

Reasoning with Mental Images: Towards a Cognitively Adequate Computational Architecture

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Outline

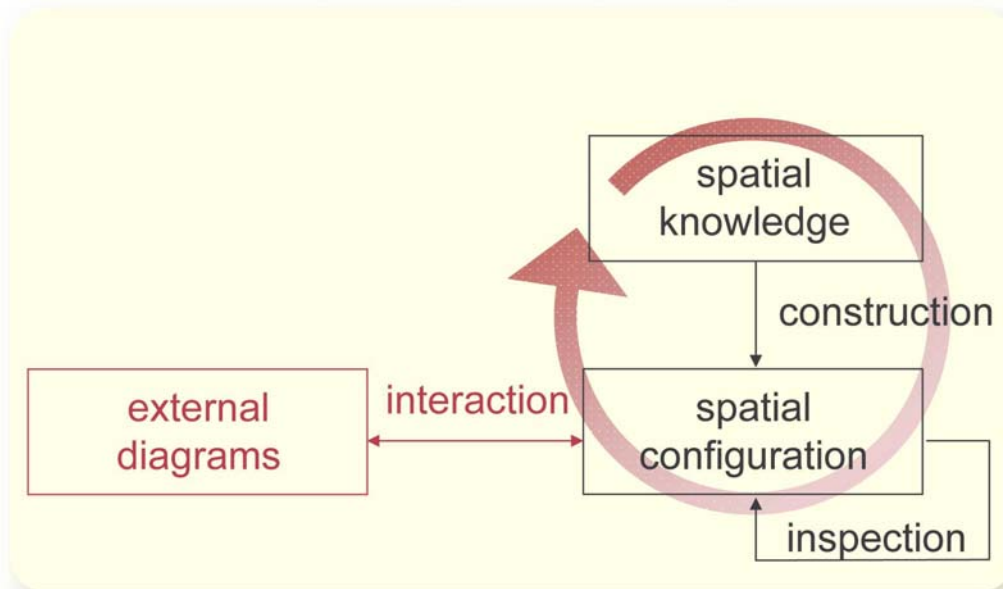


- Recap
- *Casimir*
- From psychological findings to computational structures
- Design procedure
- Format of mental images
- Flow of control
- Outlook



R1-[ImageSpace]

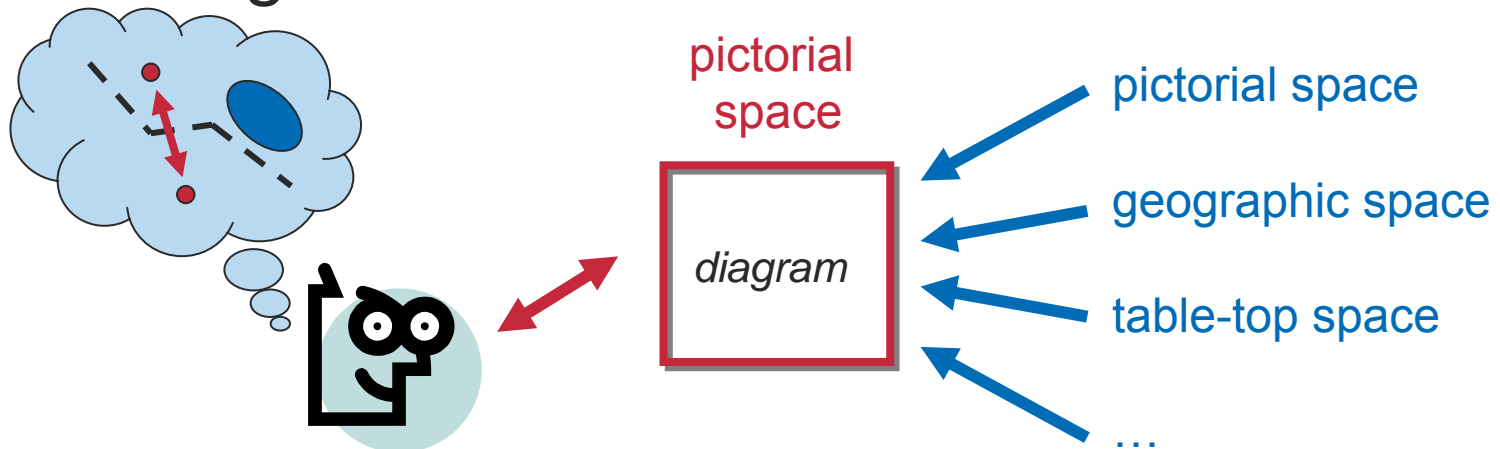
- Computational modeling and investigation of mental image-based spatial reasoning





R1-[ImageSpace]

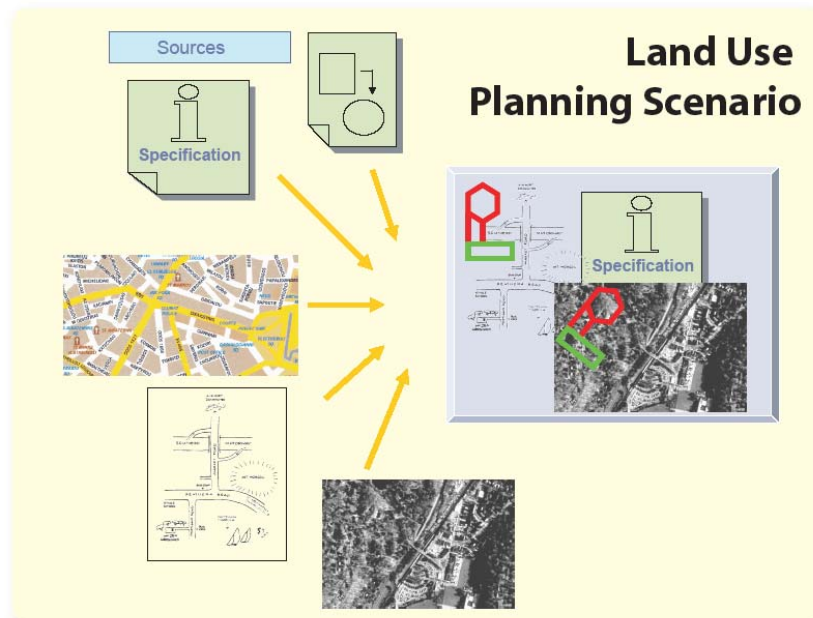
- External offloading
- Model-based assistance for spatial reasoning tasks
- Assistance with respect to limitations in WM capacities; Cooperative human-computer reasoning





