Human-Computer Interaction

Lecture 6: Programming languages

USABILITY OF NOTATIONS

Cognitive Dimensions of Notations

- 'Discussion tools' for use when considering alternative designs of programming languages, and other complex information systems
  - Suitable for analytic evaluation before, during and after a design process (e.g. iterative prototyping)
  - But not a checklist of ideal features
- We have to escape 'superlativism'
  - I think the best programming language is … !
- All real design is about trade-offs
  - What is better – a Lamborghini or a tractor?
  - Do they have design principles in common?

Where do we find information structures?

- Not only programming languages, but anything with internal structure (relationships, dependencies etc)
  - UML diagrams, Spreadsheets, Travel bookings, Musical compositions, Technical manuals, Novels
- Structured information devices involve:
  - a notation
  - an environment
  - a medium
- Consider example dimension: *Viscosity*
  - simplified preview definition:
    "a viscous system is hard to modify"

Example: modifying structure of text

- Notations:
  - inserting text in a novel is easier than in more structured formats like a newspaper
- Environment:
  - structures in a word processor are easier to modify, on pencil and paper are harder to modify
- Media:
  - any part of a text on paper can be accessed easily, but harder on a dictaphone (example – Philip Pullman).

Definitions

- Notation:
  - The perceived marks or symbols (as covered in visual representation lecture), and the correspondence to what they are supposed to mean
- Environment:
  - The operations and tools provided for users to navigate, read and manipulate the perceived marks
- Medium:
  - Where the marks are being made (screens, paper, Post-Its, tangible objects, augmented reality)

User experience of notational systems

- Interaction is viewed as building, modifying and navigating an information structure
- Usability depends on the structure of the notation and the tools that the environment provides for manipulating marks within the medium
- Dimensions like viscosity draw attention to aspects of user experience when interacting with the information structure
- Different *activities* have different profiles (e.g. the facilities you need when reading a technical manual are different from those you need when writing one)

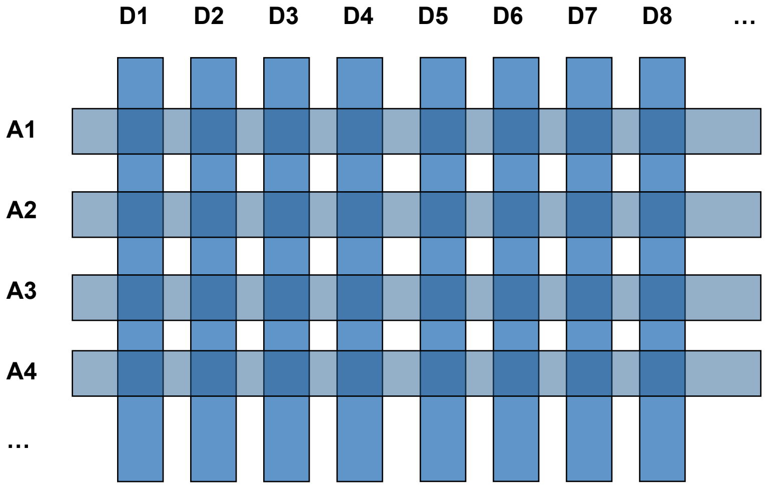
Construction activities: building information structure

- Incrementation
  - add a new formula to a spreadsheet
- Transcription
  - convert an equation to a spreadsheet formula
- Modification
  - change spreadsheet for a different problem
- Exploratory design
  - programming on the fly (“hacking”)

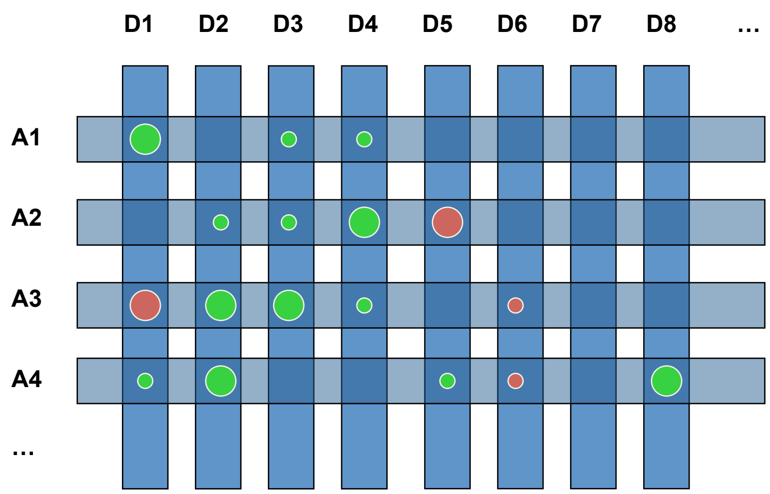
Interpretation activities: reading information structures

