

Intelligent Processing and Applications

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Lecture Contents:-

Computational Intelligence (CI)

Human Computer Interface (HCI)

Intelligent Image Processing (IIP)

Content Based Image Retrieval(CBIR)

Intelligent Computing (IC=CI)

- The notion of artificial intelligence in computing started with attempts at **replicating the human ways of reasoning in computing.**

To classify a device as “intelligent,” it should necessarily satisfy the following requirements:-

1. Learning/adapting: It should be able to learn from the environment it is working in.
2. Decision making/classification: It should be able to make decisions relevant to the environment it is deployed in, on new and unknown inputs.

What is computational intelligence all about?

- Many engineering and scientific problems may be solved by using numerical algorithms; theory is known, equations formulated, either analytical or numerical solutions are required.

Such problems require high-performance computing, but no intelligence: just press the key and wait for an answer.

- Other problems may be easily formulated, but all algorithms solving them may be NP hard, requiring almost infinite amount of computations to solve complex cases.
- Yet other problems have no algorithms at all!
- **Problems, for which effective algorithms cannot be formulated require intelligence to solve them.**

Some non-algorithmizable problems

(these require CI)

- Understanding meaning of sentences (queries), all problems related to natural language analysis.
- Perception: recognition of signals, phoneme recognition, olfactory(smell) signals – first step in robotics.
- Visual perception: face recognition, object recognition and many computer vision problems.
- Hand-written characters recognition for PDAs or security.
- Control and planning problems in robotics and control of non-linear complex systems with many degrees of freedom.
- Medical diagnostics, interpretation of medical images and biomedical signals (EEG, ECG ...), therapy planning.
- Playing complex games, like strategic war games.
- Solving untypical problems, or problems requiring creativity.

Advanced Intelligent Computing Theories and Applications (Book) by De Shuang Huang et.al, Springer,2008

Contents :

1. Evolutionary computing and Genetic algorithm
2. Knowledge discovery and Data Mining
3. Methods of computing optimization
4. Fuzzy systems and soft computing
5. Intelligent computing in pattern recognition
6. Intelligent computing in Bio-I informatics
7. Intelligent control and automation
8. Intelligent fault diagnosis
9. Intelligent computing in communication
10. Intelligent sensor networks
11. Intelligent image retrievals
12. Intelligent Power Grids

INTELLIGENT IMAGE PROCESSING

- The topics include under

Intelligent techniques :

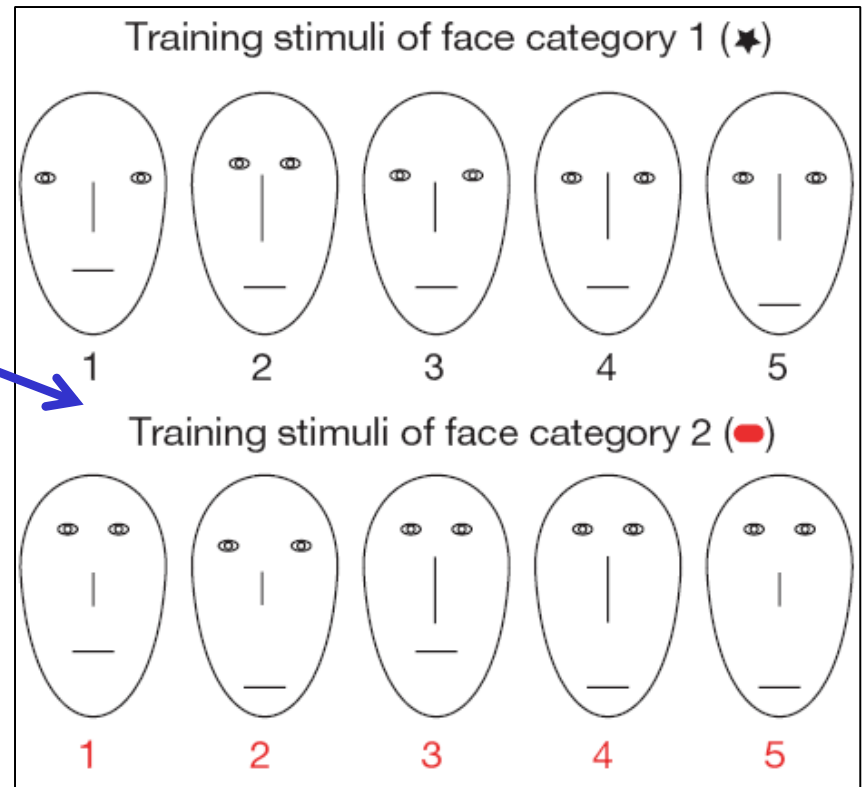
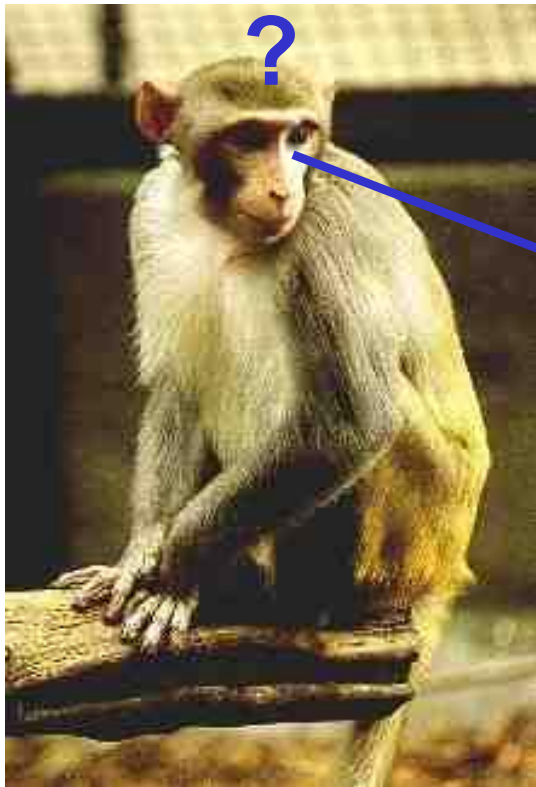
- Fuzzy logic
 - Evolutionary computation
 - Swarm intelligence
 - Bio-inspired computing
 - Neural networks
 - Probabilistic reasoning
 - Machine learning
 - Rough sets and near sets
- in:**
- Image filtering
 - Video processing/tracking
 - image restoration
 - Computer vision
 - Computer vision
 - Image segmentation
 - Feature extraction
 - Image registration
 - Image classification
 - Image coding/transmission
 - Pattern recognition
 - Biometrics
 - Document analysis
 - 3D processing
 - Medical imaging
 - Real World Applications

The practical applications of Intelligence can be seen to span the following areas.

1. **Feature extraction:** Extracting specific features of interest for the domain of application. Minimum Features--humans/ animals constantly do this.
2. **Cognition or understanding:** To make “sense” of unknown data (after training) when presented
3. **Adaptive technologies:** Technologies that can respond to changing environments
4. **Optimization problems:** Optimizing complex problems
5. **Data mining:** Making sense of and identifying trending patterns, interpreting or selecting relevant information from huge volumes of data----Web mining

Motivational example from Biology [1]

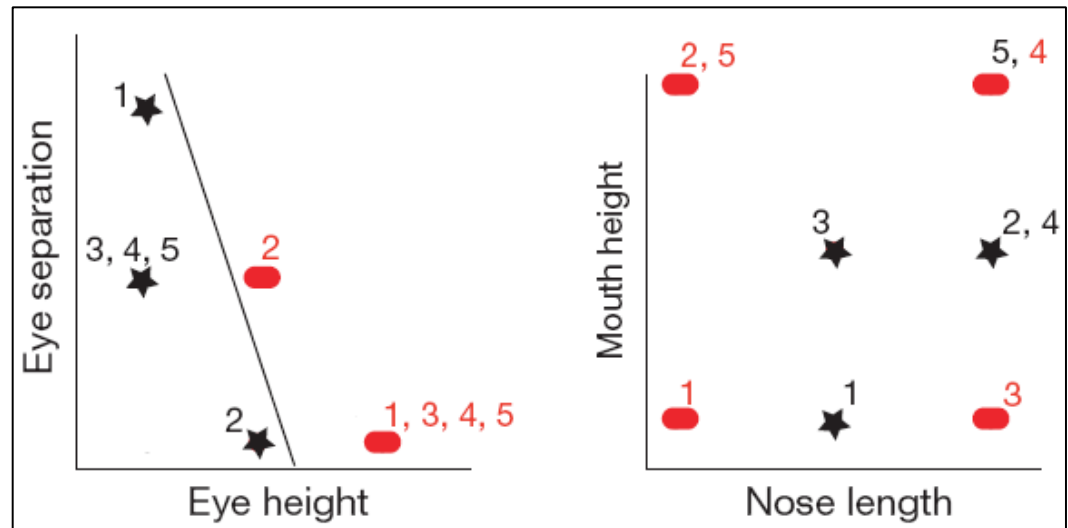
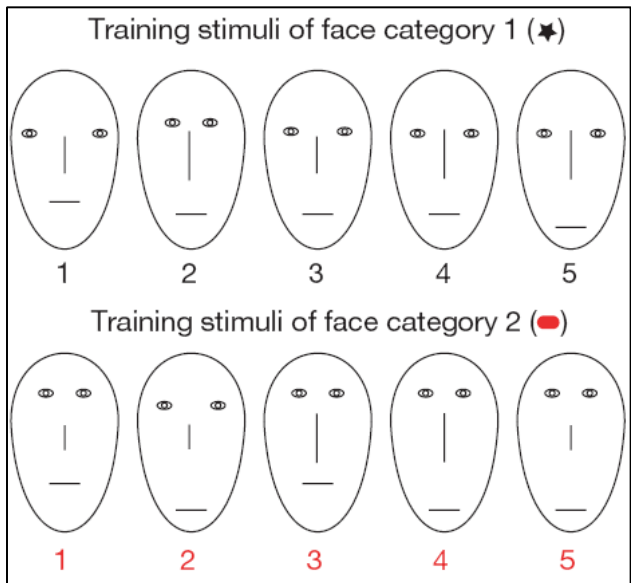
Monkeys performing classification task



