Granular Computing

Web Intelligence, Brain Informatics and all that

Introduction to Granular Computing

Web Intelligence, Brain Informatics and All That

What is Web Intelligence?

Web Intelligence consists of the following:

- **Web Human-Media Engineering:**
  Web page design, multimedia representation, processing, visualization, Web interfaces.

- **Web Information Management:**
  Internet & Web data quality & information transformation; multi-dimensional Web databases & OLAP; multimedia management; new Web data models; Web knowledge management,; Web page generation & updating; Web security, integrity, privacy & trust.

- **Web Information Retrieval:**
  Approx. retrieval, conceptual information extraction; image, multi-linguistic & multimedia information retrieval; new retrieval models, Web content cataloging and indexing.
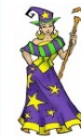
Web Intelligence, Brain Informatics and All That (cont)

- **Web Agents:**
  e-mail filtering & semi-automatic reply; information filtering & navigation guides.
- **Web Mining and Farming:**
  web text & data mining and knowledge discovery; web-based ontology engineering; Web-based reverse engineering; web farming, web-log mining, and web warehousing.
- **Web Information System Environment Foundations:**
  competitive dynamics of Web sites, emerging Web technology, network community formation and support, new Web information description and query languages, theories of small world Web, Web information system development tools, and Web protocols.

Web Intelligence, Brain Informatics and All That (cont)

- ### Web-Based Applications:
    business intelligence; customer relationship mgmt; marketing; electronic library; Web-based decision support systems, Web--based distributed systems, Web-based electronic data interchange (EDI), Web marketing, and Web publishing.

Missing Element: Learning

Any software produced without a learning component is obsolete

Web Intelligence for the Functionally Illiterate and the Cognitively Impaired.

Requires multi-modalities, speech, natural language, machine-aided Translation, machine learning, multimedia, databases, …

Food for Thought

- Did you ever consider buying an Edsel?

- Could the Three Mile Island nuclear accident have been avoided?

- How can major national grocery chains adjust their product admixture and availability according to the perceived buying habits of shoppers possessing different demographic indicators?

- What makes a mountain a mountain, and not a mountain range?

- Where does a stream end and a river begin?

Brain Informatics

Brain Informatics (BI) has emerged as an interdisciplinary research area that studies the mechanisms underlying the human information processing system. BI investigates essential functions of the brain, ranging from perception to thinking, and encompassing such areas as multi-perception, attention, memory, language, computation, heuristic search, reasoning, planning, decision-making, problem-solving, learning, discovery, and creativity.

The goal of BI is to develop and demonstrate a systematic approach to achieving an integrated understanding of both macroscopic and microscopic level working principles of the brain, by means of experimental, computational, and cognitive neuroscience studies, as well as utilizing advanced Web Intelligence (WI) centric information technologies.

Brain Informatics

The main research problems in BI lie in the interplay between the studies of human brain and research in informatics. On the one hand, one models and characterizes the functions of the human brain based on the notions of information processing systems. WI centric information technologies are applied to support brain science studies. For example, the Wisdom Web and knowledge grids enable high-speed, large-scale analysis, simulation, and computation as well as new ways of sharing research data and scientific discoveries. On the other hand, informatics-enabled brain studies, e.g., based on fMRI and EEG, significantly broaden the spectrum of theories and models of brain sciences and offer new insights into the development of human-level intelligence on the Wisdom Web and knowledge grids.

Brain Informatics

In order to study BI systematically and give a holistic view of brain informatics, we highlight several major topics in each research area, as an extensional description of BI research:

