MINGW64 ~
$ curl https://en.wikipedia.org/wiki/Unix | cut -c1-110 | head
  % Total    % Received % Xferd  Average Speed   Time    Time     Time  Current
                                 Dload  Upload   Total   Spent    Left  Speed
100  250k  100  250k    0     0  1378k      0 --:--:-- --:--:-- --:--:-- 1388k
<!DOCTYPE html>
<html class="client-nojs" lang="en" dir="ltr">
<head>
<meta charset="UTF-8"/>
<title>Unix - Wikipedia</title>
<script>document.documentElement.className="client-js";RLCONF={"wgBreakFrames":false,"wgSeparatorTransformTabl
"All articles needing additional references","All articles with specifically marked weasel-worded phrases","Ar
"pageLanguageCode":"en","pageLanguageDir":"ltr","pageVariantFallbacks":"en"},"wgMFDisplayWikibaseDescriptions"
"ext.visualEditor.desktopArticleTarget.noscript":"ready","ext.wikimediaBadges":"ready","ext.uls.interlanguage"
<script>(RLQ=window.RLQ||[]).push(function(){mw.loader.implement("user.options@12s5i",function($,jQuery,requir

tomas@Lobsang MINGW64 ~
$ curl https://en.wikipedia.org/wiki/Unix | grep -o -P 'href="/wiki/.*?"' | head
  % Total    % Received % Xferd  Average Speed   Time    Time     Time  Current
                                 Dload  Upload   Total   Spent    Left  Speed
100  250k  100  250k    0     0  1664k      0 --:--:-- --:--:-- --:--:-- 1677k
href="/wiki/File:UNIX_logo.svg"
href="/wiki/File:Simh-pdp11-unix-sysiii.png"
href="/wiki/Unix_System_III"
href="/wiki/PDP-11"
href="/wiki/Programmer"
href="/wiki/Ken_Thompson"
href="/wiki/Dennis_Ritchie"
```

Exploratory programming workspaces

Environment that lets you figure something out interactively..

Data science, but also general programming

Are there common patterns of working?

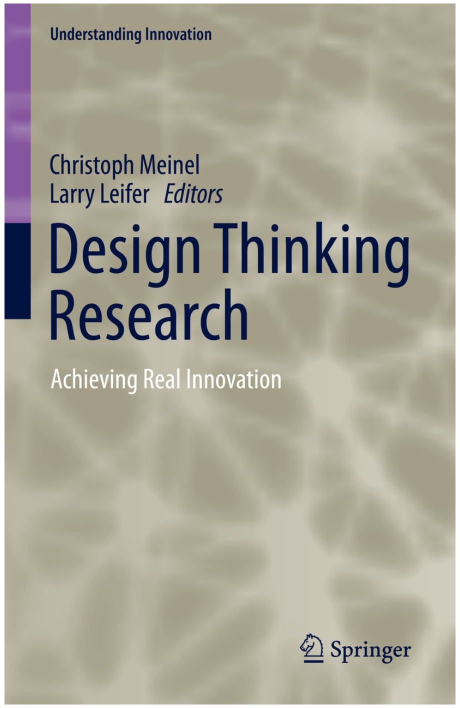
Taeumel et al. (2022)

A Pattern Language of an Exploratory Programming Workspace

- Patterns in exploratory tools
- Smalltalk, notebooks, UNIX
- System design and ways of using

Conversation in context

- Seven patterns covering three aspects
- Questions, context, responses
- Capture needs, forces, structure, trade-offs, etc.

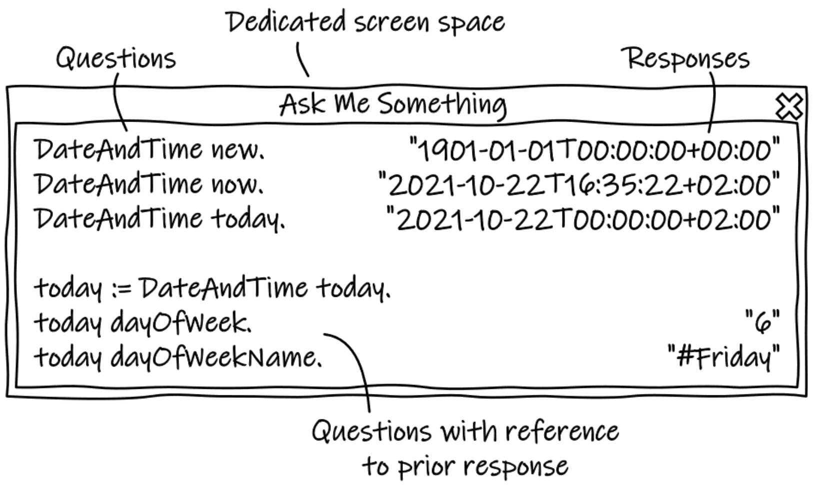

Understanding Innovation

Christoph Meinel
Larry Leifer *Editors*

Design Thinking Research

Achieving Real Innovation

Springer



```
DateAndTime new.           "1901-01-01T00:00:00+00:00"
DateAndTime now.           "2021-10-22T16:35:22+02:00"
DateAndTime today.         "2021-10-22T00:00:00+02:00"

today := DateAndTime today.