[1] Nathasha Sigala, Nikos Logothetis: Visual categorization shapes feature selectivity in the primate visual cortex. *Nature* Vol. 415(2002)

Motivational example from Biology

Monkeys performing classification task



Diagnostic features:

- Eye separation
- Eye height

Non-Diagnostic features:

- Mouth height
- Nose length

Motivational example from Biology

Monkeys performing classification task

Results:

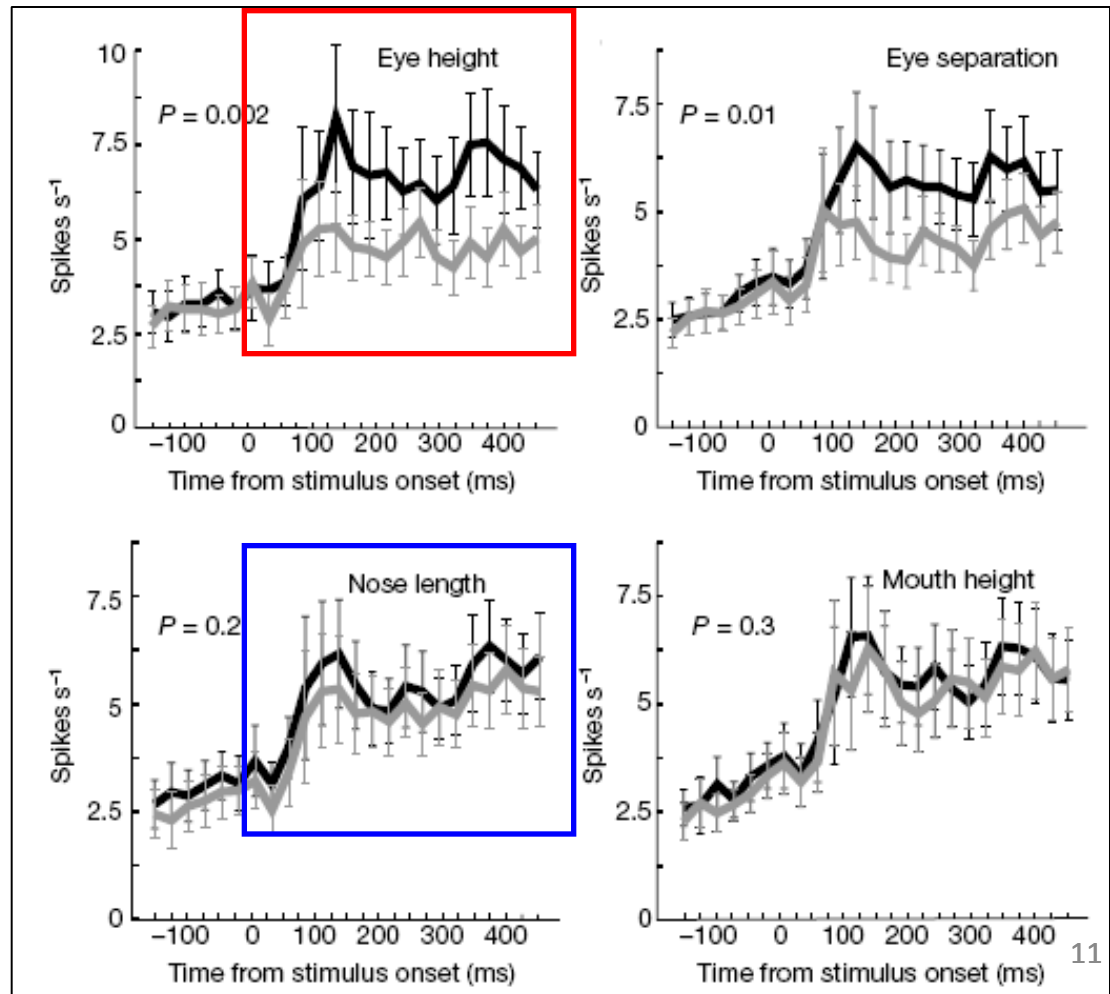
- activity of a population of 150 neurons in the anterior inferior temporal cortex was measured
- 44 neurons responded significantly differently to at least one feature
- After Training: 72% (32/44) were selective to one or both of the diagnostic features (and not for the non-diagnostic features)

Motivational example from Biology

Monkeys performing classification task

Results:

(population
of neurons)



Application of CI (contd--)

- **Pattern recognition problems:**
 - images of all kinds, medical images;
 - insects, birds, animals by their voices
 - biological structures, protein types, folding etc.
- **Data mining problems: Knowledge Discovery in Data(KDD)**
 - understanding data, not just pattern classification
 - finding short explanation of data structure(organization) and association rules
 - using the knowledge discovered to reason in expert systems etc.
- **Information Retrieval:**
 - semantic information retrieval;
 - searching in large databases and in the Web;
 - latent semantic analysis and other methods of dimensionality reduction of document search terms;
 - automatic summarization of texts, dialog and chatter bot systems etc.
- **Detection of regularities:**
 - If we do not know what we are looking for: Detection of patterns, detection of (ir)regularities in signals, for example in heart ECG

Intelligent decision support:

- support for business decisions, like pricing, upgrading, personalization of services;
- increasing response rates of advertising campaigns;
- support for medical diagnostics, evidence-based medicine;
- creating causal networks to explain inferences;
- models of customer and shopping behavior or service user behavior;

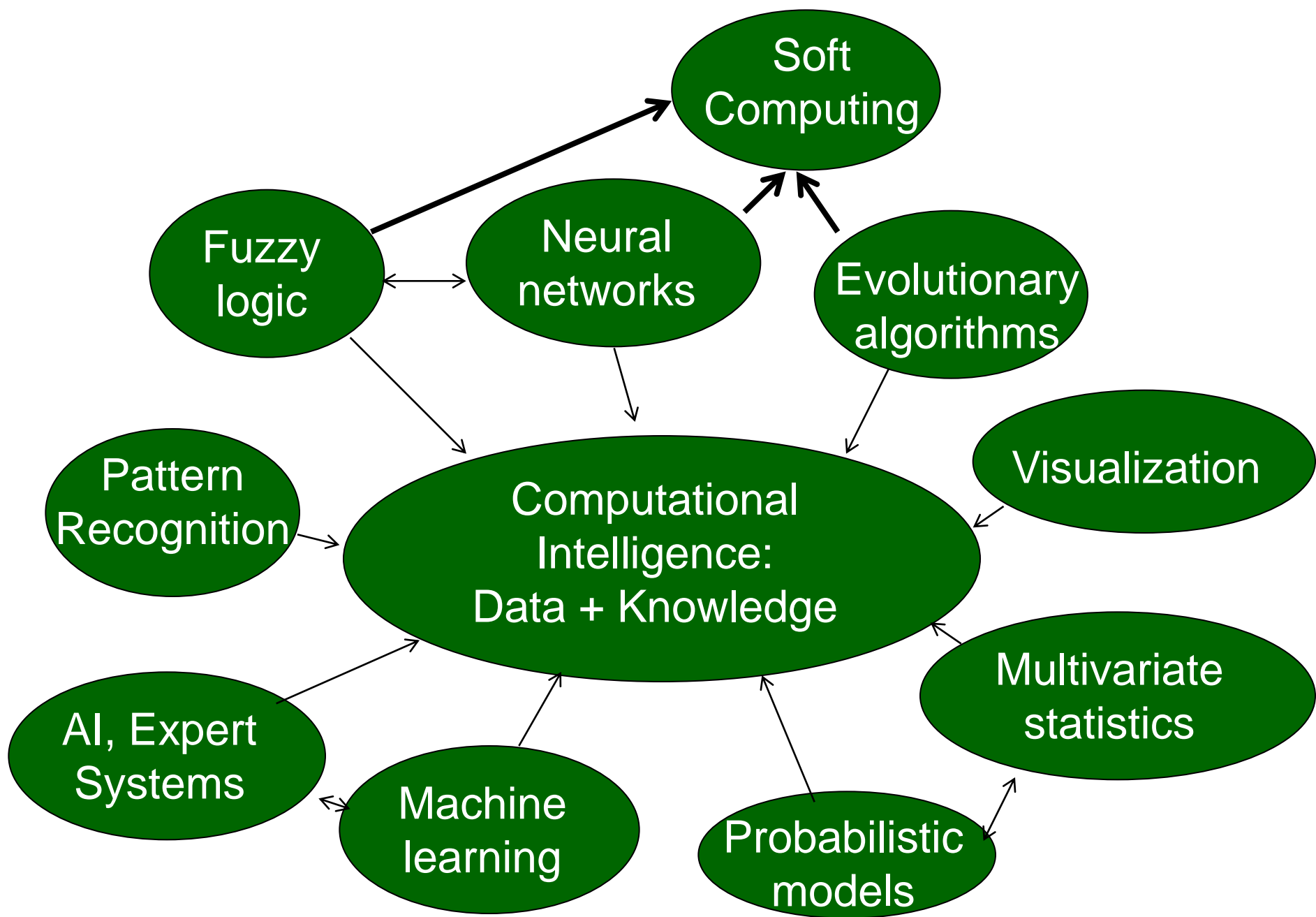
Andreas Weigend (www.weigend.com)

“Amazon.com” might be the world's largest laboratory to study human behavior and decision making

AI & Intelligent Systems

- **Conventional Artificial Intelligence Techniques** deal with precision, certainty and rigor. The guiding principle of **soft computing** is to exploit the tolerance for imprecision, uncertainty, low solution cost, robustness, partial truth to achieve tractability, and better rapport with reality .
- **Intelligent Systems**, provide **human-like expertise such as domain knowledge, uncertain reasoning, and adaptation to a noisy and time-varying environment-----**are important in tackling practical computing problems.
- **Data --> Knowledge using Data mining**

S/C ,in Japan, is called Human like information processing.