- Thinking and perception-centric investigations of HIPS:
    - Human reasoning mechanisms (e.g., principles of human deductive/inductive reasoning, common-sense reasoning, decision-making, and problem-solving);
    - Human learning mechanisms (e.g., personalized user/student models);
    - Human multi-perception mechanisms and visual,auditory, and tactile information processing;
    - Modeling brain information processing mechanisms (e.g., neuro-mechanism, mathematical, cognitive and computational models of HIPS).
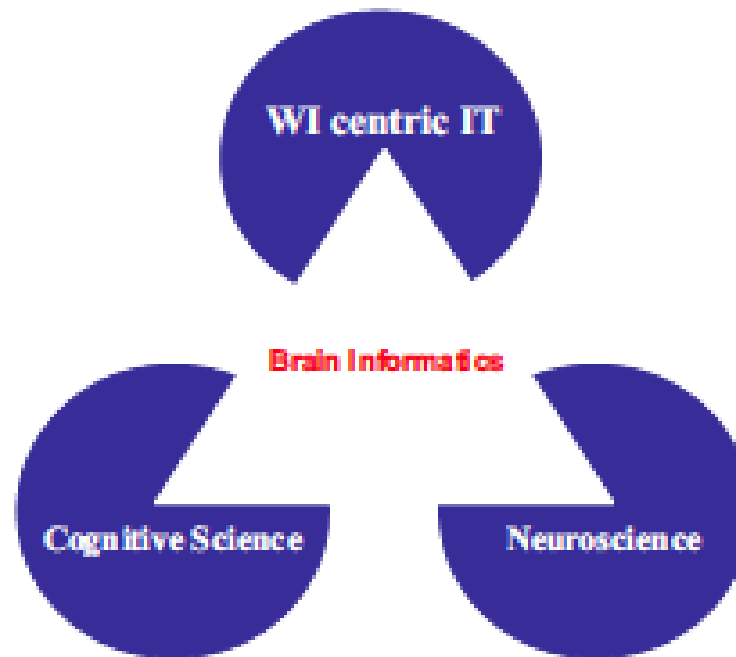
Brain Informatics

- Information technologies for the management and use of brain data:
    - Human brain data collection, pre-processing, man-agement, and analysis;
    - Databasing the brain and constructing data brain models;
    - Multi-media brain data mining and reasoning;
    - Simulating spatiotemporal characteristics and flow in HIPS;
    - Developing brain data grids and brain research sup-port portals.
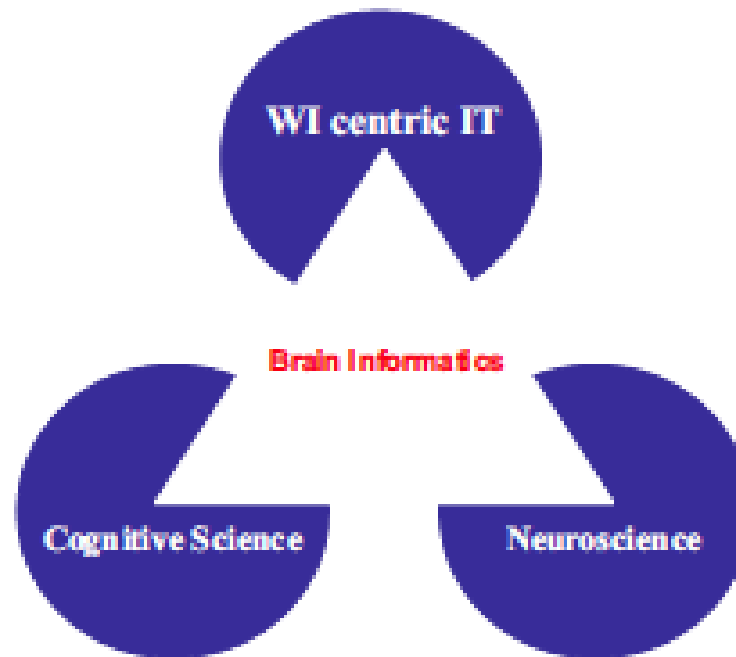
Brain Informatics

The relationship between Brain Informatics and other brain science related disciplines as well as the WI centric IT