R1-[ImageSpace]

- scenarios from urban and land use planning, design of functional spaces, smart office (SFB scenario)





Modeling Goals

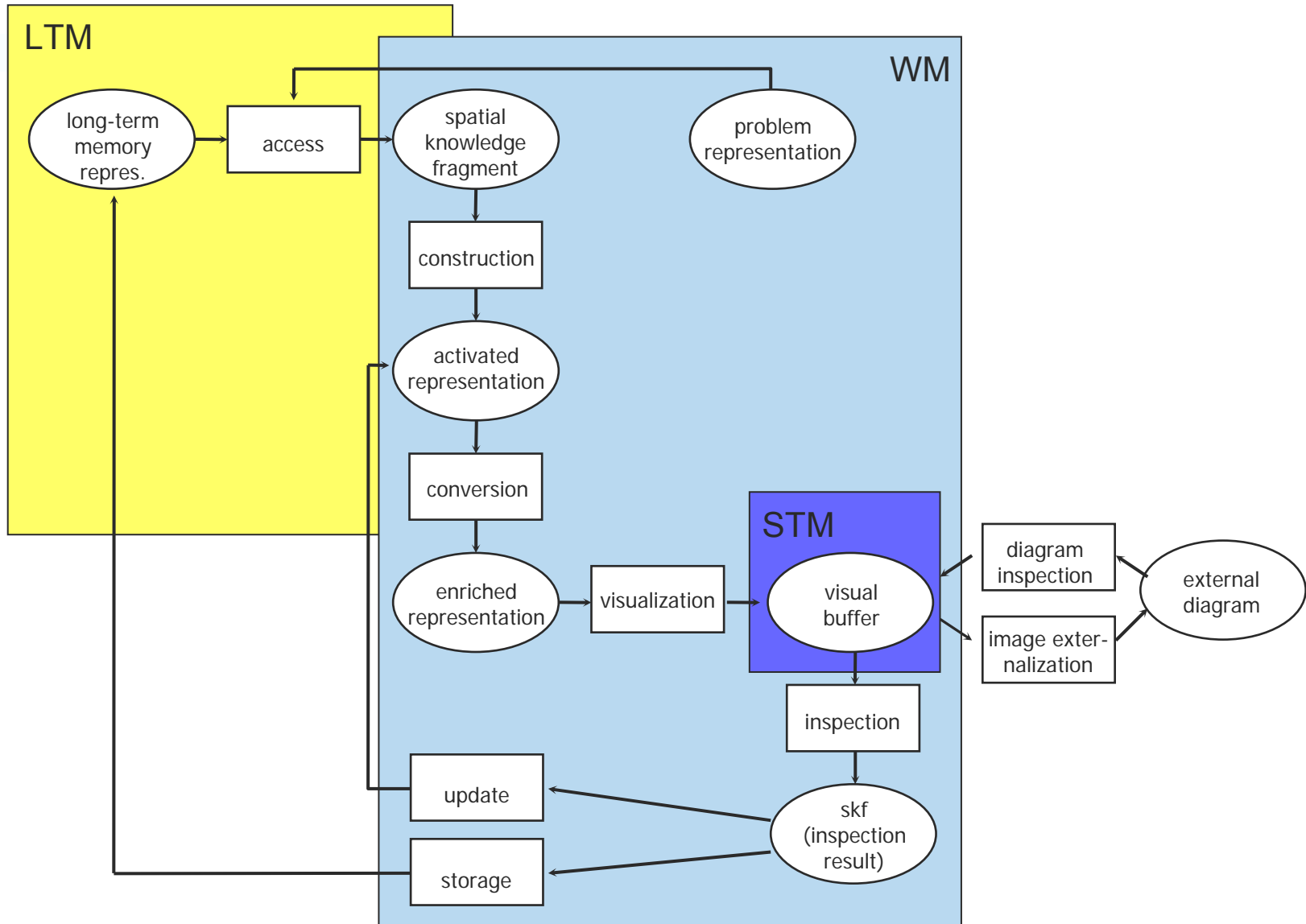
- Computational investigation of image-based mental reasoning processes
 - Identification & description of functional mental components
 - Investigate dynamic interaction between components
- Computational model
 - Identification of representation structures
 - Model of image-based mental processes

Casimir



Cognitive
architecture
Specification, and
implementation of
mental
image-based
reasoning