Intelligent Computing (IC) ref:15

Knowledge-based systems (KBS) and intelligent computing systems have been used in the medical planning, diagnosis and treatment ,weather prediction.

- The KBS consists of rule-based reasoning (RBR), case-based reasoning (CBR) and model-based reasoning (MBR), whereas Intelligent Computing Method (ICM) encompasses genetic algorithm (GA), artificial neural network (ANN), fuzzy logic (FL) and others.
- The combination of methods in KBS such as CBR–RBR, CBR–MBR and RBR–CBR–MBR and
- the combination of methods in ICM is ANN–GA, fuzzy–ANN, fuzzy–GA and fuzzy–ANN–GA. The combination of methods from KBS to ICM is RBR–ANN, CBR–ANN, RBR–CBR–ANN, fuzzy–RBR, fuzzy–CBR and fuzzy–CBR–ANN.

CI(combining hard & soft computing)

- How to combine s/c techniques with traditional methods (hard computing)
- **Hybrid methods** that are most effective than alone.---i.e. Fusion of s/c & hard computing—linked to applications.

This is akin to redeeming features of life that we are able to use many things without understanding every detail of them.

Our brain has 2 specialized hemispheres. **Left** for logic, maths, analysis, signal processing etc, and the **Right** for recognition, creativity, synthesis, parallel programming etc. Both are connected closely to one another, through the *corpus callosum*, which consists of 200 million nerves . Each hemisphere is continuously supporting & complementing the activities of the other.

Roger W Sperry(NL in medicine 1981) discovered the functional specializations of the cerebral hemispheres. So, it is natural to think of combining the functions of Left brain (HC) and the Right brain (SC). The massive bundle of connecting nerves correspond to the fusion or interface between the 2 computing paradigms. **By combining both we have Computational Intelligence ;** ie. computer based implementation

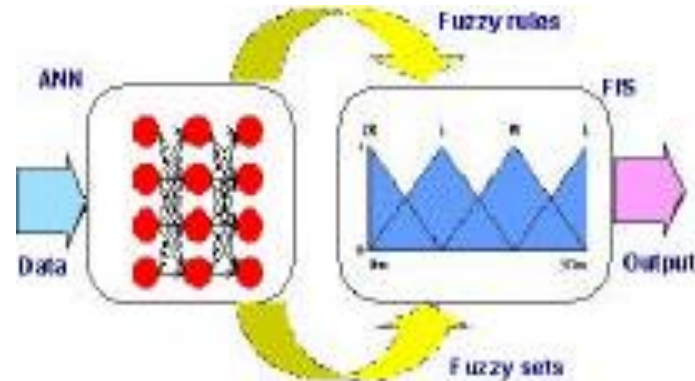
with high m/c IQ.

CI is a subset of AI ; knowledge(Interesting information) incorporation in a non numerical way (FL+NN with a proper interface)

Fusion Architectures

- Fusion architecture is important, because it is not effective to force 2 algorithms together . Most of them contain loose connection of SC & HC.
- More intimate connections (true symbiosis & fusion implementation at different levels of hierarchy) offer future research/development.
- In fusion, the algorithms/methodologies, parameter wise/structure(design) wise, **are dependent on each other for functional reinforcement.**

Ex:-ANN +Fuzzy



In the simplest way, a cooperative model can be considered as a preprocessor wherein **ANN learning mechanism determines the FIS membership functions or fuzzy rules from the training data**. Once the FIS parameters are determined, ANN goes to the background. The rule based is usually determined by a clustering approach (self organizing maps) or fuzzy clustering algorithms. Membership functions are usually approximated by neural network from the training data.

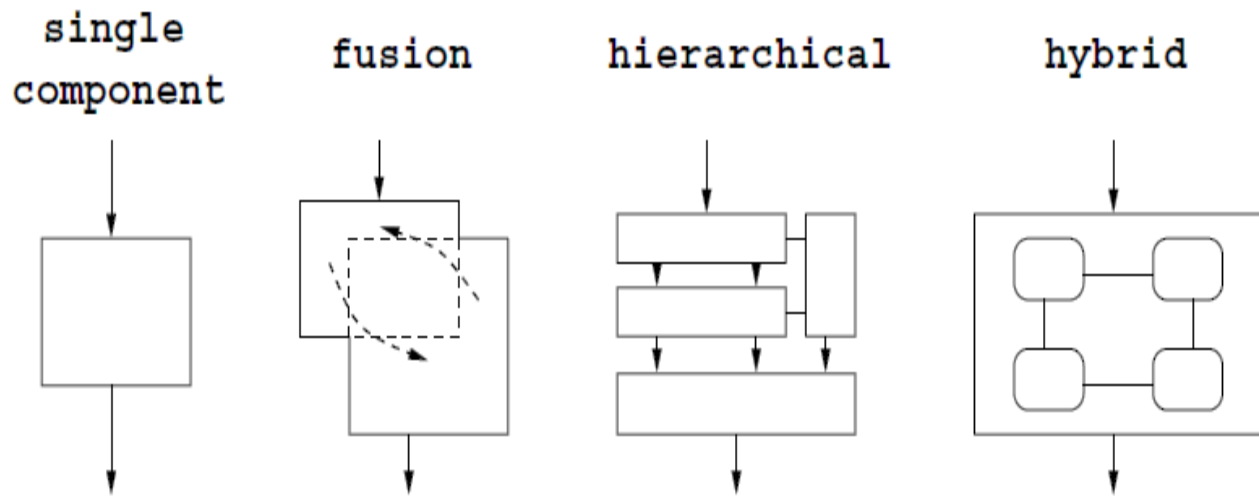


Fig. 1. Different categories of intelligent system designs based on neural and fuzzy techniques.

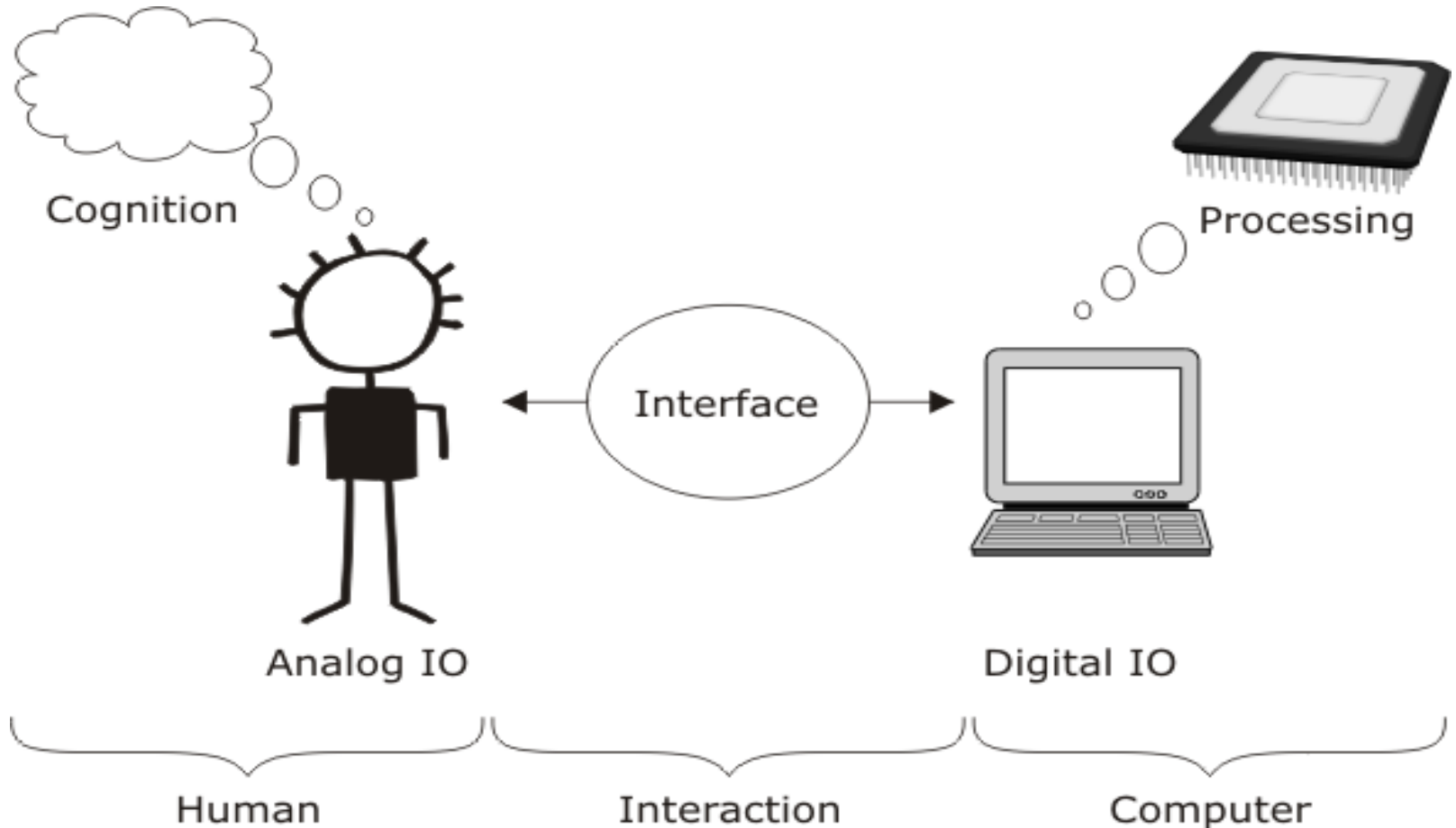
While all other schemes above are cascaded or feed-forward,
in Fusion these are bi-directionally coupled
(using feedback)

Intelligent Agents

- **Intelligent Agents** are applications that perform repetitive tasks, without being managed by a human.
- The [Agents](#) are also referred to as “robots”, “bots”, “crawlers” and “worms”.
- A popular use for the software is shopping. [Shopping bots](#) automatically check web-sites for the best prices. Then alert the user through email about the best price.
- Also, another popular use for agents are from websites such as [Monster](#). At Monster, the bots automatically check the job posts weekly. After the bots or agent finds a post that matches a description from the job seeker, the program alerts the user through email. This prevents the job seeker from checking continuously. The agent saves large amount of time.