- Search
  - find a value specified in a spreadsheet
- Comparison
  - fault-finding, checking correctness
- Exploratory understanding (sensemaking)
  - analyse a business plan presented in a spreadsheet

Dimensions and Activities are orthogonal



Profiles describe desirable combinations



SOME DETAILED DIMENSIONS

Dimensions covered today:

- Abstraction
  - types and availability of abstraction mechanisms
- Hidden dependencies
  - important links between entities are not visible
- Premature commitment
  - constraints on the order of doing things
- Secondary notation
  - extra information in means other than formal syntax
- Viscosity
  - resistance to change
- Visibility
  - ability to view components easily

Not covered in detail today:

- Closeness of mapping
  - closeness of representation to domain
- Consistency
  - similar semantics expressed in similar forms
- Diffuseness
  - verbosity of language
- Error-proneness
  - notation invites mistakes
- Hard mental operations
  - high demand on cognitive resources
- Progressive evaluation
  - work-to-date checkable any time
- Provisionality
  - degree of commitment to actions or marks
- Role-expressiveness
  - component purpose is readily inferred
- And more …
  - Research continues to identify new dimensions

Viscosity

- ***Resistance to change: the cost of making small changes.***
- Repetition viscosity:
  - e.g. manually changing US spelling to UK spelling throughout a long document
- Domino (was "Knock-On") viscosity:
  - e.g. inserting a figure in a document means updating all later figure numbers, their cross-references, the list of figures, the index ...

Viscosity features

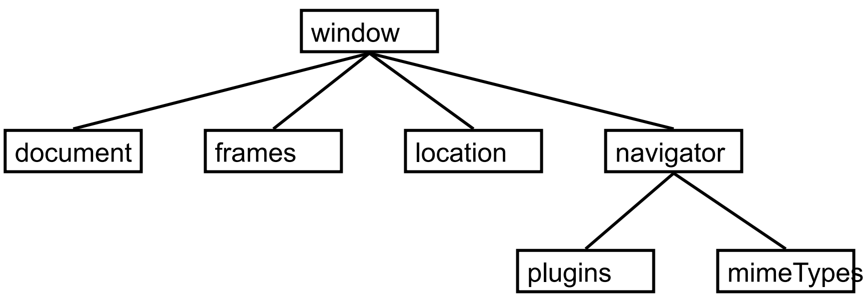
- Viscosity becomes a problem when you need to change your plan: it is a function of the work required to change a plan element.
- It is a property of the system as a whole
- May be different for different operations
- Often happens when designers assume system use will only involve incrementation, but that users will never change the structure.

Viscosity examples

- Repetition viscosity example:
  - When the user has one document in mind, but it is stored as a collection of files, which must be edited separately to change style in all.
- Domino viscosity example:
  - In structures with high inter-dependency, such as timetables.
- Combinations of the two are the worst!

Combined domino/repetition

- Common in graphic structures, genealogical trees, hypertexts …
  - e.g. tree showing part of JavaScript hierarchy



Workarounds & trade-offs

- Separate exploratory & transcription stages
  - e.g. pencil sketch before ink
- Introduce a new abstraction
  - e.g. AutoNumber facility
- Change the notation
  - e.g. quick dial codes for telephone

Hidden Dependencies

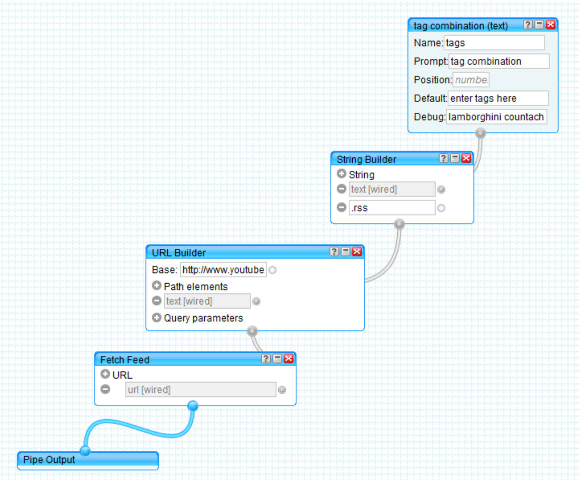
- ***A relationship between components such that one is dependent on the other, but the dependency is not fully visible.***
- The one-way pointer:
  - e.g. your Web page points to someone else's - how do you know when they move it?
- Local dependency:
  - e.g. which spreadsheet cells use the value in a given cell?