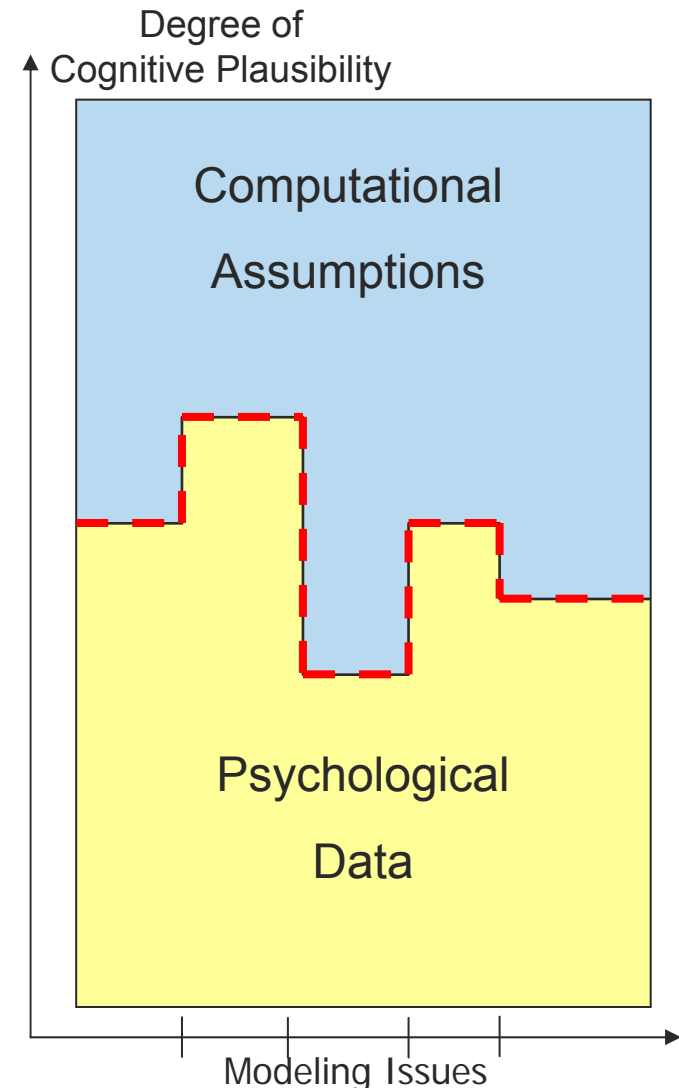
Exemplary Cycle in Casimir



From Psychological Findings to Computational Concepts



- for some issues
 - many psychological findings
 - can be well integrated into a coherent computational structure
 - for other issues
 - findings are sparse
 - less amenable to integration
 - ambiguous/contradictory
- degree of cognitive plausibility varies over different functional model components:
- close correspondence to psychological data
versus
more abstracted, interpretative structures





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- **Design Procedure**
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Design Procedure

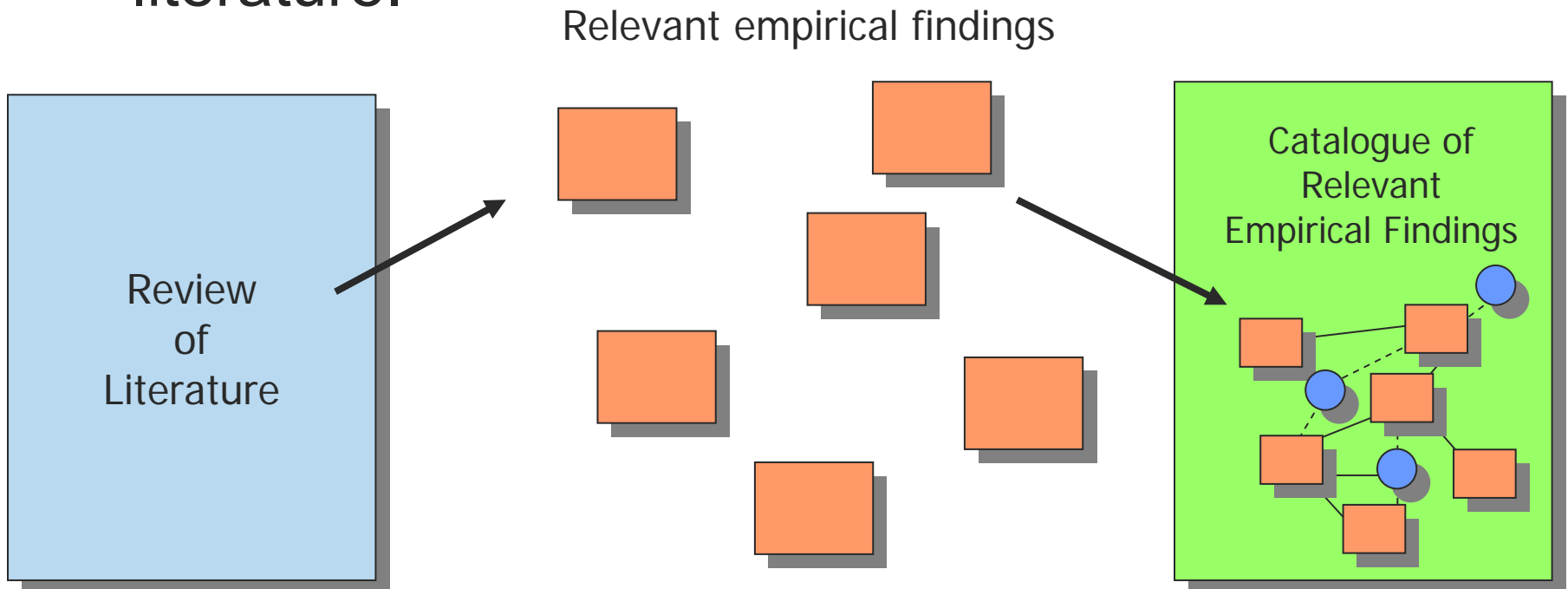


- (1) Systematic review of the relevant findings from the **psychological and cognitive science** literature.
- (2) Formulation of **functional implications**
- (3) Derivation of **basic requirements** for creating a comprehensive **computational** model
- (4) **Specification** of model parts and relations between parts
- (5) **Implementation**



Design Procedure

(1) Systematic review of the relevant findings from the **psychological and cognitive science** literature.





