



MULTIPLE ALIGNMENT AS THE “DOUBLE HELIX” OF INTELLIGENCE

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SUMMARY

- Information compression as a **unifying theme** in human intelligence, computing, and mathematics.
- **Multiple alignment** as the key concept in the **SP theory of intelligence** and the **SP computer model**.
- Simplification and integration across several areas of perception, learning, and thinking.
- Potential benefits and applications.
- Development of a **high-parallel SP machine**.

THE TURING MACHINE AS A UNIFYING THEORY?

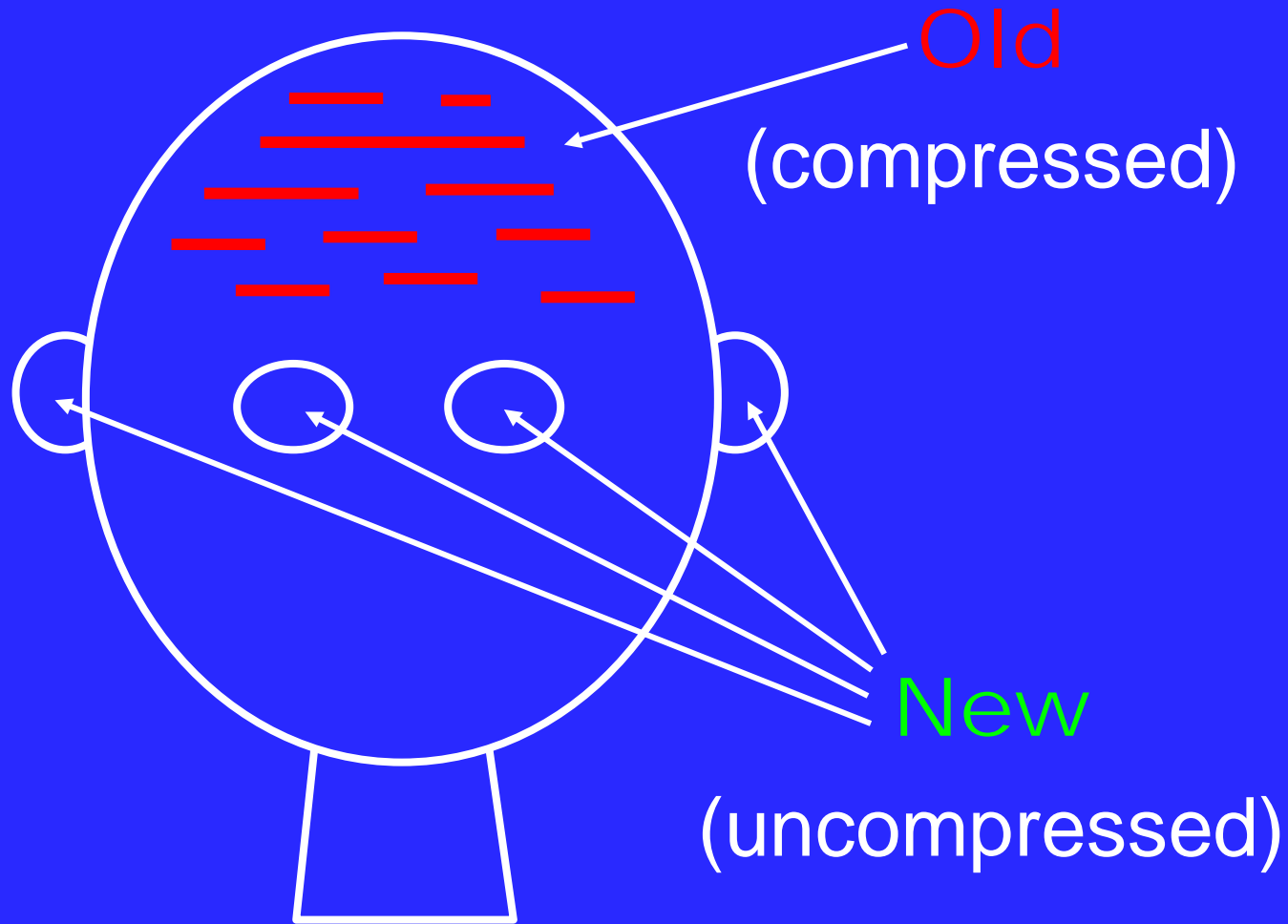
- The Turing model has been brilliantly successful but does not solve the problem of **fragmentation** in artificial intelligence and mainstream computing.
- Alan Turing saw that computers might become intelligent (Turing, 1950), **but the Turing model, in itself, does not tell us how!**
- The SP theory aims to plug the gap.