Hidden Dependency features

- Hidden dependencies slow up information finding.
- Tolerable in exploratory design, but not in modification
- May be responsible for high frequency of errors in spreadsheets.

Hidden Dependency examples

- GOTO statements didn't have a corresponding COME-FROM.
  - Block structure brings symmetry
- Data-flow makes dependencies explicit



Workarounds & trade-offs

- Require explicit cueing
  - e.g. import and export declarations
- Highlight different information
  - e.g. data-flow language
- Provide tools
  - e.g. spreadsheets which highlight all cells that use a particular value

Premature Commitment / Enforced Lookahead

- ***Constraints on the order of doing things force the user to make a decision before the proper information is available.***

Premature commitment features

- Only occur if three conditions hold:
  - target notation contains internal dependencies
  - access to both source and target is order-constrained
  - the constrained order is inappropriate
- Happens when designer's view of "natural sequence" is at variance with user's needs
- Results in 2nd and 3rd attempts at task

Premature commitment examples

- Telephone menu systems
- Four-function calculator
  - (1.2 + 3.4 - 5.6) / ((8.7 - 6.5) + (4.3))

More types and examples

- Defining database schemas before the data
- Filing systems (library shelving by Dewey)
- Surreptitious order constraints
  - Provisional relationships in E-R diagram
- Effect of medium
  - Exacerbated when 'marks' are transient (e.g. in an auditory medium)

Workarounds & trade-offs

- Decoupling
  - e.g. the signwriter paints the sign elsewhere
- Ameliorating
  - premature commitment is not so bad if viscosity is low & bad guesses can be corrected
- Deconstraining
  - e.g. GUI interfaces often remove constraints on order of actions

Abstractions

- ***An abstraction is a class of entities or grouping of elements to be treated as one entity*** (thereby lowering viscosity).
- Abstraction barrier:
  - minimum number of new abstractions that must be mastered before using the system (e.g. Z)
- Abstraction hunger:
  - require user to create abstractions

Abstraction features

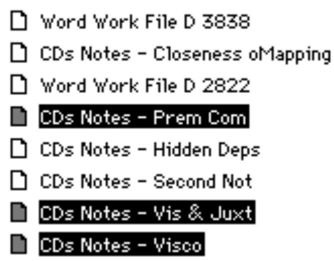
- Abstraction-tolerant systems:
  - permit but do not require user abstractions (e.g. word processor styles)
- Abstraction-hating systems:
  - do not allow definition of new abstractions (e.g. spreadsheets)
- Abstraction *changes the notation*.

Abstraction implications

- Abstractions are hard to create and use
- Abstractions must be maintained
  - useful for modification and transcription
  - increasingly used for personalisation
- Involve the introduction of an *abstraction manager* sub-device
  - including its own viscosity, hidden dependencies, juxtaposability etc.

Abstraction examples

- Persistent abstractions:
  - Style sheets, macros, telephone memories
- Definitions and exemplars
  - Powerpoint templates, CAD libraries
- Transient abstractions:
  - Search and replace, selection aggregates



Workarounds & trade-offs

- Incremental abstractions
  - low abstraction barrier, tolerates new additions, provides alternatives (but may confuse)
- Overcoming abstraction-repulsion
  - abstractions decrease viscosity, but increase problems for occasional / end-users
- Programming by example?
  - can introduce abstract hidden dependencies

Secondary Notation

- ***Extra information carried by other means than the official syntax.***
- Redundant recoding:
  - e.g. indentation in programs, grouping contol knobs by function
- Escape from formalism:
  - e.g. annotation on diagrams

Secondary Notation features

- Redundant recoding
  ➡ easier comprehension
  ➡ easier construction.
- Escape from formalism
  ➡ more information
- Is secondary notation ever bad?
  - what about the brevity bigots?
- Designers often forget that users need information beyond the “official” syntax.
  - and even try to block the escapes people use

Secondary Notation examples

- Redundant recoding
  - Telephone number layout
  - Front panel of a car radio
  - Functional grouping

0114 225 5335
or
0 11 42 25 53 35?