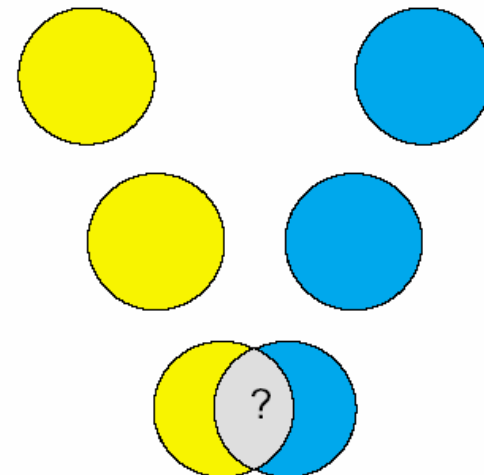
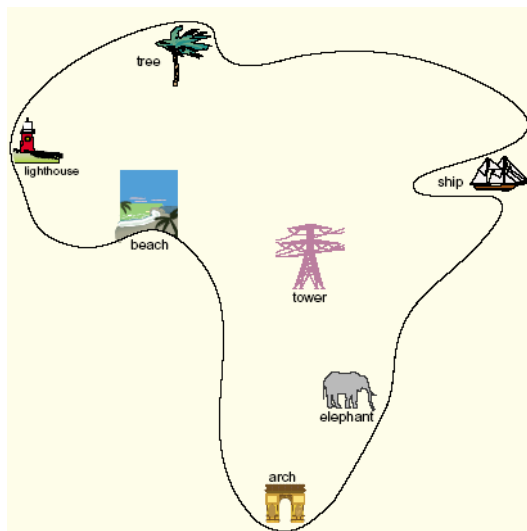
Design Procedure

- (1) Systematic review of the relevant findings from the **psychological and cognitive science** literature.
- (2) Formulation of **functional implications**
 - (2a) the representational format of mental images, and
 - (2b) the mental processes and functions involved.
- (3) Derivation of **basic requirements** for creating a comprehensive **computational** model
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The Format of Mental Images (2a)

- analogical representation
- pictorial vs. propositional format
- some imagery tasks may be solved visually, whereas others may be solved non-visually (e.g. involving basic spatial configurations)



The Format of Mental Images (2a)



- Functional overlap between perception- and imagery systems
 - close functional coupling
more overlap with later perceptual stages
 - partial dissociation
e.g. in structural reinterpretation

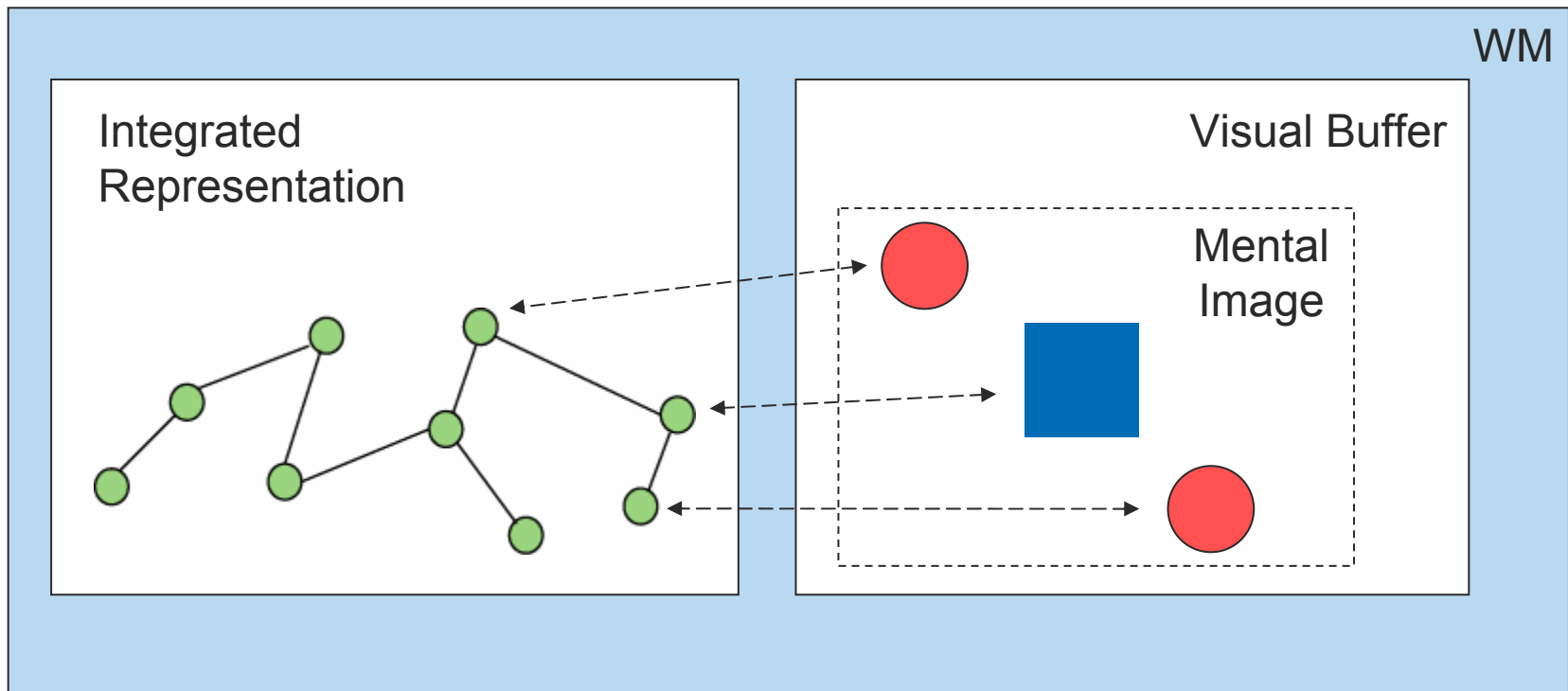


- continuous scale of gradually blended subsystems
- In some respect like pictures, in other respects different