-----OOOO-----

Human-computer interaction (HCI)



Human-computer interaction(HCI)

- HCI tackles questions concerning how people interact with computers
 - Are computers intuitive or complicated?
 - Are computers rewarding or frustrating?
 - How can computers be made accessible to everybody (eg different physical abilities, different languages etc.)?
 - To what extent can computer interaction be standardized?
 - Are computers “user-friendly”?
 - What does it mean to be “user-friendly”?



The HotHand device: a ring worn by electric guitar players that uses motion sensors and a wireless transmitter to create different kinds of sound effects by various hand gestures.

Eye movements have been used for many years as a way of supporting the disabled in interacting with computers, but now we are also **seeing the advent of 'brain computer interfaces'**. Such systems allow, for example, people with severe physical disabilities to use their **brain waves to interact with their environment**.

Real-time brainwave activity is beginning to be used to control digital movies, turn on music, and switch the lights on and off. These interfaces can even control robot arms, allowing paralyzed individuals to manipulate objects.

Applications of HCI

- HCI systems have their application in domains ranging from service call centers, to intelligent automotive systems, to games and entertainment industries as well.
- HCI can even be applied in social and emotional development research areas for assistance in gathering information in the fields of psychology, psychiatry, social sciences, and so forth.
- Human affect or emotion and its application in computing is a multidisciplinary field involving, psychology, linguistics, vision and speech analysis, and machine learning. The most popular affects include ---happiness, sadness, fear, anger, disgust.
- The tills (device recording amount of purchase) in pubs, Mac Donald's, etc., are often just ordinary PCs with specialised keyboards.
- Games consoles (touch and feel) – the Super Nintendo was a 6502-based machine, like the BBC Model B
- Computers are often adapted for people with disabilities–e.g. computers operated by blow-pipes, and Stephen Hawking's speaking computer.

- A traditional human-computer interface (HCI) makes use of standard devices such as keyboard, mouse, displays, and so forth, which rely on capturing explicit information from the user while ignoring a vast amount of implicit data.
- **As computing for future expectations implies that an HCI needs to be anticipatory and human-centered and able to detect and respond to subtle changes in human behavior.**
- Some examples of HCIs include the system of **Lisette and Nazos**, combining facial expressions with physiological signals for detection of user emotions; the model of embodied cognition, mapping users' active states, learning or adapting to user behavior based on their facial responses;
- **Lisette and Nazos** developed a system architecture for monitoring and responding to human multimodal affect and emotions via multimedia and empathetic avatars; mapping of physiological signals to emotions and synthesizing the patient's affective information for the health-care provider. **They used a wireless non-invasive wearable computer to collect physiological signals and mapping these to emotional states.**

MIT Wearables (1996-)

What's a Wearable?

Wearable computing hopes to shatter this myth of how a computer should be used.

A person's computer should be worn, much as eyeglasses or clothing are worn, and interact with the user based on the context of the situation.

With heads-up displays, unobtrusive input devices, personal wireless local area networks, and a host of other context sensing and communication tools, the **wearable computer can act as an intelligent assistant**, whether it be through a Remembrance Agent, augmented reality, or intellectual collectives.



Essentially, Computer and the Human are merging!

FEATURED ARTICLE

[How Wearables Worked their Way into the Mainstream](#)

Thad Starner, who has been wearing a "homebrew" computer with a head-up display as part of his daily life since 1993, discusses why it has taken so long for wearables to capture consumer interest. He discusses the various challenges of designing wearable systems and presents five different phases of head-mounted displays, illustrating how improvements in technology allowed progressively more useful and usable devices.

[Read full article...](#)

Output Devices

CyberSphere (1998)



The scientists Eyre and Eureka in VR-Systems UK have been researching a CyberSphere, a device, which consists of a large, translucent sphere containing the user.

The images are distortion-corrected and then projected on the surface of the sphere, allowing the user a full 360 degree field of view.

It also allows the user to move around in the world, by walking inside the ball, which will move in response to the users movements.

© VR-Systems, United Kingdom

Fig :The dancer staring at the user that abandons the installation before ritual is finished .

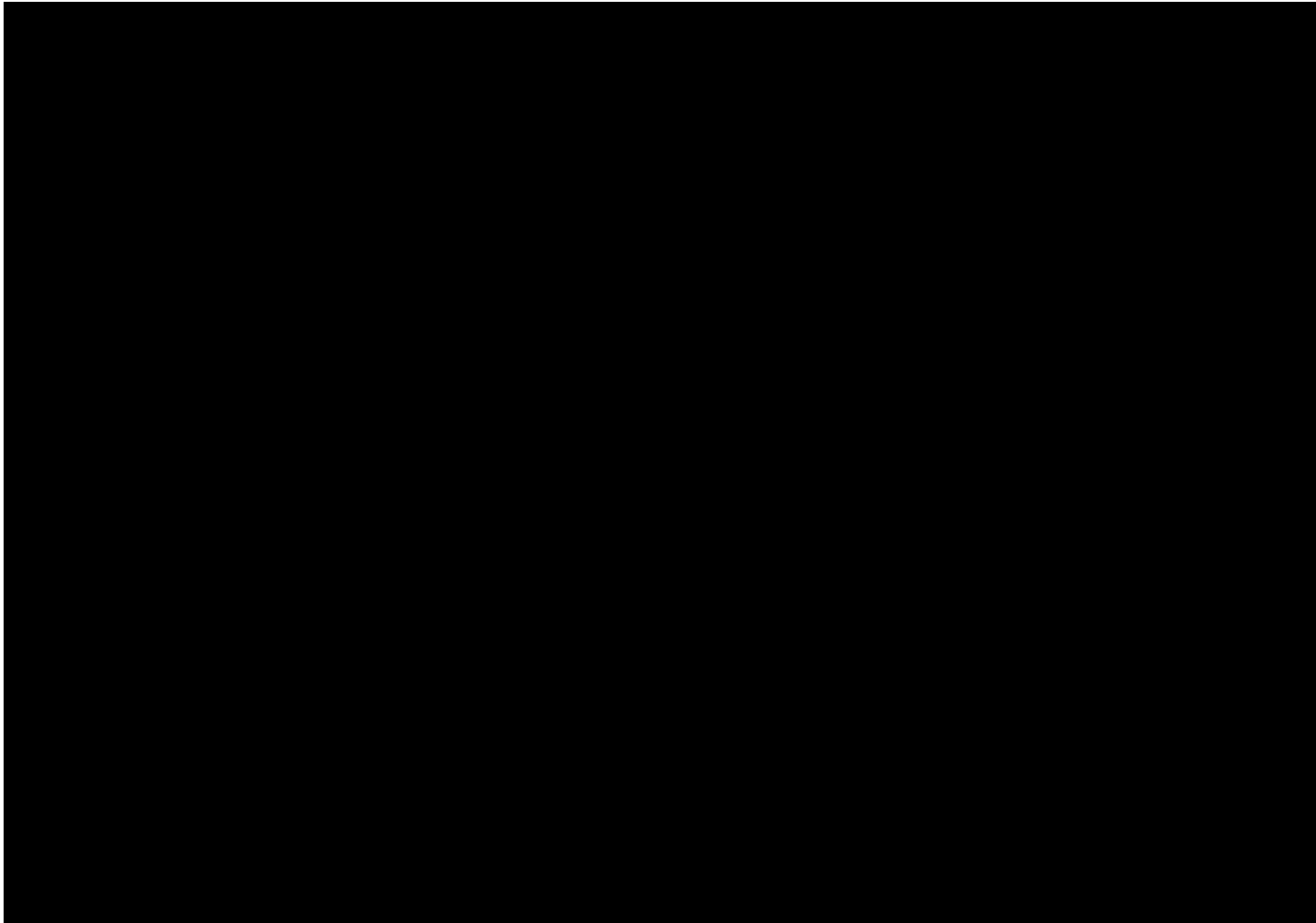


MIT Invents A Shape shifting Display You Can Reach Through And Touch.

- <http://www.fastcodesign.com/3021522/innovation-by-design/mit-invents-a-shapeshifting-display-you-can-reach-through-and-touch>
- At the [MIT Media Lab](#), the [Tangible Media Group](#) believes the future of [computing](#) is tactile. Unveiled today, [the inFORM](#) is MIT's new scrying pool for imagining the interfaces of tomorrow. Almost like a table of living clay, the inFORM is a surface that three-dimensionally changes shape, allowing users to not only interact with digital content in meatspace, but even hold hands with a person hundreds of miles away. And that's only the beginning.



Augmented reality (BMW Car repair)



HCI: Looking Forward(Ref:22)

Technology is changing, people are changing, and society is changing. All this is happening at a rapid and rather alarming rate. What can the HCI community do to intervene and help?