today dayOfWeek.                                  "6"
today dayOfWeekName.                       "#Friday"
```

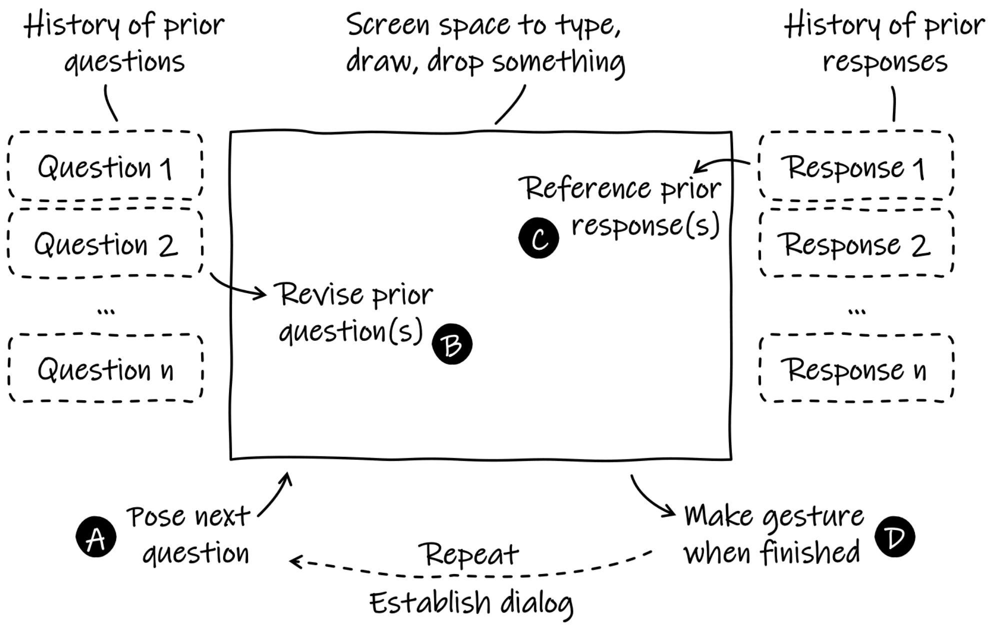
Programmer, environment, interaction context

"It is all about you working on a project in an environment while continually switching between different interaction contexts"

Conversation in context

Forces resolved by the pattern

- Want to ask question about something
- Finding the right place to ask
- Finding the right words to use
- Understanding complex technical answer


History of prior questions
Screen space to type, draw, drop something
History of prior responses
Question 1
Question 2
...
Question n
Response 1
Response 2
...
Response n
Reference prior response(s)
C
Revise prior question(s)
B
A
Pose next question
Repeat
Establish dialog
Make gesture when finished
D

Conversation in context

Solution structure

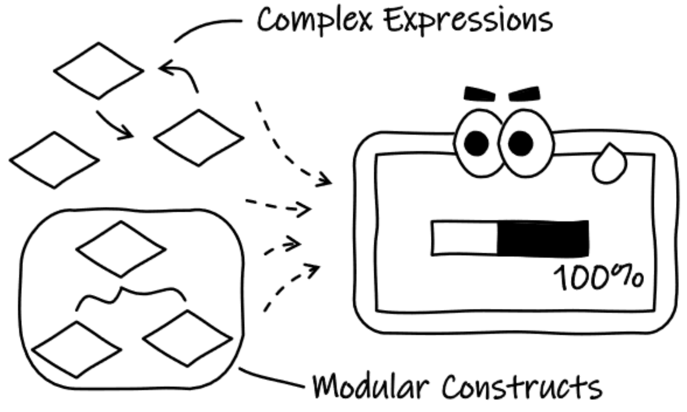
Iterative question and answer interaction with persistent context

Support for revising questions asking follow-up questions

Further patterns

Elaborate inquiry

- Difficult to ask complex questions
- Use stepwise composition
- Refer to previous answers



Proxy transport

- Need to access external information
- May be big or use an odd format
- Embed into local context with lazy loading

Further patterns

Context, forces, solution

- **Coach your environment** by adding information
- **Concepts in shards** need to be linked
- **Simple response** to be found iteratively
- **Pause and explore** to better understand

Pattern languages

Designing pattern languages

WHAT'S THIS?