Structural Correspondence

- Correspondence to entities in integrated representation



Mental Processes Involved in Mental Imagery (2b)



- memory activation
- image generation, transformation, maintenance, inspection
- storage
- externalization, external diagram inspection
- executive processes
- binding and release of knowledge fragments in mental models
- ...



Flow of Control

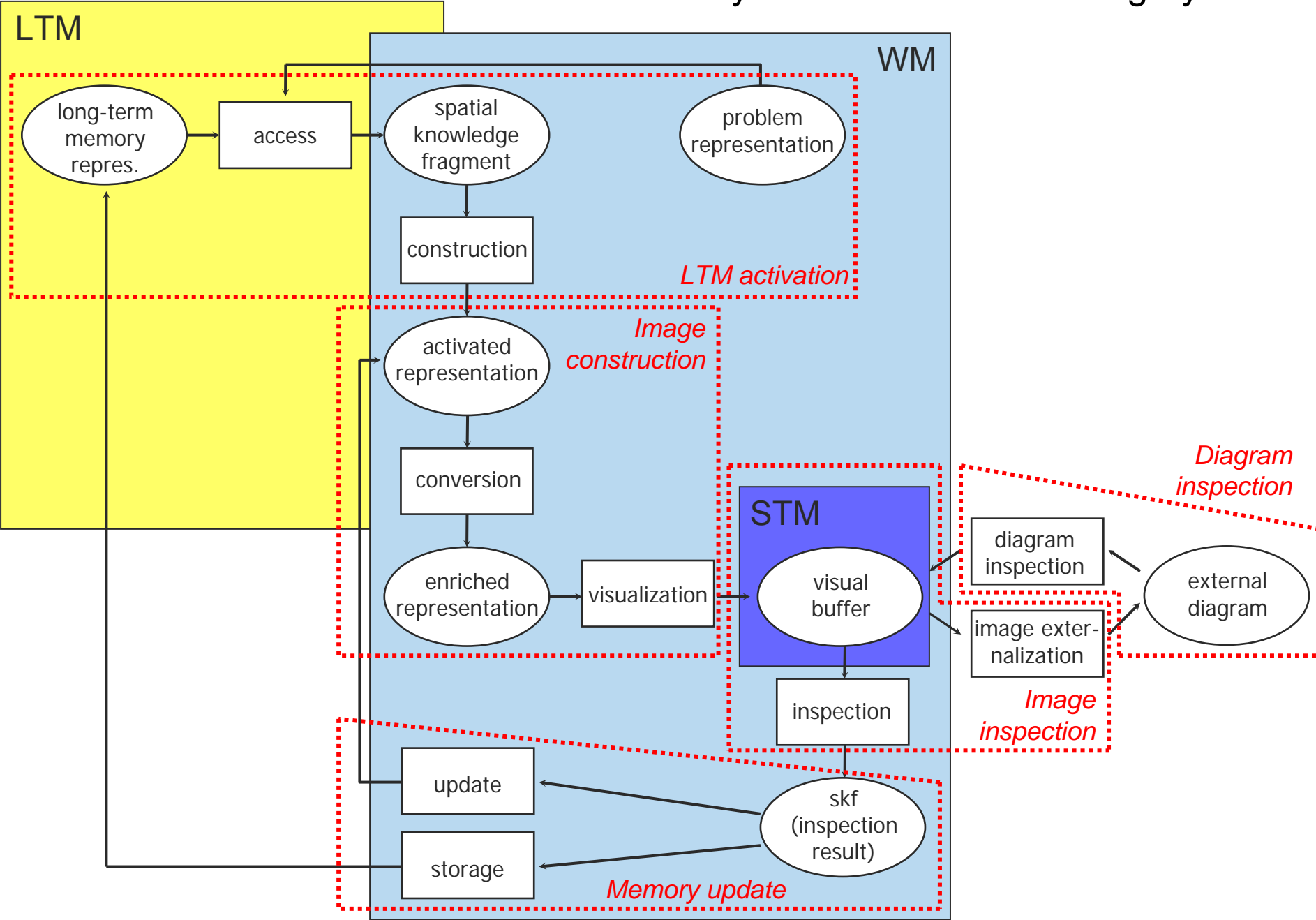
- Functional Implications derived from Psychological Findings
 - Executive processes (but no “central executive”)
 - Distributed systems (functional and neural)
 - Global flow of control results from local goals
 - Dynamic collaboration between components
 - Close relation to resource management
 - Interference (dual-task experiments)