How can it build on what it has achieved? Specifically, we suggest that HCI needs to extend its methods and approaches so as to focus more clearly on human values and be more inventive.

HCI will need to form new partnerships with other disciplines, too, and for this to happen HCI practitioners will need to be sympathetic to the tools and techniques of other trades.

Finally, HCI will need to re-examine and reflect on its basic terms and concepts. Outdated notions of the 'user', the 'computer' and 'interaction' are hardly sufficient to encompass all that HCI will need to attend to think anew-with intelligence .

Intelligent computing

A View point

- IEEE Fellow Michael I. Jordan says that hardware designers creating chips based on the human brain, are engaged in a faith-based undertaking.
- The preeminent mind in the field of machine learning, thinks that the breathless computers-as-brains ideology, on which computer design is based, has sent the industry down the wrong path.

Human Vs Computer

Human attributes:-

Learning (Patterns & developing Links among patterns), **Knowledge** (developing links & constraints) & **Intelligence**(recall the patterns that are stored) -----linked to Perception of Patterns(mostly by Humans)—not possible by Machines.

Ex:- painting starts with a sketch/ outline pattern.

Learning “addition” is a concept development, concept of a room. How ?—we do not know!!!

Over the years..

- Earlier--Books without problems
- Later--Only Problems(ex: Parker & Smith in EE)
- Now--Solutions—worked out examples-no thinking.

Contents learnt in a computer can be deleted, but NOT in humans.

Non reproducibility in Humans (human writing with acceptable variations)

Both Human Intelligence & CI are complementary

Future Computers should grasp:-

-Patterns

-Concepts

-vagueness/ similarity

Conclusion

Humans can read well characters/patterns—not m/cs.

Airport security still needs humans—replacing by m/cs –not possible.

No m/c algorithm for analyzing the data we collect from cameras, speech etc.

M/c and Human way of looking at things are different.

There is a gap in the processing/ representation in both:-----

In Humans—it is processing & then representation—ex:-human recognition, remembering names of people etc.

In M/Cs—it is representation & then processing-ex speech, sampling etc, in images—pixels.

Two different architectures:-

In M/C –no pattern concept

In humans--- only patterns (different from PR books)

We remember well if anything is told in the form of a story(analogues to a pattern)

Art of story telling in modern education(like in our childhood)—is more interesting.

Computational brain modeling

- Combined research in the field of computer science and neuroscience has empowered to build a computational structure analogous to the brain cognitive processing, to provide for Intelligent Information Processing.
- In Switzerland ,the Blue brain project(using IBM Blue gene/L super computer)—to analyze the multilayered brain data & modeling.
- Brain disorders are caused by not only a few neurons but also how they are wired.

Human Connectome Project by NIH

BRAIN by NSF

Google Brain project

Intelligent Image Processing (IIP)
by Steve Mann, John Wiley & Sons 2002
Humanistic Intelligence as a basis for IIP

- The author approaches the fundamental ideas of wearable computing and personal imaging that takes the reader from original wearable photographic computer inventions of the 1970s, through to the modern EyeTap system. This fascinating technology promises to change the way we live and the way we communicate, and Intelligent Image Processing (IIP) provides a detailed, technical, and stimulating guide for those who wish to learn about or contribute to this promising future.

Intelligent Image Processing

- EyeTap technology comprises eyeglasses or contact lenses that cause the eye itself to function, in effect, as if it were both a camera and a display.
- There are a wide range of commercial applications for this technology, including telephones that allow users to see each other's points of view, and systems that improve the sight of the visually impaired. These systems have been proven for electronic news gathering in hostile environments such as fires, floods, riots, and documenting human rights violations-all giving rise to a new genre of first-person cinematography.
- The invention blurs the boundary between seeing and recording, and the boundary between computing and thinking. It will radically change the way pictures are taken, memories are shared, and news is documented.

Humanistic Intelligence(HI)

HI is a new information-processing framework in which the processing apparatus is inextricably intertwined with the natural capabilities of our human body and intelligence.

- The motivating factor in humanistic intelligence is that we realize the close synergy between the intelligence that arises from the **human being in the feedback loop of a truly personal computational process**. Rather than trying to emulate human intelligence, HI recognizes that the human brain is perhaps the best neural network of its kind, and that there are many new signal processing applications, within the domain of **personal imaging**, that can make use of this excellent but often overlooked processor that we already have attached to our bodies. **Devices that embody HI are worn (or carried) continuously during all facets of ordinary day-to-day living.**

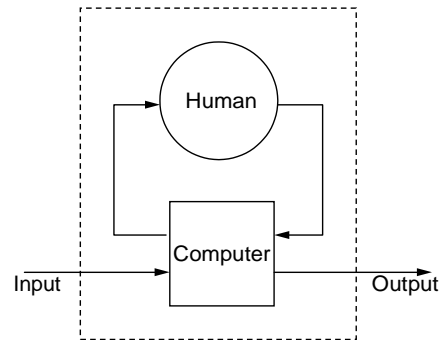
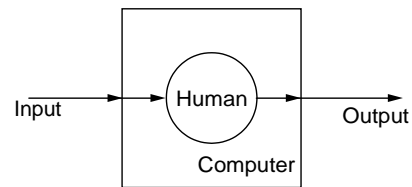
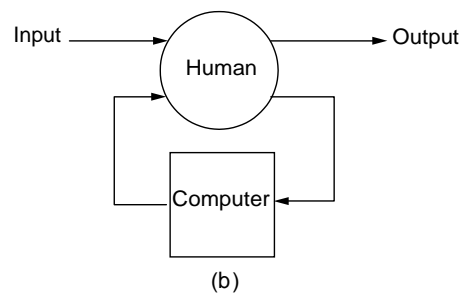
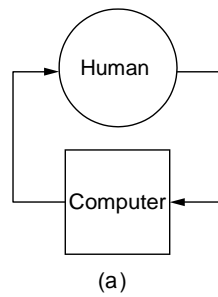
•**Through long-term adaptation they begin to function as a true extension of the mind and body.**

•**Personal imaging** is an integrated personal technologies, personal communicators, and mobile multimedia methodology.

- Personal imaging devices are characterized by an “always ready” usage model, and comprise a device or devices that are typically carried or worn so that they are always with us.

Why Humanistic Intelligence

- It is not, at first, obvious why one might want devices such as cameras to be operationally constant:- to facilitate new forms of intelligence that assist the user in new ways.
- Devices embodying HI are not merely intelligent signal processors that a user might wear or carry in close proximity to the body but are devices that turn the user into part of an intelligent control system where the user becomes an integral part of the feedback loop.



Basic operational modes of wear Computers

What is eye tap

The EyeTap is a name for a device that is worn in front of the eye that

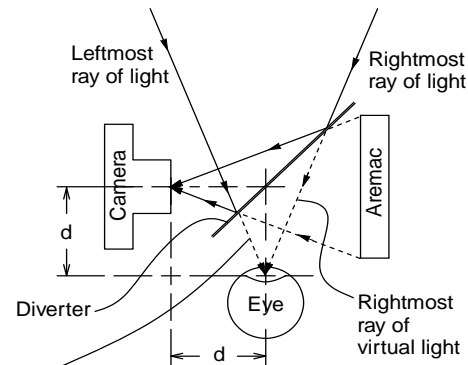
- Acts as a camera to record the scene available to the eye, and
- Acts as a display to superimpose a computer-generated imagery on the original scene available to the eye.



On Eye Tap

- A computationally mediated visual reality is a natural extension of the next generation computing machines. Already we have witnessed a pivotal shift from mainframe computers to personal/personalizable computers owned and operated by individual end users. We have also witnessed a fundamental change in the nature of computing from large mathematical “batch job” *calculations to the use of computers as a communications medium. The explosive growth of the Internet* (which is primarily a communications medium as opposed to a calculations medium), and more recently the World Wide Web, is a harbinger of what will evolve into a **completely computer-mediated world**. Likely in the immediate future we will see all aspects of life handled online and connected. This will not be done by implanting devices into the brain—at least not in the near future—but rather by noninvasively “tapping” the highest bandwidth “pipe” into the brain, namely the eye. This “eye tap” forms the basis for devices that are being currently built into eyeglasses (prototypes are also being built into contact lenses) to tap into the mind’s eye.

- What's an aremac? That's a camera in reverse — equipment that converts electronic image data into light. For example, you can use a computer monitor as an aremac.



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(a)



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- **Figure 1.3** Early embodiments of the author’s original “photographer’s assistant” application of personal Imaging. (a) Author wearing WearComp2, an early 1980s backpack-based signal-processing and personal imaging system with right eye display. Two antennas operating at different frequencies facilitated wireless communications over a full-duplex radio link. (b) WearComp4, a late 1980s clothing-based signal processing and personal imaging system with left eye display and beamsplitter. Separate antennas facilitated simultaneous voice, video, and data communication.

THE WRISTWATCH VIDEOPHONE: A FULLY FUNCTIONAL “ALWAYS READY” PROTOTYPE



Figure 2.3 The wristwatch videoconferencing computer running the videoconferencing application underneath a transparent clock, running XF86 under the GNUX (GNU + Linux) operating system: (a) Worn while in use; (b) Close-up of screen with GNUX “cal” program running together with video window and transparent clock.



Figure 2.9 Early personal safety device (PSD) with radar vision system designed and built by the author, as pictured on exhibit at List Visual Arts Center, Cambridge, MA (October 1997). The system contains several sensing instruments, including radar, and camera systems operating in various spectral bands, including infrared. The headworn viewfinder display shows what is behind the user when targets of interest or concern appear from behind. **The experience of using the apparatus is perhaps somewhat like having eyes in the back of the head, but with extra signal processing as the machine functions like an extension of the brain to provide visual intelligence. As a result the user experiences a sixth or seventh sense as a radar vision system.** The antenna on the hat was for an early wireless Internet connection allowing multiple users to communicate with each other and with remote base stations.