DOUGLAS HOFSTADTER'S SIX-WORD AUTOBIOGRAPHY. AFTER ALL THOSE 700-PAGE TOMES, I GUESS HE WANTED TO TRY FOR BREVITY.
HUH. LET'S SEE...
I'M SO META, EVEN THIS ACRONYM
...WHOA.
I THINK HE NAILED IT.

Where patterns come from?

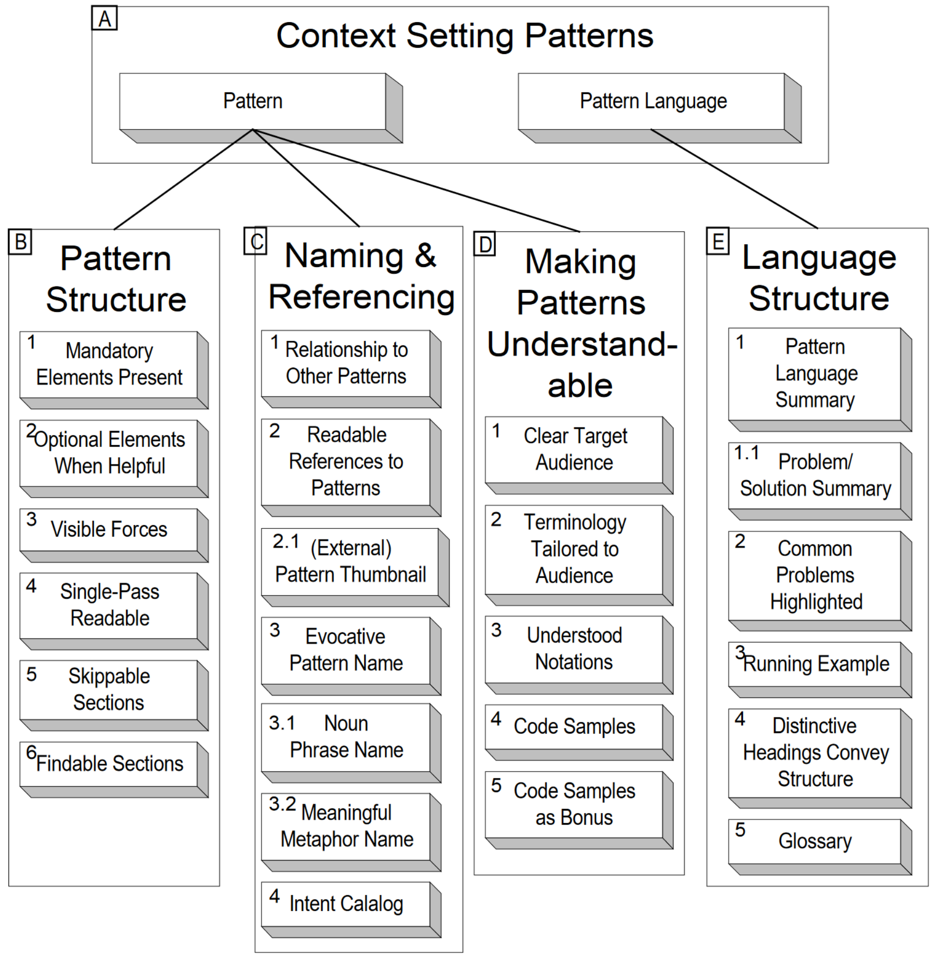
Pattern languages for creating pattern languages

No single systematic method that would always work

Pattern writing

Where patterns come from

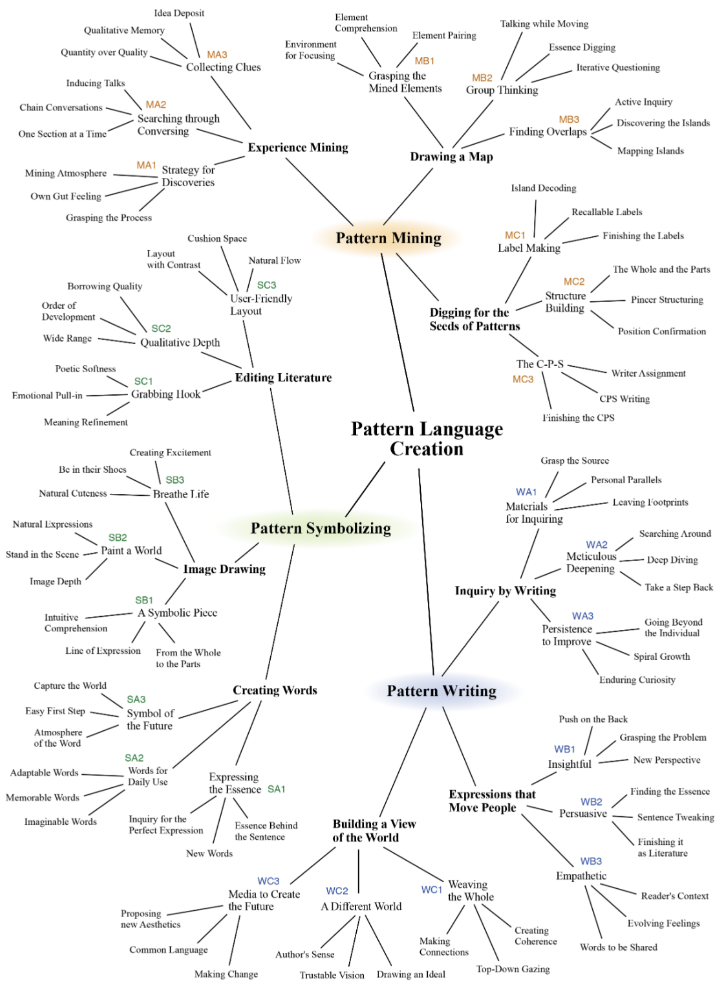
- Shared and evolved in a community
- Repeated solutions in past software systems
- Personal experience with a problem
- Focused group collaboration (origins of wiki!)


A
Context Setting Patterns
Pattern
Pattern Language
B
Pattern Structure
1 Mandatory Elements Present
2 Optional Elements When Helpful
3 Visible Forces
4 Single-Pass Readable
5 Skippable Sections
6 Findable Sections
C
Naming & Referencing
1 Relationship to Other Patterns
2 Readable References to Patterns
2.1 (External) Pattern Thumbnail
3 Evocative Pattern Name
3.1 Noun Phrase Name
3.2 Meaningful Metaphor Name
4 Intent Calalog
D
Making Patterns Understand-able
1 Clear Target Audience
2 Terminology Tailored to Audience
3 Understood Notations
4 Code Samples
5 Code Samples as Bonus
E
Language Structure
1 Pattern Language Summary
1.1 Problem/ Solution Summary
2 Common Problems Highlighted
3 Running Example
4 Distinctive Headings Convey Structure
5 Glossary

A pattern language for pattern writing

(Meszaros+Doble, '97)

How to structure, write and present patterns & pattern languages



A pattern language for creating pattern languages

(Iba+Isaku, 2016)

Hints on pattern mining

Collect experiences

Map and find overlaps

Structure in clusters

Practical tips

How to write a pattern language

- Patterns are about resolving forces
- Patterns should have fixed format
- Context, forces, structure, related patterns
- System structure or human interaction with it

Concepts and methods

Learning from architecture

Learning from unaverage clues

(Jacobs, 1961)

Cannot reduce city to a single statistic

Look for informative singleton clues!