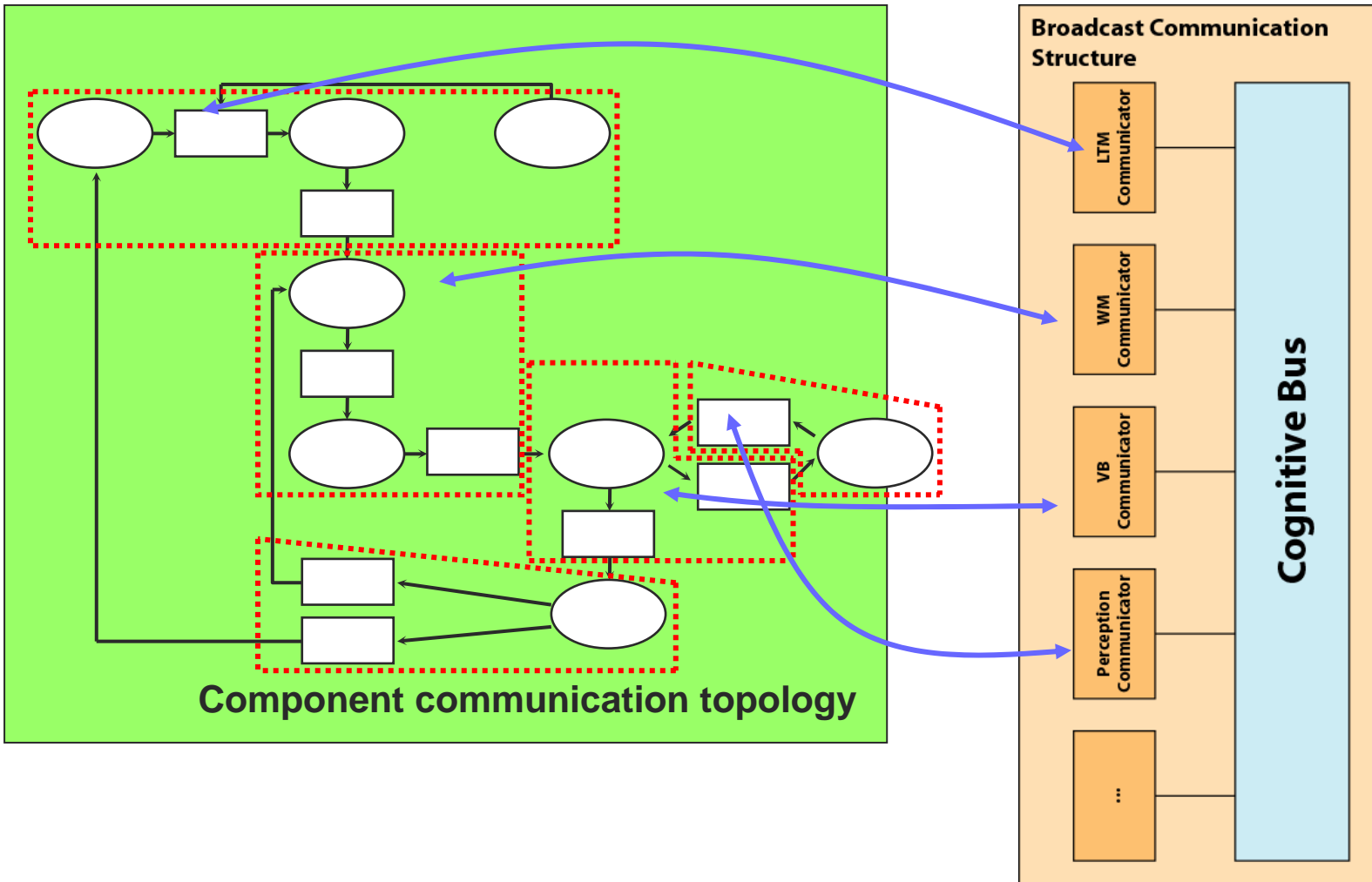
Design Procedure

- (1) Systematic review of the relevant findings from the **psychological and cognitive science** literature.
- (2) Formulation of **functional implications**
- (3) Derivation of **basic requirements** for creating a comprehensive **computational** model, specifically regarding
 - (3a) different processing pathways,
 - (3b) principal subsystems,
 - (3c) general control structures.
- (4) **Specification** of model parts and relations between parts
- (5) **Implementation**