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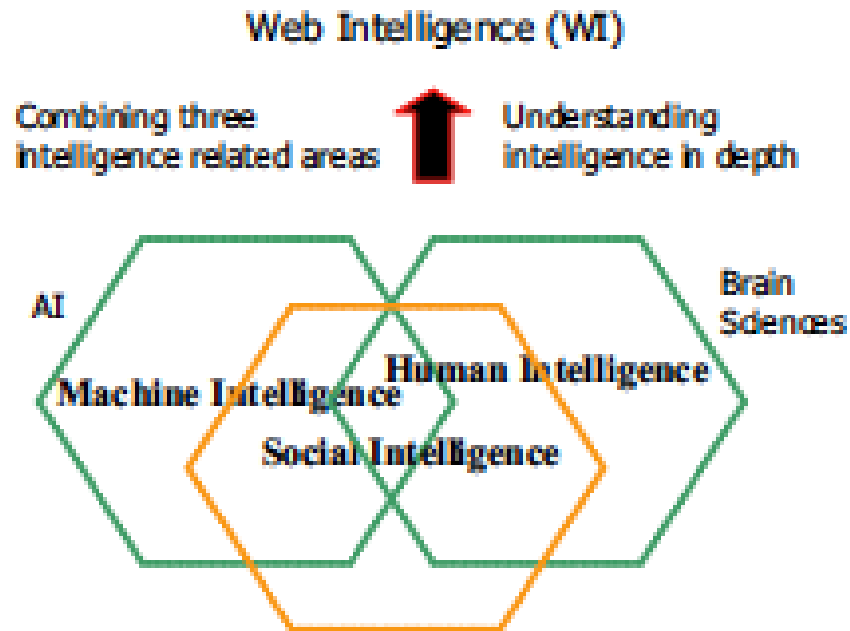
Brain Informatics

Neuroscience is beginning to provide direct measurement and observation of humans to understand directly how our intellects work. These measurements are challenging our understanding of the relationship between mind and action, leading to new theories and calling old ones into question. New instrumentation (fMRI etc.) and advanced information technologies are causing a revolution in WI and brain sciences. This revolution is bi-directional:

- **WI for BI:** WI based technologies (e.g., the wisdom Web, data mining, multi-agent, and data/knowledge grids) will provide a new powerful platform for brain sciences;

- **BI for WI:** New understanding and discovery of the human intelligence models in brain sciences (e.g., cognitive science, neuroscience, and brain informatics) will yield new WI research and development.
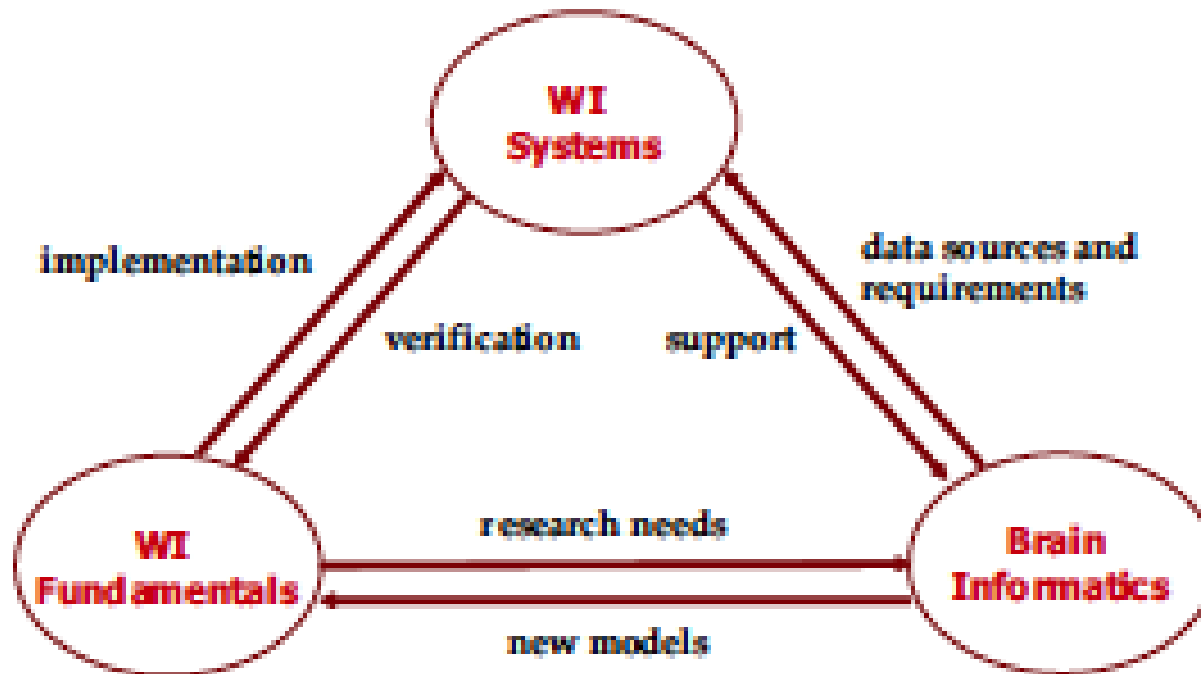
Brain Informatics