Demo

Commodore 64 BASIC

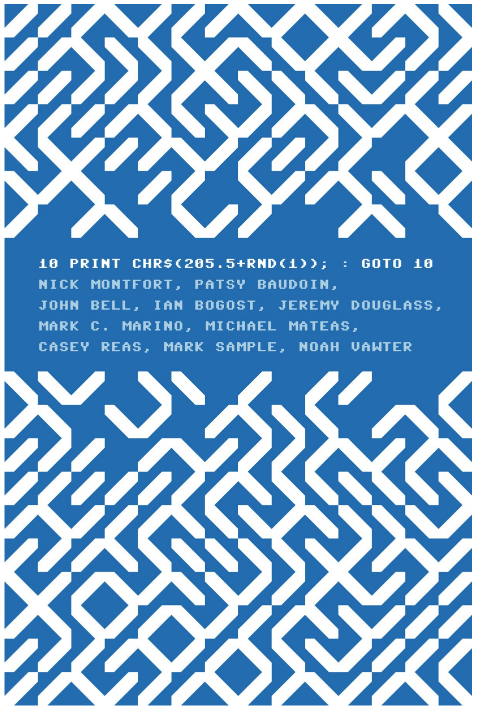
10 PRINT CHR$(205.5+RND(1)); : GOTO 10

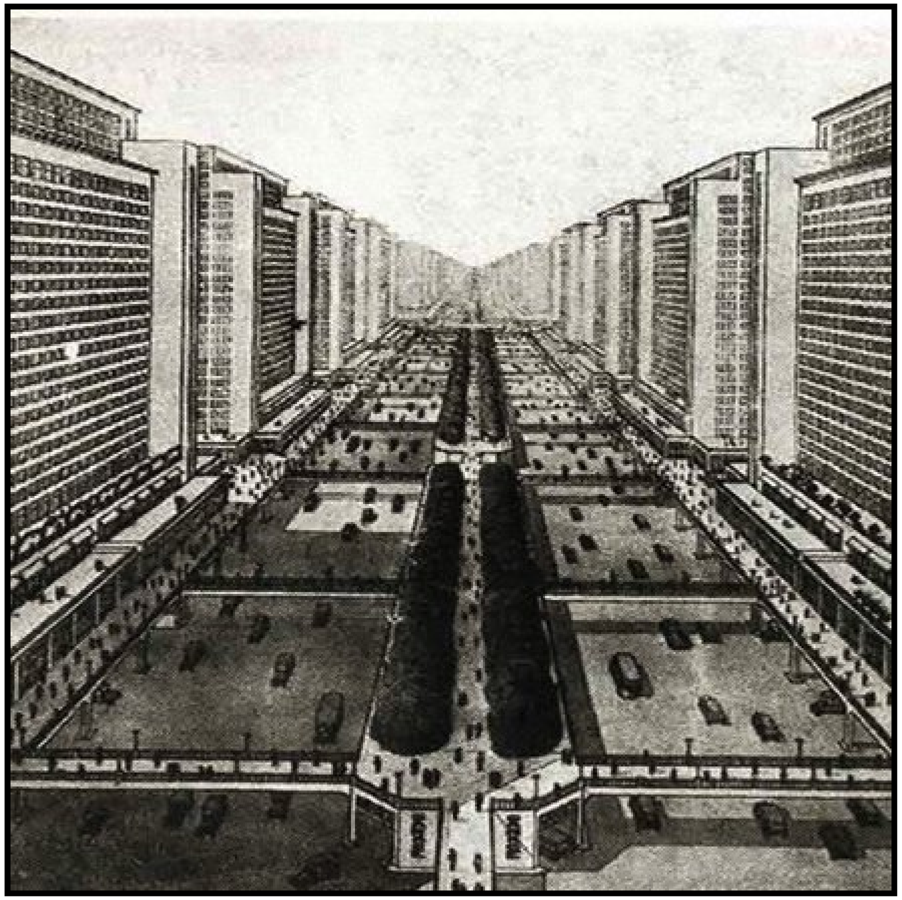
Technical aspects

- Edit & run in one terminal
- Line numbers for navigation
- Simple with **POKE** for hackers

Social aspects

- Path from a user to a programmer
- Commodore 64 boots into BASIC!
- Learn by copying from magazines


10 PRINT CHR$(205.5+RND(1)); : GOTO 10
NICK MONTFORT, PATSY BAUDOIN,
JOHN BELL, IAN BOGOST, JEREMY DOUGLASS,
MARK C. MARINO, MICHAEL MATEAS,
CASEY REAS, MARK SAMPLE, NOAH VAWTER



What works despite the theory

(Jacobs, 1961)

Elegant theories
that are convincing
but do not work

Document what
actually works
in practice instead!

Information hiding

Good software engineering

- Divide systems into modules
- Hide implementation details
- Expose only what is needed

Why should this work?

- Basic principle of OOP!