Postulated Subsystems for a Mental Imagery Model



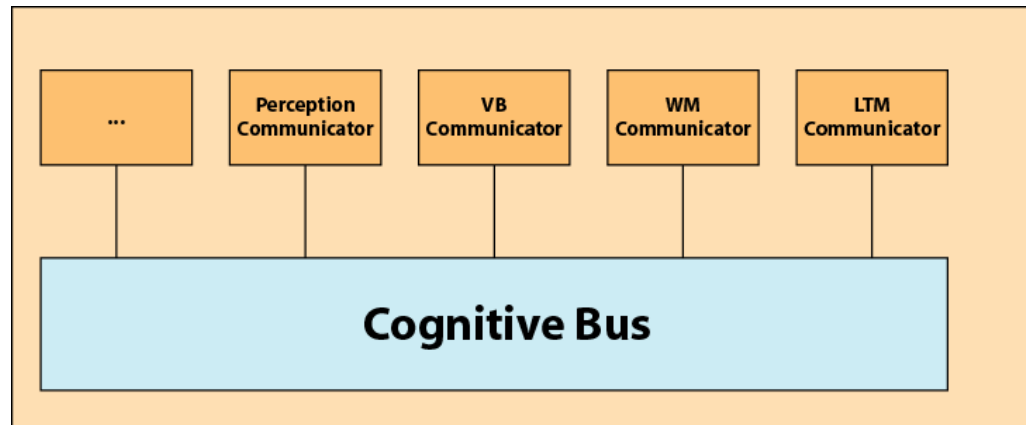
Control Flow



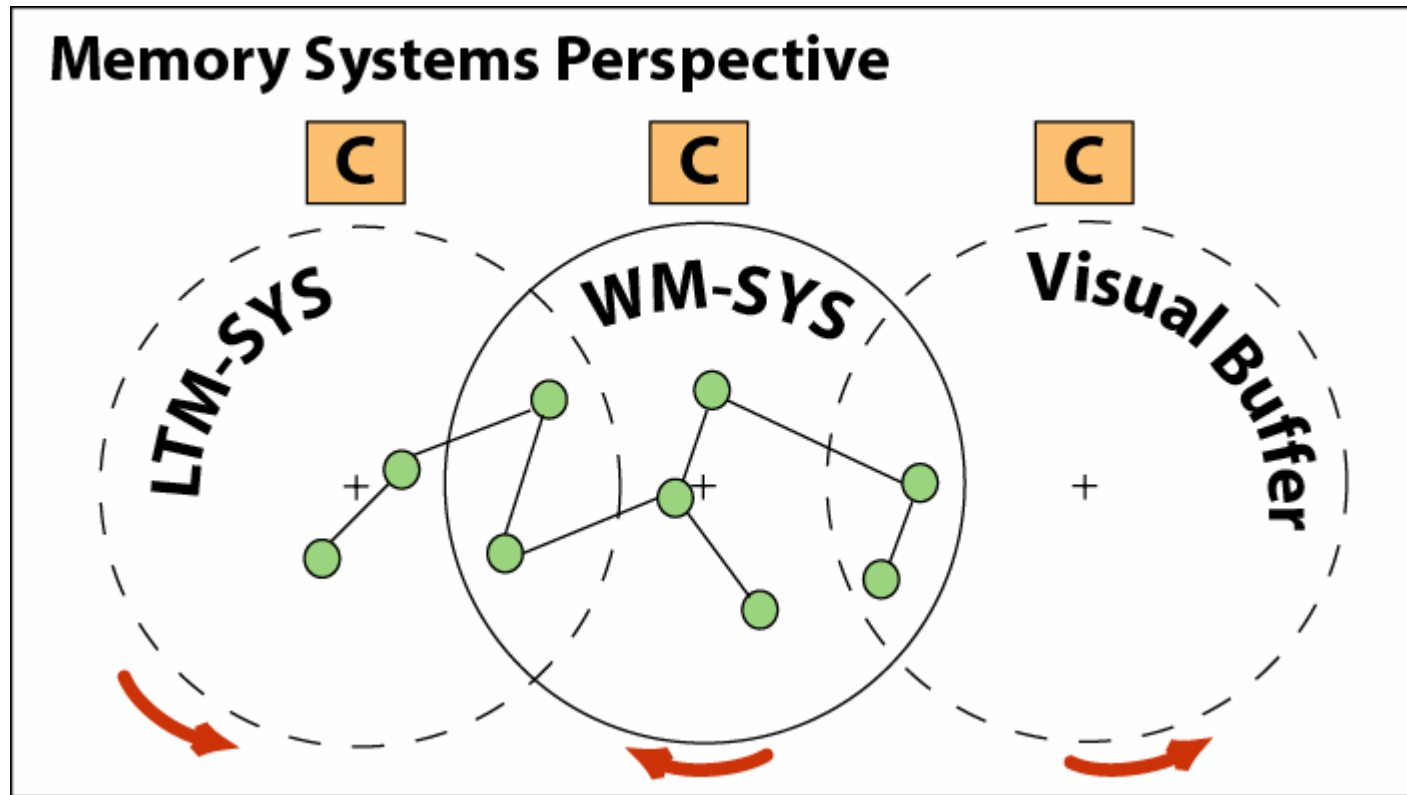


Cognitive Bus

- Functionally abstracted, integrative computational structure
- Comprises a set of computational assumptions



“Data Transfer”





Design Procedure

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 - (4a) functional aspects and
 - (4b) representational aspects
- (5) **Implementation**

Specification



- Distinction between
 - Representation Structures
 - Representations
 - Processes
 - (Sub)systems

Basic Computational Concepts

collage-container^{ρσ}

place^{ρσ}

collage^ρ

collage fragment^ρ

form^{ρσ}

collage fragment chunk^ρ

chunk-entity-association-container^{ρσ}

chunk-entity-association^ρ

mental image^ρ

visual buffer^σ (VB^σ)

entity^ρ

spatial concept^ρ

n-ary spatial relation^ρ

spatial knowledge fragment^ρ (SKF^ρ)

integrated representation^ρ

activated representation^ρ

LTMframe^{ρσ}

LTMsys^σ

aLTMframe^{ρσ}

WMframe^{ρσ}

WMcore^σ

WMsys^σ

mental model^ρ (MM^ρ)

visual mental model^ρ (VMM^ρ)

WM manager^σ (WMman^σ)

LTM manager^σ (LTMman^σ)

working memory^Σ (WM^Σ)

long-term memory^Σ (LTM^Σ)

cognitive bus^σ (CogBus^σ)

subsystem-subsystem-association-container^{ρσ}

subsystem-subsystem-association^ρ

...