BACKGROUND

- Information compression in brains and nervous systems (Fred Attneave, Horace Barlow, and others).
- Models of language learning: compression of information via the matching and unification of patterns.
- Principles of minimum-length encoding (Solomonoff and others).
- Several observations point to the importance of information compression in computing, mathematics, and logic.

OVERALL ORGANISATION OF THE SP SYSTEM



ELEMENTS OF THE SP THEORY

- All knowledge is expressed as **patterns**—arrays of atomic symbols in one or two dimensions.
- All processing is done by **compression of information**:
 - Via the **matching and unification** of patterns.
 - More specifically, via the building of **multiple alignments**.
- **Probabilities** may be calculated for multiple alignments and inferences from multiple alignments.
- The SP theory is realised in the **SP71** computer model.
- SP patterns may be realised in **SP-neural**: a modified version of Donald Hebb's **cell assembly** concept.

MULTIPLE ALIGNMENT: A CONCEPT BORROWED FROM BIOINFORMATICS

```
      G G A      G      C A G G G A G G A      T G      G      G G A
      | | |      |      | | | | | | | | | |      | |      |      | | |
      G G | G      G C C C A G G G A G G A      | G G C G      G G A
      | | |      | | | | | | | | | | | |      | |      |      | | |
A | G A C T G C C C A G G G | G G | G C T G      G A | G A
      | | |      | | | | | | | | | |      | |      |      | | |
      G G A A      | A G G G A G G A      | A G      G      G G A
      | | |      | | | | | | | | | |      | |      |      | | |
      G G C A      C A G G G A G G      C      G      G      G G A
```


MULTIPLE ALIGNMENT IN THE SP THEORY

- The system aims to find multiple alignments that enable a **New** pattern to be encoded economically in terms of one or more **Old** patterns.
- Multiple alignment provides the key to:
 - **Versatility** in the representation of different kinds of knowledge.
 - **Versatility** in different kinds of processing in AI and mainstream computing.
- Some of that versatility can be seen in the three slides that follow. **These examples are output from the SP computer model.**

0				t w o				k i t t e n s				p l a y	0			
1							< Nr 5	k i t t e n >					1			
2						< N Np	< Nr		> s >				2			
3				< D Dp 4	t w o >								3			
4				< NP	< D		>	< N					4			
5												< Vr 1	p l a y >	5		
6												< V Vp	< Vr	> >	6	
7	< S Num			;	< NP							>	< V		> >	7
8	Num PL			;					Np				Vp			8

(a)

0			t	o					k	i	t	t	e		m	s				p	l	a	x	y	0
1								< Nr	5	k	i	t	t	e	n	>									1
2					< N	Np	< Nr								>	s	>							2	
3					< D	Dp	4	t	w	o	>													3	
4					< NP	< D					>	< N							>	>				4	
5																									
6																									
7	< S	Num		;	< NP														>	< V	Vp	< Vr		>	>
8	Num	PL		;			Np																		8

(b)

```

0          1          2          3          4
                                                T
                                                Tibs
                                                C ----- C
                                                cat
M ----- M
mammal
A ----- A
animal
head ----- head
carnassial-teeth
#head ----- #head
body ----- body
white-bib ----- white-bib
#body ----- #body
legs ----- legs
retractile-claws
#legs ----- #legs
eats ----- eats
breathes
has-senses
...
#A ----- #A
furry ----- furry
warm-blooded
...
#M ----- #M
purrs ----- purrs
...
#C ----- #C
tabby
...
#T

0          1          2          3          4

```

0	1	2	3
car_not_start	- car_not_start		
	cns0		
	no_fuel	----- no_fuel	
		nf1	
		blocked_fuel_line	- blocked_fuel_line
			bf11
			faulty_valve

0	1	2	3
---	---	---	---

(a)

0	1	2	3
car_not_start	- car_not_start		
	cns1		
	no_spark	----- no_spark	
		nsp1	
		battery_flat	- battery_flat
			bf1
			short_circuit

0	1	2	3
---	---	---	---

(b)

HIGH-LEVEL BENEFITS OF THE SP THEORY

- Conceptual **simplicity** combined with descriptive and explanatory **power** across several aspects of intelligence.
- **Simplification** of computing systems, including software.
- **Deeper insights** and **better solutions** in several areas of application.
- Seamless **integration** of structures and functions within and between different areas of application.