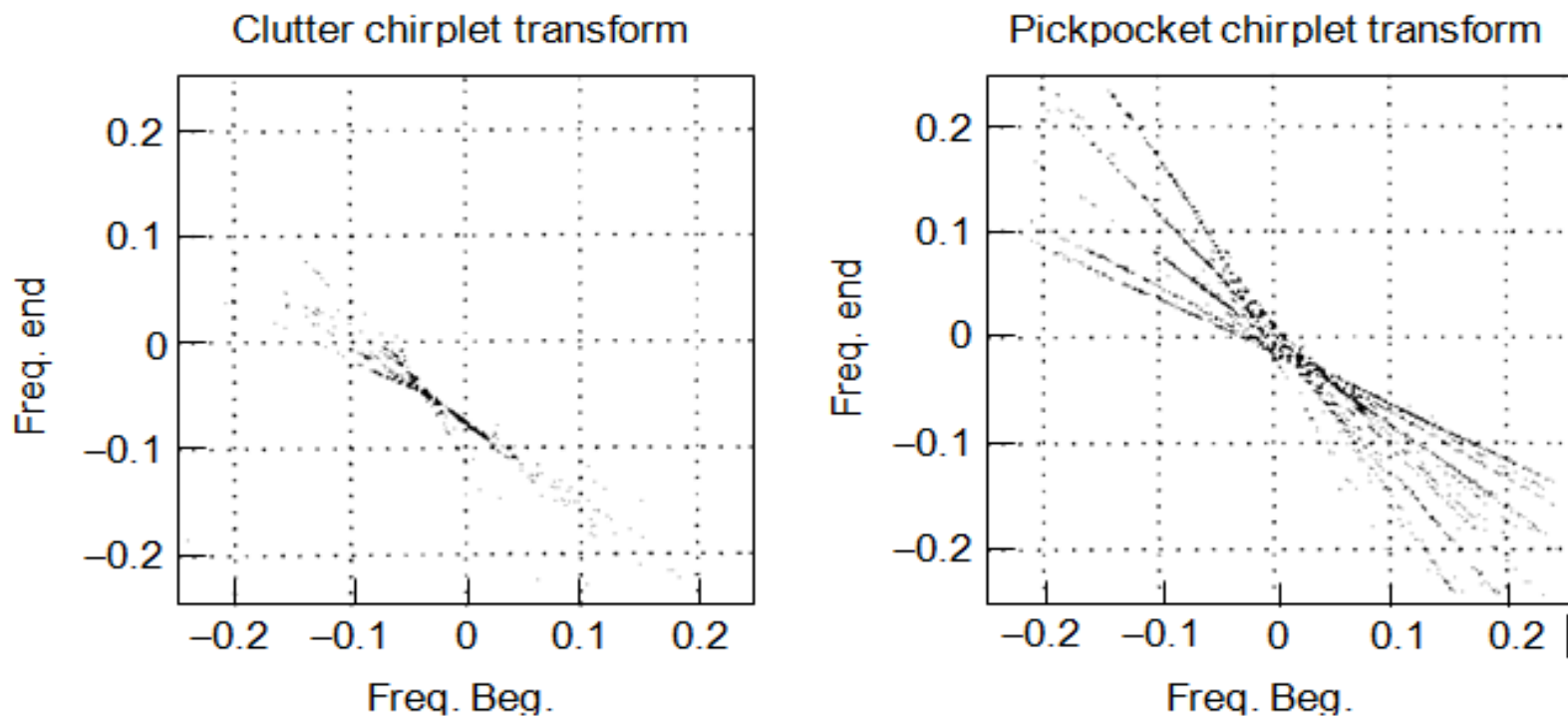


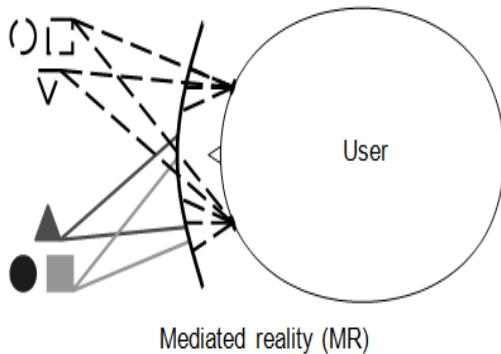
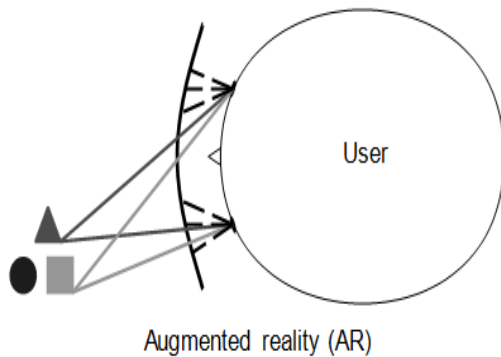
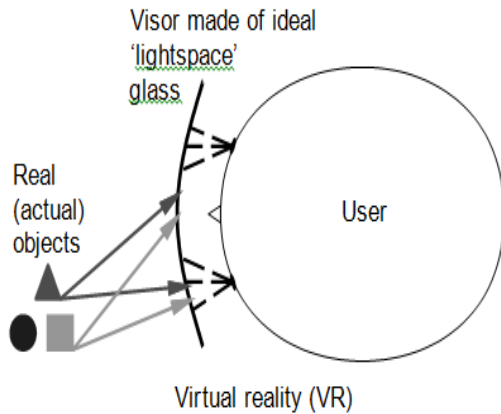
Figure 2.12 Chirplet transforms for ground clutter only, and pickpocket only. Ground clutter falls in the lower left quadrant because it is moving away from the radar at both the beginning and end of any time record (window). Note that the pickpocket is the only kind of activity that appears in the lower right-hand quadrant of the chirplet transform. Whenever there is any substantial energy content in this quadrant, we can be very certain there is a pickpocket present.



Figure 2.19 Living in a “Rot 90” world. It was found necessary to rotate both cameras rather than just one. Thus it does not seem possible to fully adapt to, say, a prism that rotates the image of each eye, but the use of cameras allows the up-down placement of the “eyes.” The parallax, now in the up-down direction, affords a similar sense depth as we normally experience with eyes spaced from left to right together with left-right parallax.



Figure 2.21 Giant's eyes: Extended baseline. (a) With a 212 mm baseline, author could function in most everyday tasks but would see crosseyed at close conversational distances. (b) With a 1 m baseline, author could not function in most situations but had a greatly enhanced sense of depth for distant objects (e.g., while looking out across the river). Wires from the cameras go down into author's waist bag containing the rest of the apparatus. Inbound transmit antenna is just visible behind author's head.



- **Figure 3.6** Eyeglasses made from lightspace analysis and lightspace synthesis systems can be used for virtual reality, augmented reality, or mediated reality. Such a glass, made into a visor, could produce a virtual reality (VR) experience by ignoring all rays of light from the real world, and generating rays of light that simulate a virtual world.
- Rays of light from real (actual) objects indicated by solid shaded lines; rays of light from the display device itself indicated by dashed lines. The device could also produce a typical augmented reality (AR) experience by creating the “illusion of transparency” and also generating rays of light to make computer-generated “overlays”.
- Furthermore it could “mediate” the visual experience, allowing the perception of reality itself to be altered. In this figure a less useful (except in the domain of psychophysical experiments) but illustrative example is shown: objects are *left-right reversed* before being presented to the viewer.

Applications

- There are variations between images, even if they seem, to the human eye, belong to the same category of images and seem to be very similar: contrast characteristics of satellite images are different due to weather; tissue density from different patients differs between X-ray images; tissue appears different in MR-images if slice thickness taken was different.
- These variations can be strong enough to force a segmentation algorithm to produce wrong segments or an edge detection algorithm to produce incomplete borders with some set of parameters that worked for the image before.
- These are domains where the tasks to be performed are always similar but much more complex than the quality control tasks, like measuring aneurysms in CT images, finding tissue suspected to be cancerous in MR-mammographies, finding all bridges in a satellite image or finding all images with sunsets in an image database.

- A system shell developed for modeling and execution control of knowledge-based image analysis tasks. The approach enables the flexible modeling and use of adaptive image analysis sequences to perform image-understanding tasks in complex, varying and knowledge-intensive domains such as medical image understanding.
- The shell supports the construction of two separated knowledge bases. The **first** containing knowledge **about image processing algorithms** and their parameters and the **second** containing information **about image contents**. This allows domain-specific control and validation. The image analysis process is controlled through an inference engine, which is based on a configuration system. The shell is called Cyclops System and is presently being used on the development of medical imaging applications.

Research is Still ON

- After three decades research, there is still no general computer vision approach, capable to provide the technology to develop a general-purpose vision system, able to deal with different tasks and images, like the human vision apparatus. One of the main challenges in image understanding is to develop a flexible, adaptable system, capable of performing complex image analysis tasks and of extracting information from varying scenes or images. In Computer Vision, the state-of-art is still that we have sorts of different, very specialized algorithms for edge-detection, segmentation, filtering, blurring and so on. If we intend to perform some image analysis task, we have to carefully choose, combine and parameterize some of those algorithms adequately. This restricts Computer Vision solutions to narrow application domains and even there, we cannot be sure that some combination of algorithms will perform in a stable and reliable manner for all images of a given category. We can identify two kinds of application domains, where existing image analysis algorithms could, in theory, be used to develop solutions: Domains where the analysis task is simple, the image acquisition is done under controlled conditions and the objects appearing in the images are known before. The second is the unknown situation.

Computer Vision

- Still an open problem
- Controlled environments have good algorithms
- Where there is an uncertainty, use human in a loop for some functions. This may be better than total automation.