a spatio-analogical representation structure

a structure that is part of the collage-container^{ρσ}; can hold collage fragments^ρ

the representation held on the collage-container^{ρσ}

figural part of a collage^ρ

a structure that holds collage fragment chunks^ρ

is an association of a set of collage fragments^ρ

a structure that holds a chunk-entity-association^ρ

a representation that comprises an association of a collage fragment chunk^ρ and an entity^ρ

a representation comprised of a collage^ρ and collage fragment chunks^ρ

a cognitive subsystem that comprises the collage-container^{ρσ} and forms^{ρσ}, and processes^π that operate on them

a basic mental representation [e.g. related to objects in the universe of discourse]

a basic mental representation [e.g. described by spatial models in the universe of discourse]

a mental representation that consists of a spatial concept^ρ that spans n entities^ρ

an association of n entities^ρ and an n-ary spatial relation^ρ

a representation that comprises one or more SKF^ρs such that each SKF^ρ is directly or by transitivity associated with each other SKF^ρ

is an integrated representation^ρ [see aLTMframe^{ρσ}]

a structure that holds integrated representations^ρ

is a cognitive subsystem that comprises LTMframes^{ρσ} and processes^π that operate on them

a joint part of a LTMframe^{ρσ} and a WMframe^{ρσ}; it holds activated representations^ρ

a structure that can comprise integrated representations^ρ

a cognitive subsystem that comprises WMframes^{ρσ} and processes^π that operate on them

a cognitive subsystem that comprises the VB^σ, the WMcore^σ, chunk-entity-association-containers^{ρσ}, and processes^π that operate on these

is a representation in WMcore^σ that comprises integrated representations^ρ

is a representation in WMsys^σ that comprises a mental model^ρ *M*, a mental image^ρ *I*, and a set of chunk-entity-associations^ρ *A*, such that for each entity^ρ and collage fragment chunk^ρ in each chunk-entity-association^ρ of *A* there exist an entity^ρ in *M* and a collage fragment chunk^ρ in *I*.

a cognitive subsystem that comprises processes^π that operate on WMsys^σ and CogBus^σ

a cognitive subsystem that comprises processes^π that operate on LTMsys^σ and CogBus^σ

a cognitive system that comprises WMsys^σ and WMman^σ

a cognitive system that comprises LTMsys^σ and LTMman^σ

a cognitive subsystem that comprises subsystem-subsystem-association-containers^{ρσ} and processes^π that operate on these

a structure that holds a subsystem-subsystem-association^ρ

a representation that comprises an association of two subsystems

...

Basic Computational Concepts

collage-container^{pσ}
place^{pσ}

a spatio-analogical representation structure
a structure that is part of the collage-container^{pσ}; can hold collage fragments^p

collage fragment ^p	figural part of a collage ^p
form ^{pσ}	a structure that holds collage fragment chunks ^p
collage fragment chunk ^p	is an association of a set of collage fragments ^p
chunk-entity-association-container ^{pσ}	a structure that holds a chunk-entity-association ^p
chunk-entity-association ^p	a representation that comprises an association of a collage fragment chunk ^p and an entity ^p
mental image ^p	a representation comprised of a collage ^p and collage fragment chunks ^p
visual buffer ^σ (VB ^σ)	a cognitive subsystem that comprises the collage-container ^{pσ} and forms ^{pσ} , and processes ^π that operate on them

visual mental model^p (VMM^p)

is a representation in WMsys^σ that comprises a mental model^p M , a mental image^p I , and a set of chunk-entity-associations^p A , such that for each entity^p and collage fragment chunk^p in each chunk-entity-association^p of A there exist an entity^p in M and a collage fragment chunk^p in I .

WM manager^σ (WMman^σ)

a cognitive subsystem that comprises processes^π that operate on WMsys^σ and CogBus^σ

LTM manager^σ (LTMman^σ)

a cognitive subsystem that comprises processes^π that operate on LTMsys^σ and CogBus^σ

working memory^Σ (WM^Σ)

a cognitive system that comprises WMsys^σ and WMman^σ

long-term memory^Σ (LTM^Σ)

a cognitive system that comprises LTMsys^σ and LTMman^σ

cognitive bus^σ (CogBus^σ)

a cognitive subsystem that comprises subsystem-subsystem-association-containers^{pσ} and processes^π that operate on these

subsystem-subsystem-association-container^{pσ}

a structure that holds a subsystem-subsystem-association^p

subsystem-subsystem-association^p

a representation that comprises an association of two subsystems

...

...



Specification

- iterative refinement
 - in-depth specification of concepts
 - commitment to interpretations
 - further formalization
- towards implementation



Design Procedure

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THANK YOU!

INTERNATIONALES QUALITÄTSNETZWERK

Spatial Cognition Research Center

Vortrag im Rahmen des SFB/IQN-Kolloquium Bremen:

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Universität Bremen

Reasoning with Mental Images: Towards a Cognitively Adequate Computational Architecture

Computational modelling of cognitive processes, based on psychological findings, necessarily has to make systematic assumptions in the modelling process: for some issues many psychological findings exist that can be well integrated into a coherent computational structure; for other issues, empirical findings may be sparse or less amenable to an integration into comprehensive computational theories. As a result, the degree of cognitive plausibility varies over different functional model components. Some components may be modelled in close correspondence to psychological data, whereas other components necessarily form a more abstracted, interpretative structure, possibly also incorporating a whole range of computational assumptions.

Against this background, we will present a number of design procedures for creating a specific computational architecture for reasoning with mental images: *Casimir*, the model developed in [R1-ImageSpace]. This involves the definition of basic functional and computational structures as well as the conception of more complex cognitive systems that serve as modular abstractions. It will also be shown how the essential design process can be put to work in an application perspective of mental model-based assistance in diagram-based spatial design.

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Zeit und Ort:

Freitag, 18. Juni 2004
informelle Kaffeerunde: 15:00h
Vortragsbeginn: 15:30h
MZH 5300, Bibliothekstr. 1
Universität Bremen

<http://www.cosy.informatik.uni-bremen.de/iqn/events/>