DESCRIPTIVE AND EXPLANATORY POWER

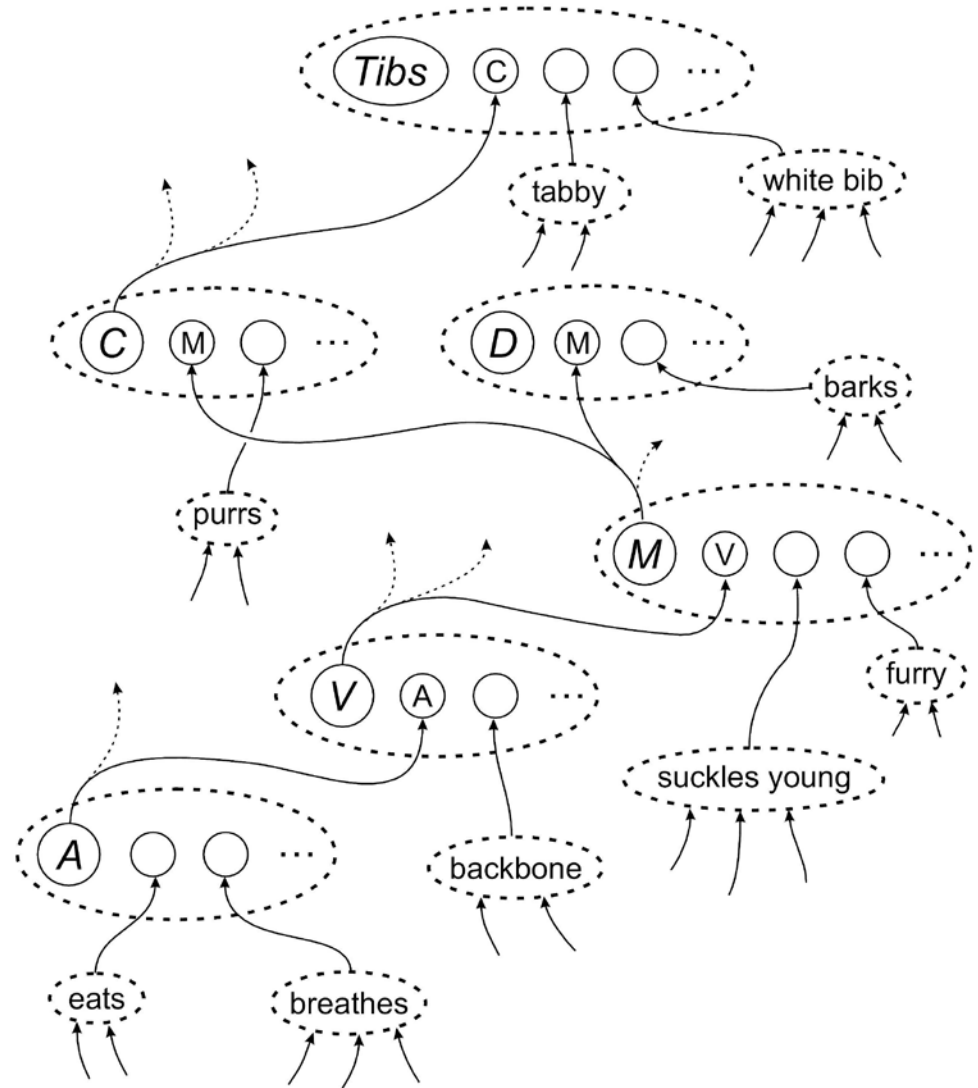
- A new concept of 'computing'.
- Representation of knowledge.
- Natural language processing.
- Pattern recognition.
- Information storage and retrieval.
- Several kinds of reasoning.
- Unsupervised learning.
- Planning and problem solving.
- Information compression.
- Human perception and cognition.

SP-neural:

SP patterns may be realised in a modified version of Hebb's cell assembly concept.