The relationship between WI and other three intelligence related research areas
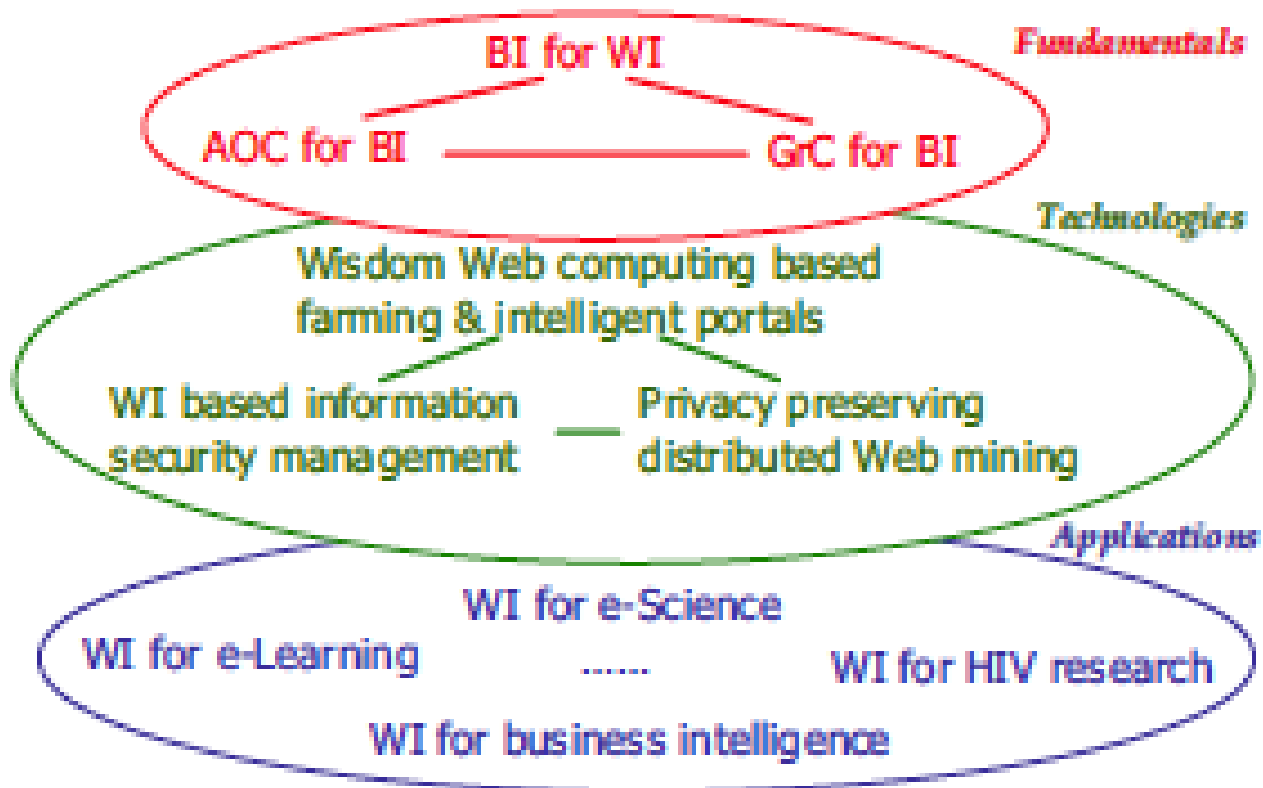
Brain Informatics

The relationship between WI and BI research

Brain Informatics

Three facets of WI related research and development

Web Intelligence meets Brain Informatics

Switch to WIMBI slides

Granular Computing – Introduction

Granular computing is a growing information processing paradigm in computational intelligence and human-centric systems. Granular computing research has attracted many practitioners. Granular computing was initially called information granularity or information granulation related to fuzzy sets research (Zadeh 1979). The term granular computing first appeared in 1997 in Zadeh's paper where it was defined as "a subset of computing with words". It is generally accepted that 1997 is considered as the birth of granular computing. Although the term granular computing is new, the basic notions and principles of granular computing occurred under various forms in many disciplines and fields (Yao, 2001, Zadeh, 1997).