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Content Based Image Retrieval (CBIR)

- Given a query image and a large data base of images, CBIR extracts visual contents (features) of the query image and compares these with the visual contents of each image in the data bank.

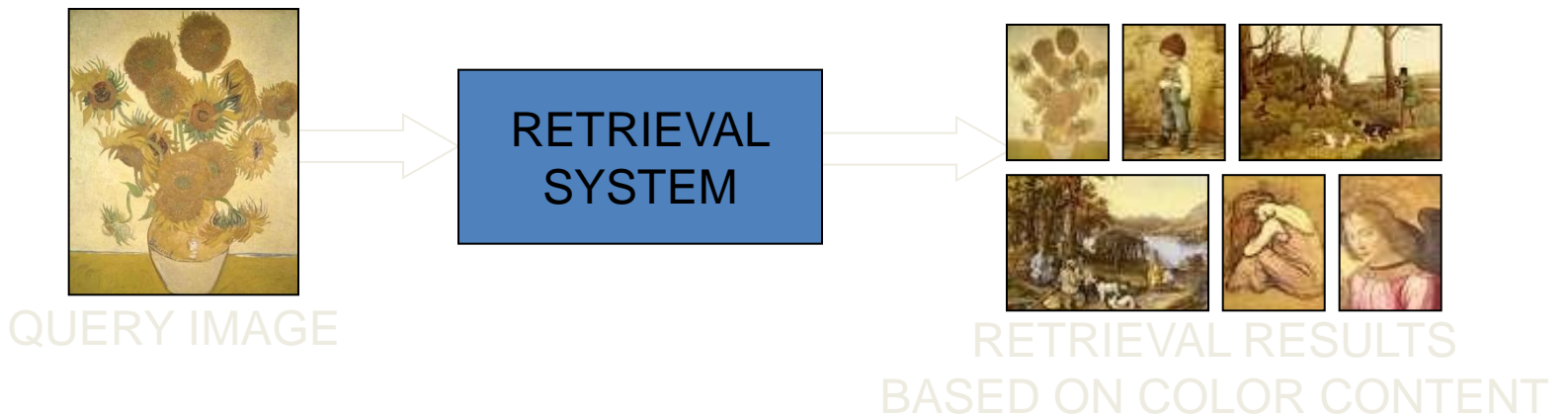
Those images in the data bank, whose visual contents closely match the visual contents of the query image, are then retrieved.

These retrieved images are supposed to be looking “similar” to the query image. However, in practice, only a few retrieved images will look similar, because the extracted visual features from any image will not fully characterize/ represent that image.

- Images that are close in feature space are, in general, not close semantically

CBIR
SIMPLE EXAMPLE

- **FOR A GIVEN QUERY IMAGE...**
 - **EXAMPLE IMAGE**
 - **ROUGH SKETCH**
 - **EXPLICIT DESCRIPTION CRITERIA**
- ...RETURN ALL 'SIMILAR' IMAGES**



Problems: what's on the images?



- How does the computer KNOW that all these objects are lamps?

Problems: what's on the images?



Old lady / Young woman



**Face / back of a person
with overcoat**



**Band master / woman
face**

- Sometimes it is not easy to understand the image even for humans!
- What do we want from machines?

Two Image Examples

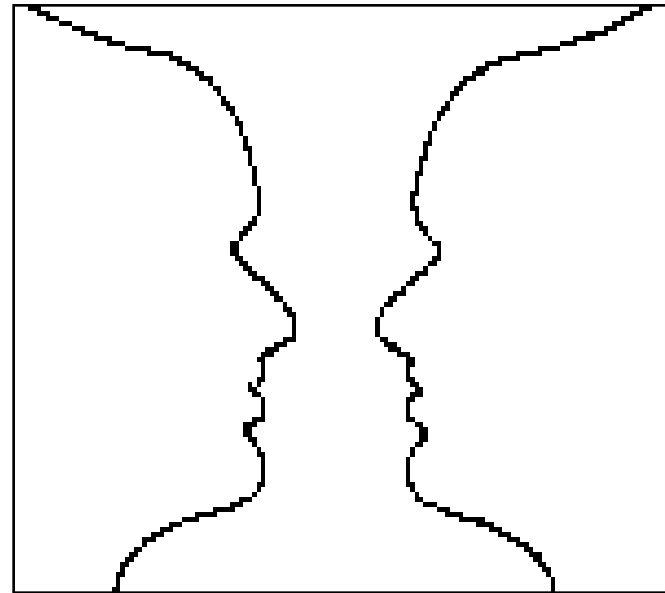
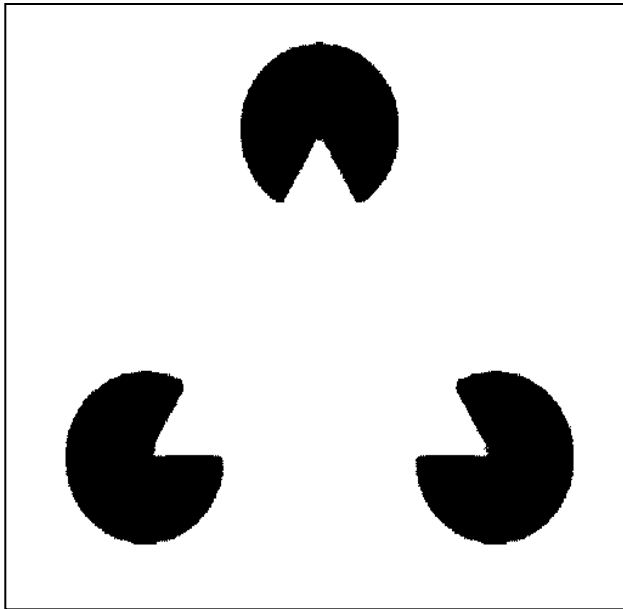


Some contents are
difficult to describe.



Almost impossible to
describe all the contents.

Why Is Image Retrieval Difficult?



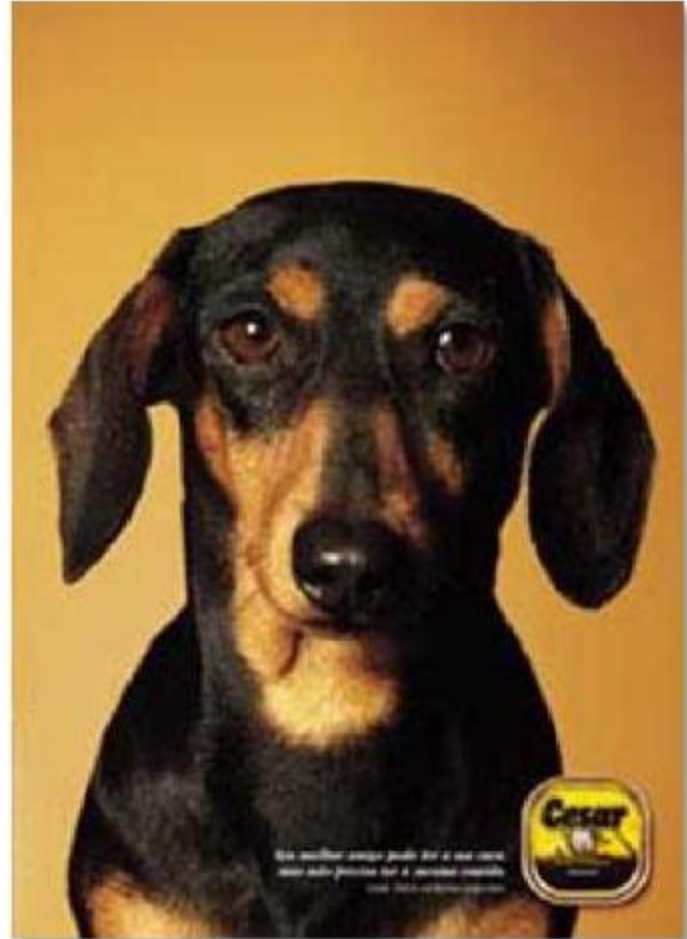
■ Important to distinguish between the physical properties of an image and how it is perceived.



An example of the **semantic gap** problem. The two images possess very similar color and texture characteristics, but differ vastly as far as the semantics are concerned.



Semantic gap



Semantic gap: The visual features (color, texture, shape, etc.) of the old lady image and the dog image are very similar, but their semantic meanings are totally different.

Perceptual versus Computational Similarity



Perceptually close

Pixel-wise close

What Do You See?



Very difficult image for CBIR

WHAT IS DEEP LEARNING?