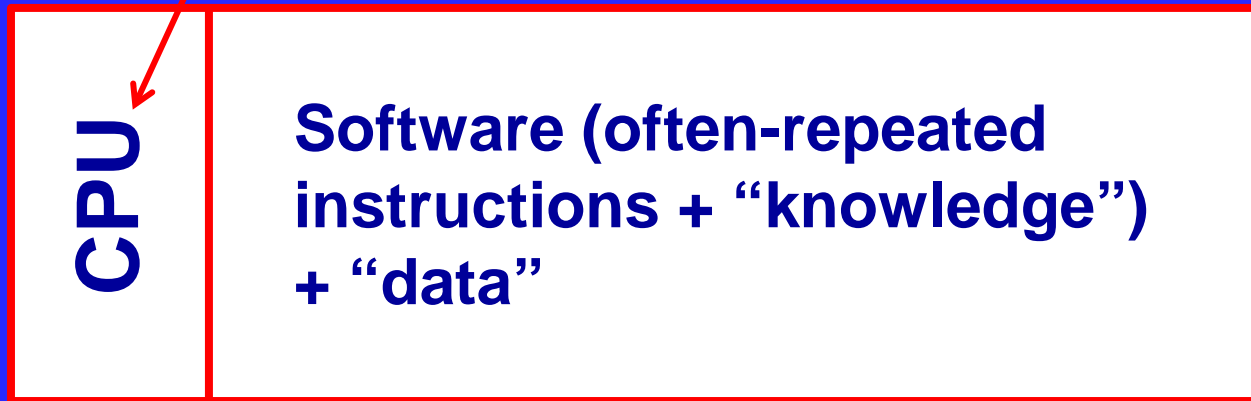
Key:

- 'C' = cat,
- 'D' = dog,
- 'M' = mammal,
- 'V' = vertebrate,
- 'A' = animal

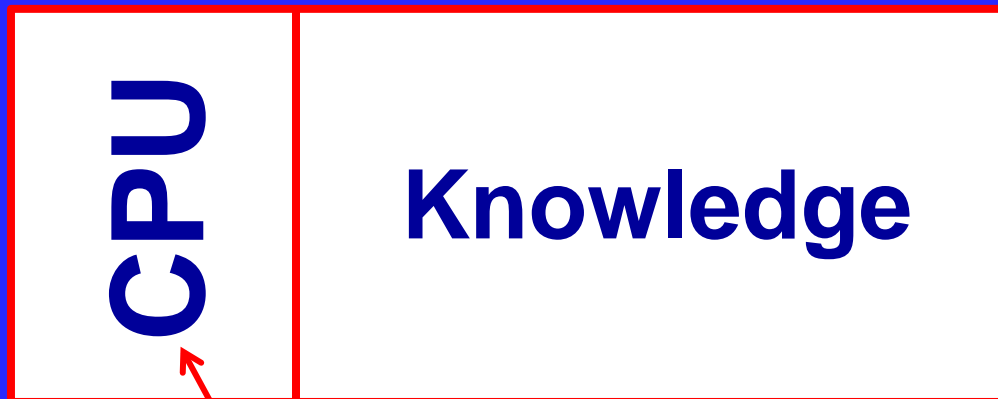


SIMPLIFICATION OF COMPUTING SYSTEMS

Without 'intelligence'



Conventional
computer



SP machine

With 'intelligence'

DEEPER INSIGHTS AND BETTER SOLUTIONS IN SEVERAL AREAS OF APPLICATION

- Natural language processing.
- Autonomous robots.
- Pattern recognition and computer vision.
- Several kinds of reasoning.
- Big data.
- The semantic web.
- Economical transmission of data.
- Data fusion.
- Bioinformatics.
- And more.

INTEGRATION

Probably the single most important benefit is:

Seamless *integration* of structures and functions within and between different areas of application.

PROPOSAL: THE DEVELOPMENT OF A HIGH-PARALLEL, OPEN-SOURCE, SP MACHINE

- Based on the SP computer model.
- Built as a software virtual machine, with high-parallel search mechanisms.
- Hosted on an existing high-performance computer.
- An open-source model, available, via the web, to researchers everywhere.
- A means for researchers to see what can be done with the system and to create new versions of it.

SP theory and SP computer model



High-parallel
Web-based

SP MACHINE

Open-source
Good user interface

Representation of knowledge

Natural language processing

Several kinds of reasoning

Planning & problem solving

Information compression

Unsupervised learning

Pattern recognition

Information retrieval

MANY APPLICATIONS



FURTHER INFORMATION

- Book: *Unifying Computing and Cognition*, CognitionResearch.org.
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