Zadeh LA, Toward a theory of fuzzy information granulation and its centrality in human reasoning and fuzzy logic, Fuzzy Sets And Systems 90 (2): 111-127, 1997
Yao YY, Information granulation and rough set approximation, International Journal of Intelligent Systems 16 (1): 87-104, 200

Granular Computing – Introduction

Similar views are shared by research in belief functions, artificial intelligence, cluster analysis, chunking, data compression, databases, decision trees, divide and conquer, fuzzy logic, interval computing, machine learning, structured programming, quantization, quotient space theory, and rough set theory

Granular computing is often loosely defined as an umbrella term to cover any theories, methodologies, techniques, and tools that make use of granules in complex problem solving. Zadeh considers granular computing as basis for computing with words, i.e., computation with information described in natural language. Yao views granular computing as a complementary and dependant triangle: structured thinking in philosophical perspective, structured problem solving in methodological perspective and structured information processing in computational perspective.

Granular Computing – Introduction

An important aspect in granular computing is to view granular computing as human-centric intelligent systems. Human-centered information processing was initiated with the introduction of fuzzy sets. Such insights have led to the development of the granular computing paradigm. From machine-centered to human-centered approaches is considered one of the trends in GrC research.

The basic ingredients of granular computing are granules such as subsets, classes, objects, clusters, and elements of a universe. These granules are composed of finer granules that are drawn together by distinguishability, similarity and functionality. Based on complexity, abstraction level and size, granules can be measured in different levels. The problem domain, i.e., the universe, exists at the highest and coarsest granule. Granules at the lowest level are composed of elements of the particular model that is used.

Granular Computing – Introduction

Granulation is one of the key issues in granular computing for problem solving. The original meaning of granulation from dictionaries is the act or process of forming something into granules. It is a process of making a larger object into smaller ones. Zadeh adopted this idea to decompose a universe to granules and pointed out "granulation involves a decomposition of whole into parts. Conversely, organization involves an integration of parts into whole." Based on this definition, there will be two operations in granular computing, i.e., granulation and organization.

Granulation involves two directions in problem solving: construction and decomposition. The construction involves the process of forming a larger and higher level granule with smaller and lower level sub-granules. The decomposition involves the process of dividing a larger granule into smaller and lower level granules.

Granular Computing – Introduction

The former is a bottom-up process and the latter a top-down process. The reason for a more general and broad view of granulation is that construction and decomposition are tightly related. When one chooses a particular granulation in an application, the benefits and efficiency of one direction is correlated to its opposite direction. If we consider a decomposition operation without the consideration of construction we may end up with a very efficient decomposition operation and a very inefficient construction.

In order to conduct granulation, it is crucial to understand relationships amongst granules. We may classify granular relationships into two groups: interrelationship and intrarelationship.

Granular Computing – Introduction

Decomposition divides a larger granule into smaller granules from which a larger granule can still be formed with construction. Construction groups smaller granules that share similarity, indistinguishability, and functionality to a larger granule. The relationship involved in the former granulation is considered as interrelationship, the latter intrarelationship. In other words, interrelationship is the basis of grouping small objects together while intrarelationship is the foundation of dividing a granule into smaller ones. Refinement and coarsening are additional types of relationships.

Granular Computing – Introduction

A granule o1 is defined as a refinement of another granule o2, or equivalently, o2 is a coarsening of o1, if every sub-granule or object of o1 is contained in some sub-granules of o2. Partitions and coverings are two simple and commonly used granulations of a universe. A partition of a universe is a collection of its non-empty and pairwise disjoint subsets whose union is the universe. It forms a covering if it is not disjoint. The subsets are called covering granules in a covering, and partition granules in a partition.

Granular Computing – Recent Developments in Granular Computing

Representative and influential research in granular computing are briefly summarized:

Philosophic and fundamental views of granular computing

Defining granular computing is one of the important research tasks for this community. Instead of simply defining what is granular computing research, Yao views the scope of granular computing from three perspectives, namely, the philosophical perspective, methodological perspective and computational perspective. It is argued that with each perspective focusing on different aspects of granular structures, the three perspectives working together will provide a more general and complementary view of granular computing.