- Can freely change internals
- Modules developed independently

Information hiding

Brief history

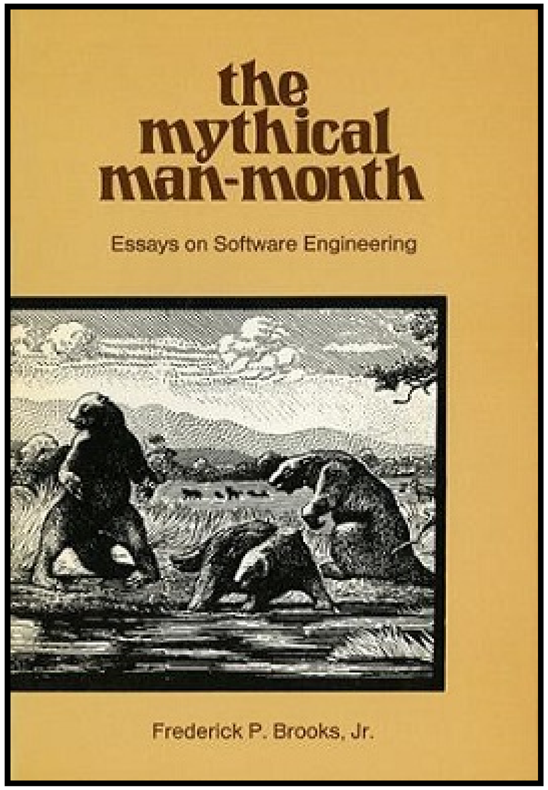
- Decomposing systems (1972)
- IBM OS/360 development (1975)
- Brooks' reflections (1995)
- Cathedral and the bazaar (1999)

Critique and alternatives

- Design is hard to anticipate
- Cumbersome & inefficient uses
- MIDI SysEx and UNIX DWARF work!

Conceptual coherence

(Brooks, 1975)



A clean, elegant programming product must present to each of its users a coherent mental model of the application.

Conceptual integrity is the most important factor in ease of use.

Post-modern programming

No grand narrative

I set out to deconstruct all the computer languages and recombine them. I lovingly reused features from many languages.

Why this works

- Worse is better
- Postmodernists prefer AND, modernists OR
- Possible to write messy & clean programs

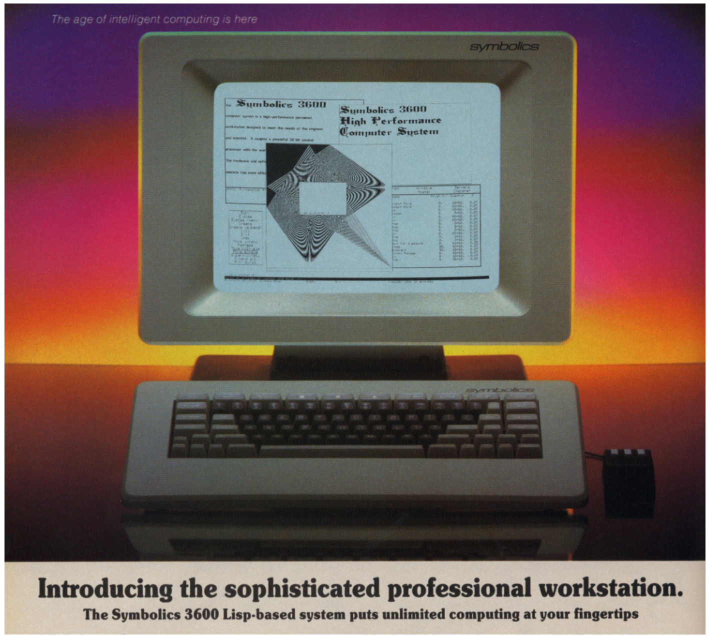
Worse is better

The right thing

- Common LISP, ITS system
- No incorrectness / inconsistency
- Completeness, then simplicity

Worse is better

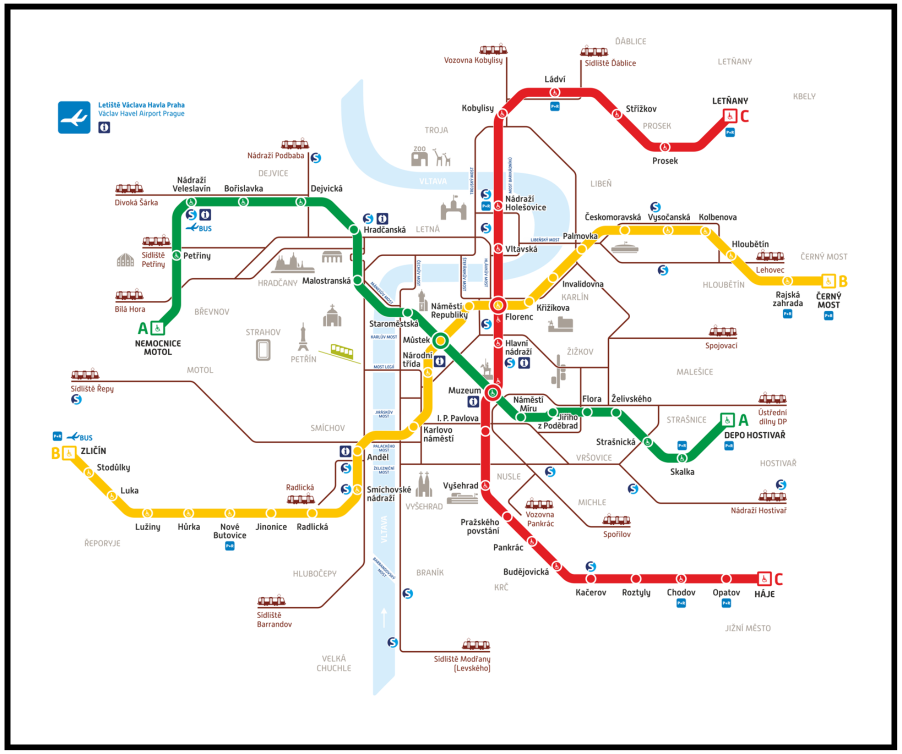
- UNIX and C language
- Simple is better than correct, consistent & complete


The age of intelligent computing is here
symbolics
Symbolics 3600
Symbolics 3600 High Performance Computer System
Introducing the sophisticated professional workstation.
The Symbolics 3600 Lisp-based system puts unlimited computing at your fingertips

Concepts and methods

Unexplored inspirations

Image of a city