A class of machine learning techniques where many layers of non-linear information processing stages or hierarchical architectures are exploited

i.e. Training networks with many layers

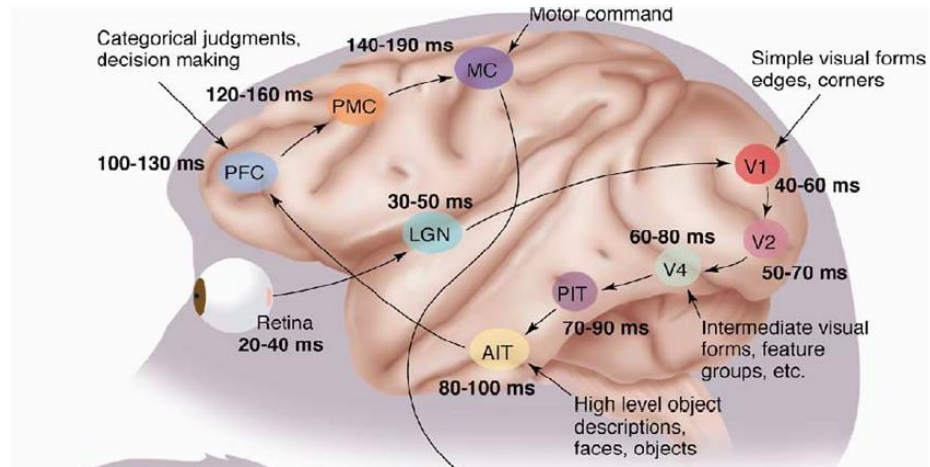
Biological: Visual cortex is hierarchical



- Each layer of hierarchy extracts features from output of previous layer
- All the way from pixels → classifier

Why Deep Learning

- Biological Plausibility – Visual cortex is hierarchical

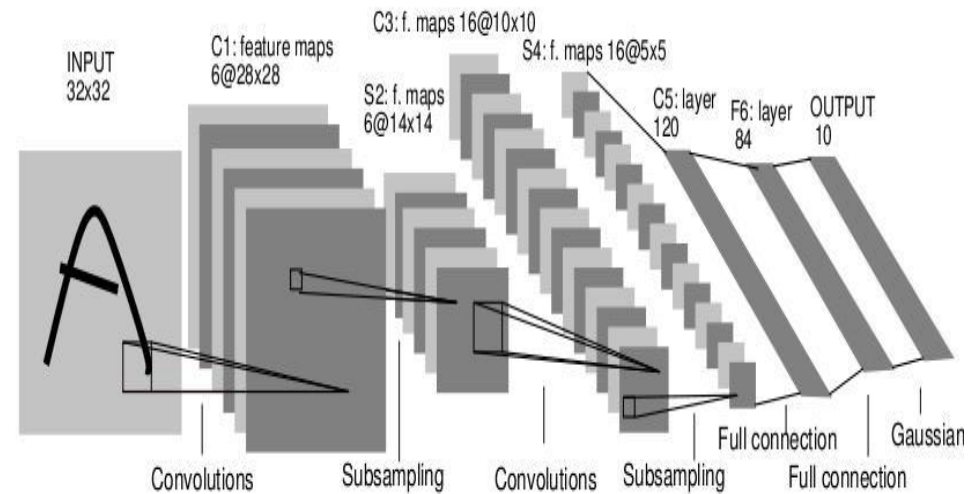


- Highly varying functions can be efficiently represented with deep architectures
- Sub-features created in deep architecture can potentially be shared between multiple tasks

Classic Approach to Training(CNN)

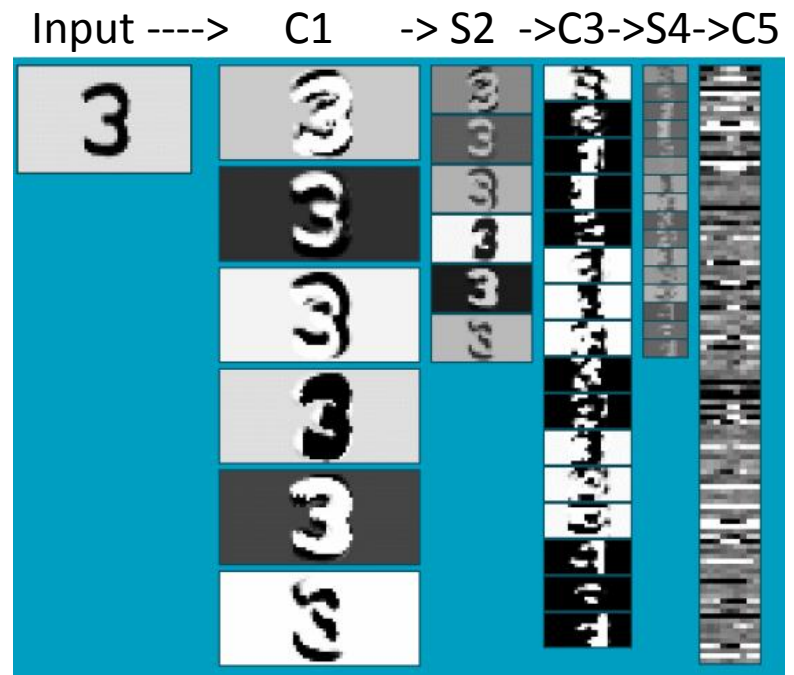
- C1 has 6 feature maps obtained by using 6 different masks on the input
- S2 has 6 feature maps obtained by averaging 2×2 non-overlapping neighborhood in
- C3 has 16 feature maps obtained using 16 different masks with specific connection mechanism from S2
- Layer C5 is a convolution layer with 120 feature maps.

Each unit is connected to a 5×5 neighborhood in all 16 feature maps in S4



- Learning
 - Supervised
 - Back-propagation
 - Need lots of labeled input data
- Problem:
 - Difficult to train deep models (vanishing gradients-error propagation)
 - Getting enough labels

CNN



Deep learning

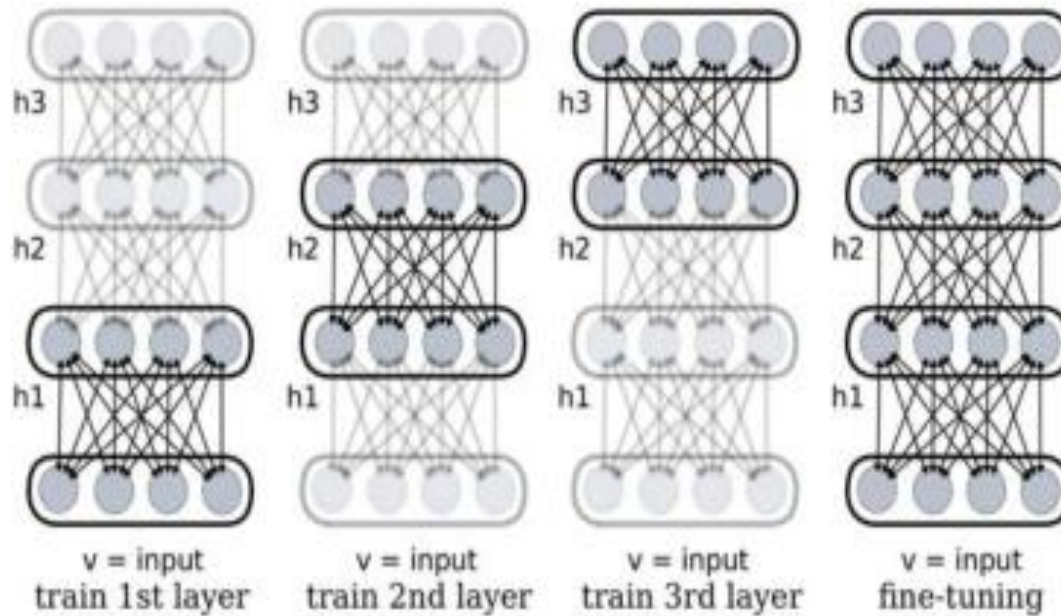


Figure 1: The deep learning scheme: a greedy unsupervised layer-wise pre-training stage followed by a supervised fine-tuning stage affecting all layers.

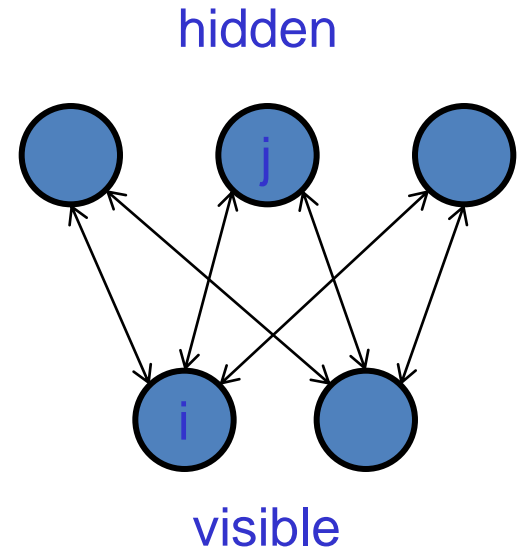
Boltzmann Machine

- Boltzmann machines can be seen as the stochastic, generative counterpart of Hopfield nets.
- A **Boltzmann machine** is a type of stochastic recurrent neural network invented by Geoffrey Hinton and Terry Sejnowski in 1985. The firing of the units is determined by a probabilistic law.
- $P(s \rightarrow 1 | x) = 1 / (1 + e^{-(X - \theta) / T})$
X=output of the neuron
 θ =threshold
- Deterministic Case:- $s = f(x) = 1$ for $x > 0$ and $= 0$ for $x \leq 0$

Restricted Boltzmann Machines

(Smolensky ,1986, called them “harmoniums”)

- We restrict the connectivity to make learning easier.
 - Only one layer of hidden units.
 - No connections between hidden and visible units.

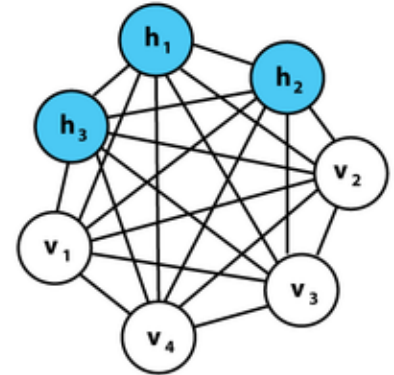


Boltzmann Machines

- Learns generative model
- Capable of learning internal representations
- Boltzmann machines with unconstrained connectivity(all to all) have not proven useful for practical problems

$$\Delta w_{i,j} = k(p_{i,j}^+ - p_{i,j}^-)$$

- P_{ij}^+ is the expectation value of i th visible unit and j th hidden unit are together on, **when input is fed to visible units.**
- P_{ij}^- is the expectation value of i th hidden unit and j th visible unit are together on.



Deep Learning

- Unsupervised training
- Model distribution of input data
- Can use unlabeled data (unlimited)
- Refine with standard supervised techniques (e.g. back prop)

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