Granular Computing – Recent Developments in Granular Computing

The philosophical perspective concerns structured thinking. The methodological perspective concerns structured problem solving. The computational perspective concerns structured information processing. Granular computing also focuses on the application of its theory to knowledge-intensive systems. The representation and processes of a system are two things to consider. Representation of a system describes the granules and granular structures within the application domain.

Human-centered and fuzzy information processing

Human-centered information processing was initiated with fuzzy sets. The insights have led to the development of the granular computing paradigm (Bargiela & Pedrycz, 2008; Zadeh, 1997). Shifting from machine-centered approaches to human-centered approaches is a trend in granular computing research.

Granular Computing – Recent Developments in Granular Computing

Granular computing adopts a structured combination of algorithmic and non-algorithmic information processing that mimics human, intelligent synthesis of knowledge from information. By integrating various different agents in which each pursues its own agenda, exploits its environment, develops its own problem solving strategy and establishes required communication strategies, one may form a more effective human-centered information system. In fact, each agent may encounter a diversity of problem-solving approaches and realize their processing at the level of information granules that is the most suitable from their local points of view. To this level, the hybrid model raises a fundamental issue of forming effective interaction linkages between the agents so that they fully broadcast their findings and benefit from interacting with others.

Granular Computing – Recent Developments in Granular Computing
Rough-Granular Computing

Rough set theory plays an important role in granular computing. Recent work studies the formation of granules with different criteria from a rough computing point of view (Skowron & Stepaniuk, 2007). When searching for optimal solutions satisfying some constraints, one of the challenges is that these constraints are often vague and imprecise. In addition, specifications of concepts and dependencies involved in the constraints are often incomplete. Granules are built in computations aimed at solving such optimization tasks. General optimization criterion based on the minimal length principle was used. In searching for (sub-)optimal solutions, it is necessary to construct many compound granules using some specific operations such as generalization, specification or fusion. These criteria can be based on the minimal length principle, can express acceptable risk degrees of granules, or can use some utility functions.

Granular Computing – Recent Developments in Granular Computing

minimal length principle The minimum description length (MDL) principle is a powerful method of inductive inference, the basis of statistical modeling, pattern recognition, and machine learning. It holds that the best explanation, given a limited set of observed data, is the one that permits the greatest compression of the data. MDL methods are particularly well-suited for dealing with model selection, prediction, and estimation problems in situations where the models under consideration can be arbitrarily complex, and overfitting the data is a serious concern.

The minimum description length principle is a formalization of Occam's Razor in which the best hypothesis for a given set of data is the one that leads to the best compression of data. MDL was introduced by Rissanen in 1978. It is an important concept in information theory and learning theory.

Granular Computing – Recent Developments in Granular Computing

Dominance-based Rough Set Approach

The dominance-based rough set approach is another representation of rough set-based granular computing methodology. It extends the classical rough set approach by utilizing background knowledge about ordinal evaluations of objects and about monotonic relationships between these evaluations (Slowinski, Greco & Matarazzo, 2007) The indiscernibility or tolerance relation among objects, which is used in the classical rough set approach, has been replaced by the dominance relation: the only relation uncontested in multi-attribute pair-wise comparisons when attribute scales are ordered. In addition, the fuzzy-rough approximations taking into account monotonic relationships between memberships to different sets may be applied to case-based reasoning.

Granular Computing – Recent Developments in Granular Computing

Other Important Research Directions

Topological views of granular computing are also attracting some researchers. For instance, Zhu (2007) studies covering-based rough sets from the topological view.

Yager (2007) adopted granular computing on information fusion applications. In particular, fuzzy sets are used to provide a granular representation of uncertain information about a variable of interest.

Zhang & Zhang (2004) proposed a theoretical framework of a fuzzy reasoning model under quotient space structure. The quotient space structure is introduced into fuzzy sets to construct fuzzy set representations of different grain-size spaces and their relationships.

Granular Computing – Recent Developments in Granular Computing

Liu et al. studied granular computing from a rough logic aspect (Liu, Sun & Wang, 2007). The granulation is based on the meaning of a rough logical formula in a given information system. It is suggested that the practicability of the granulations will offer a new idea for studying the meaning of classical logic and the meaning of other nonstandard logic.
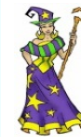
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Concluding Remarks

I'd like -

I'd like to know
what this whole show
is all about
before it's out