How do we navigate around cities?

And codebases?

Districts, landmarks and pathways

Good design supports navigability and legibility

Materials

Building materials that look bad before they go bad

Software tends to break abruptly without any warning...

Is there an alternative?

Vernacular architecture

Achieves a good fit without the continuous reinvention of forms

Can we build software without reinventing forms? Spreadsheets? Configuration?

Conclusions

Learning from architecture

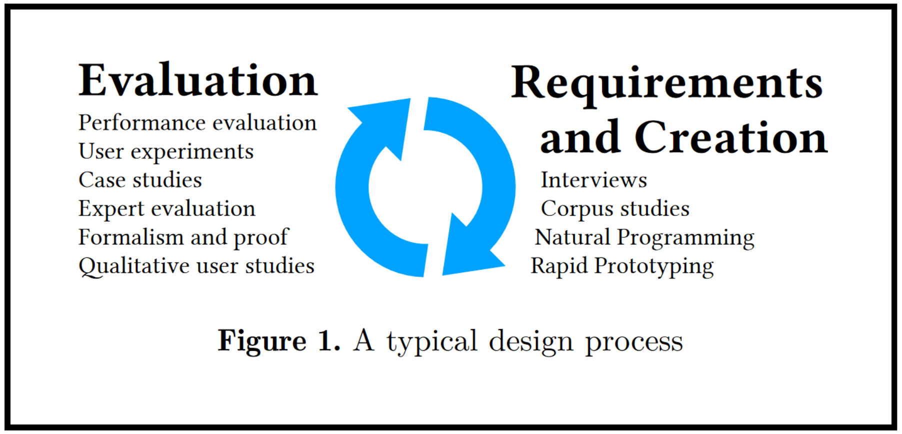


Figure 1. A typical design process

Architecture and design in context

Conceptual design rather than empirical science

Powerful methodologies for idea generation

Appropriateness is harder to evaluate - wait and see!

Reading

No information hiding?

- Varv: Reprogrammable Interactive Sofware as a Declarative Data Structure
- Available at: http://vis.csail.mit.edu/pubs/varv.pdf

What to read and how

- Declarative, extensible programming!
- Get a sense of how it works (Section 2)
- Look at evaluation (Section 5)

Conclusions

Learning from architecture and design

- Methods & concepts for complex systems
- Architecture, urban planning and design
- Design patterns & pattern languages

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https://d3s.mff.cuni.cz/teaching/nprg075

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Just for fun...

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Architecture books

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