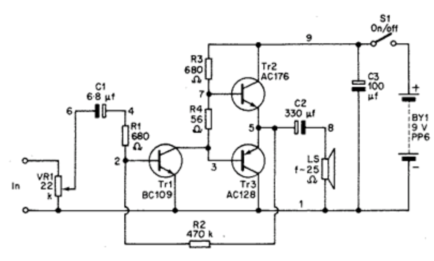
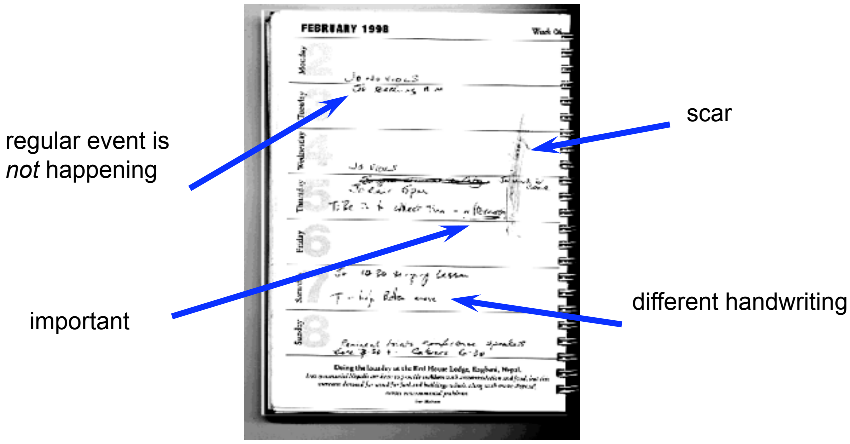


Fig. 31. The circuit diagram of a simple audio amplifier.

Secondary Notation examples

- Escape from formalism
  - Usage of calendars and diaries.



Workarounds & trade-offs

- Decoupling (if insufficient secondary notation)
  - e.g. print out hard copy, attack it with a pencil
- Enriched resources
  - e.g. tagging and annotation tools
- But extensive secondary notation introduces added viscosity (it gets out of date).
  - e.g. program comments

Visibility & Juxtaposability

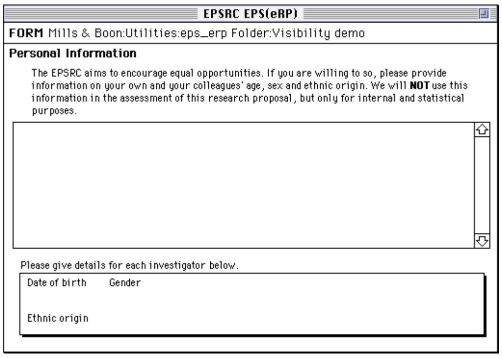
- ***Ability to view components easily & to place any two components side by side.***
- Visibility:
  - e.g. searching a telephone directory for the name of a subscriber who has a specified telephone number
- Juxtaposability:
  - e.g. trying to compare statistical graphs on different pages of a book

Visibility & Juxtaposability features

- Structure or indexing information is often invisible because designers assumed it wouldn't be needed.
- Often caused by presenting information in windows, then restricting the number of windows.
- Becomes far worse with small devices (cell-phones, PDAs, wearable computers?).

Visibility & Juxtaposability examples

- Small windows onto invisible control trees:
  - e.g. car radios, fax machines, cameras.
- Shared use displays:
  - e.g. clock-radio: time or alarm or radio station
- Form based systems:



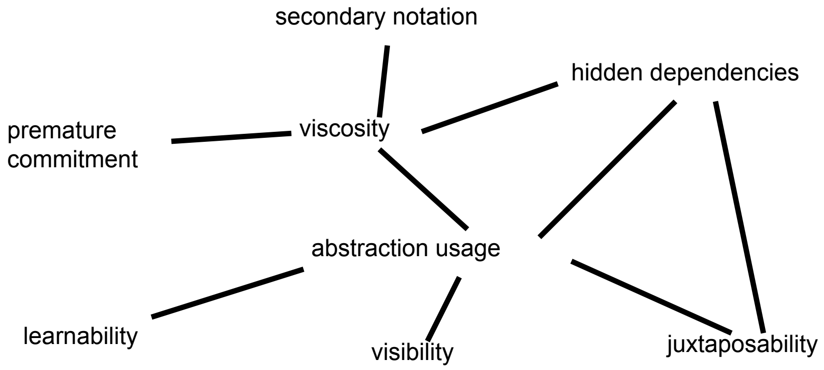
Workarounds & trade-offs

- Working memory
  - refreshed by revisiting items being compared
- External memory
  - e.g. make a hard copy of one component (a new environment that allows side-by-side viewing)
- Adding a browser
  - e.g. class browser, alternative views
- Visibility trades off against clutter, abstraction

Desirable profiles

	transcription	*incrementation*	*modification*	*exploration*
viscosity	**acceptable**	**acceptable**	**harmful**	**harmful**
hidden dependencies	**acceptable**	**acceptable**	**harmful**	**acceptable for small tasks**
premature commitment	**harmful**	**harmful**	**harmful**	**harmful**
abstraction barrier	**harmful**	**harmful**	**harmful**	**harmful**
abstraction hunger	**useful**	**useful (?)**	**useful**	**harmful**
secondary notation	**useful (?)**	**–**	**v. useful**	**v. harmful**
visibility / juxtaposability	**not vital**	**not vital**	**important**	**important**

Notable trade-offs



Some design manoeuvres

- Potential design approaches to:
  - reduce viscosity
  - improve comprehensibility
  - make premature commitment less expensive
  - remove need for lookahead
  - improve visibility

Design manoeuvres (1)

- Aim: to reduce viscosity
- Manoeuvre
  - add abstractions (so one “power command” can change many instances)
- At this cost
  - increased lookahead (to get right abstractions);
  - raises the abstraction barrier;
  - may increase dependencies among abstractions

Design manoeuvres (2)

- Aim: to improve comprehensibility
- Manoeuvre
  - allow secondary notation - let users choose placing, white space, font & colour; allow commenting
- At this cost
  - increases viscosity (because layout, colour etc not usually well catered for by environments)

Design manoeuvres (3)

- Aim: to make premature commitment less expensive
- Manoeuvre
  - reduce viscosity (so that users can easily correct their first guess)
- At this cost
  - see above, re viscosity

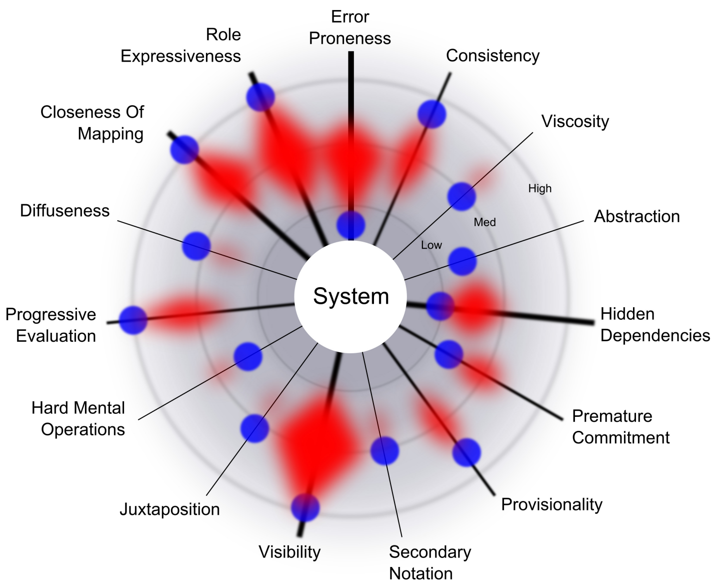
Design manoeuvres (4)

- Aim: to remove need for lookahead
- Manoeuvre
  - remove internal dependencies in the notation;
  - allow users to choose an easier decision order
- At this cost
  - may make notation diffuse, or increase errors
  - allowing free order needs a cleverer system

Design manoeuvres (5)

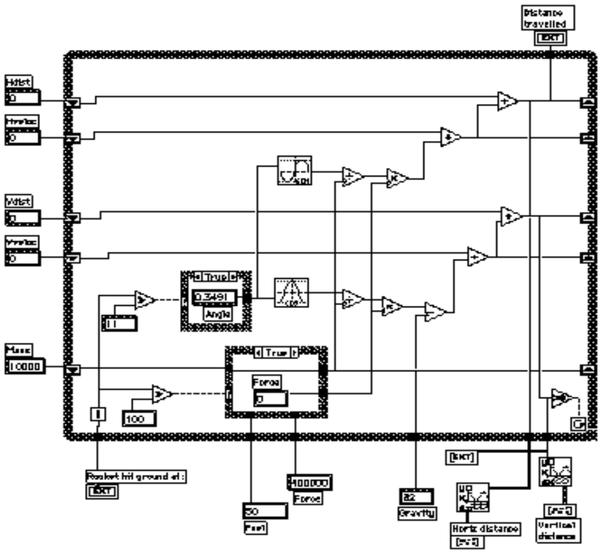
- Aim: to improve visibility
- Manoeuvre
  - add abstractions (so that the notation becomes less diffuse)
- At this cost
  - see above re abstractions

Luke Church's CD Profile Visualisation



A CASE STUDY

Example – LabView visual programming language



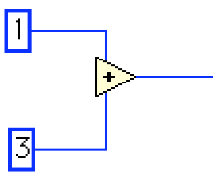
Hidden dependencies

- Visual languages make connections explicit
- But with the trade-off that they need more screen space

BASIC:

```
x = 1
... (possibly
     many
     pages of
     code here...)
y = x + 3
```

LabVIEW:

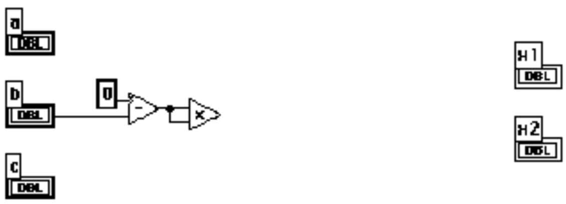


Premature commitment (1)

- Commitment to layout is a common problem e.g. x = (-b + sqr(b2 - 4ac) / 2a)
- Start with minus b …

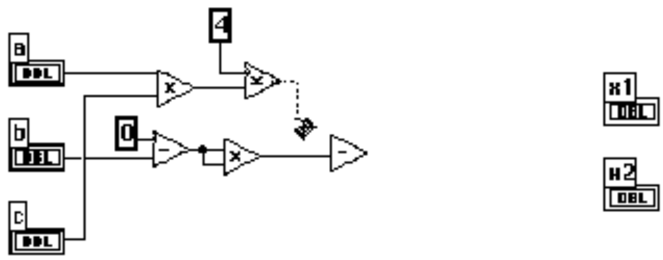
Premature commitment (2)

- … I'll need b-squared too …



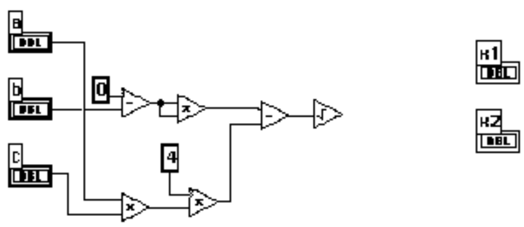
Premature commitment (3)

- … turn that into b-squared minus 4ac …



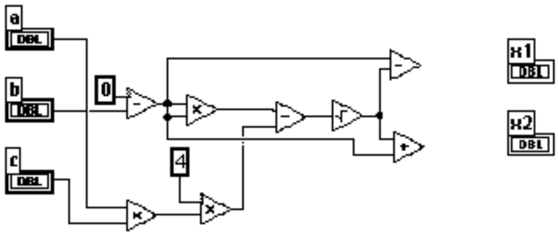
Premature commitment (4)

- … oops, that's going to be 4ac minus b-squared … try moving the 4ac chunk down and reconnecting to the 'minus' box …



Premature commitment (5)

- … OK, now I need plus or minus that …



- that's root-b-squared-minus-4ac but I still haven't used b … or the rest of the formula!

Secondary notation

- Little support for commenting
  - can only attach comment to a single item
- Spatial layout can't easily be used for grouping
- All the visual variables (degrees of freedom) are taken up by the formal syntax

Visibility & Juxtaposability

- Visibility of data flow in LabVIEW is excellent
- But control branches in LabVIEW can't be juxtaposed: