Associative Networks

Carlos García Martínez

Outline

- Introduction
- Conceptual dependency
- Propositional Networks
- Causal Networks

Introducción

- **Associative Nets:** Knowledge representation paradigm where ideas are expressed by means of nodes and arcs (graphs)
- Initially, they were oriented for natural language processing (***Semantic networks***)
- Nowadays, they are employed in many different applications

Characteristics

- Common characteristics:
  - Nodes often stand for concepts, entities, attributes, events or states
  - Several Nodes may stand for the same concept
  - Arcs create connections between nodes (relations)
- Differing characteristics:
  - Node and Arc semantics
  - Inference capacities
  - Notation

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Conceptual Dependency

- Schank, 1972, 1975. Proposed to tackle the natural language processing problem.

- Characterístics:
  - It does not depend on the language, in contrast to other models
  - ***It represents concepts instead of terms***

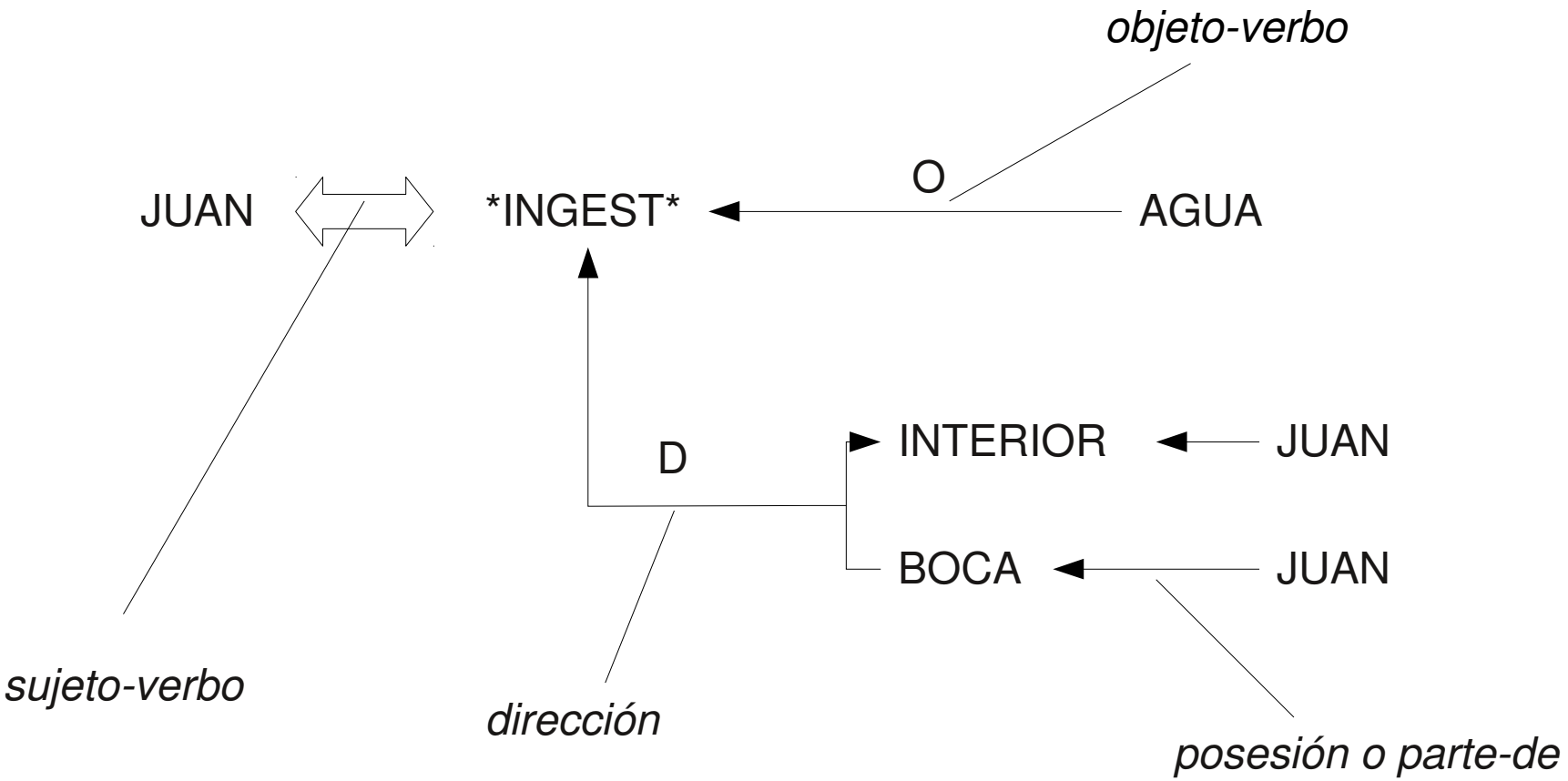
Model

- It constructs sentences by means of:
  - Six ***Conceptual Categories***:
    - Physical object
    - Action
    - Attributes of objects (adjectives)
    - Attributes of actions (adverbs)
    - Time of a conceptualization
    - Location of a conceptualization
  - 16 ***realization rules*** that links the elements of a sentence
  - A set of ***primitives*** (12 primitives are enough to represent most of natural language)

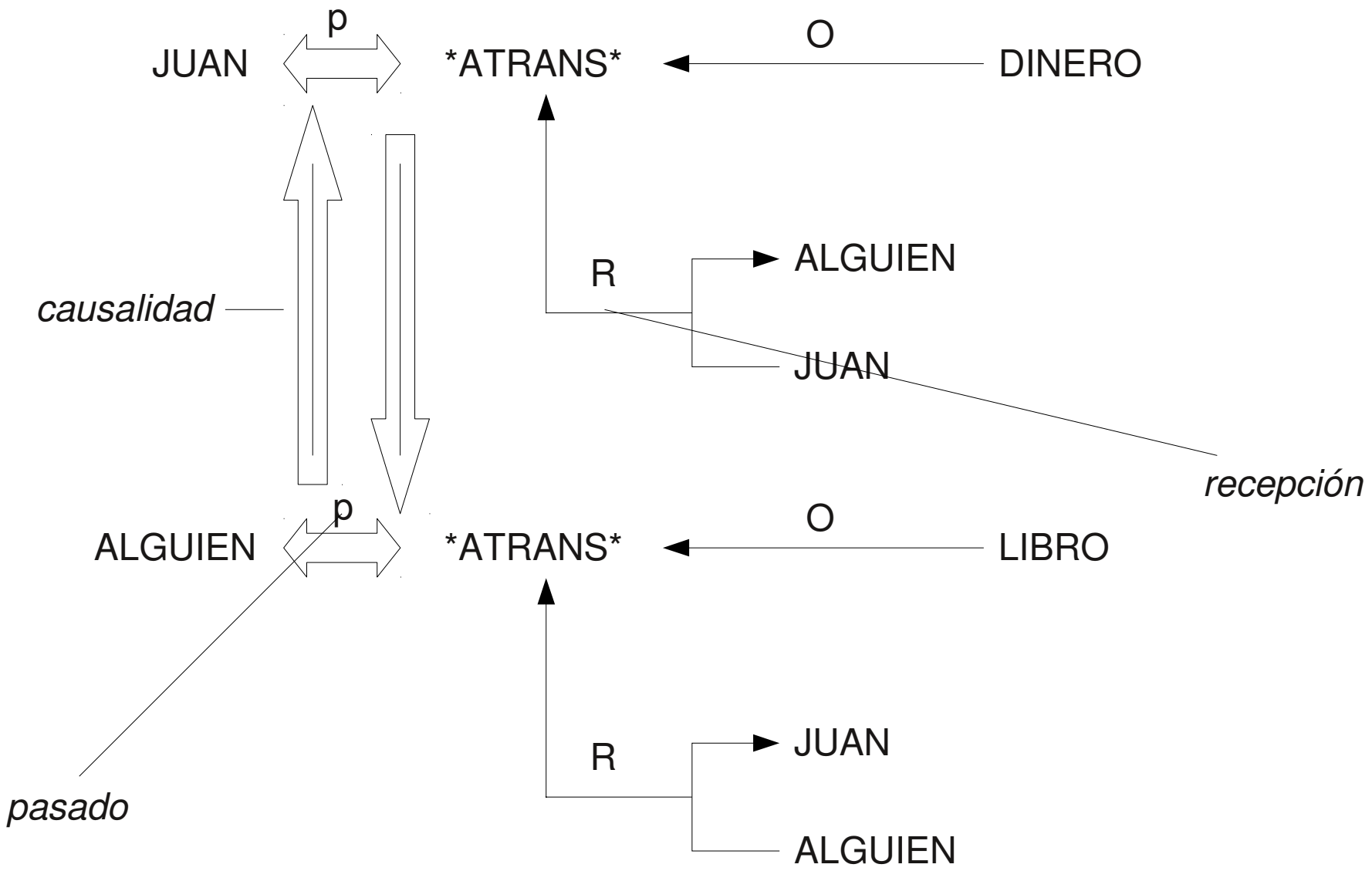
Basic primitives

- PTRANS: Transfer of the physical location of an object (go, move an object...)
- ATRANS: Transfer of an abstract relationship (give, lend...)
- MTRANS: Transfer of mental information (tell, teach...)
- PROPEL: Application of a physical force to an object (push)
- MOVE: Movement of a body part by owner (kick)
- GRASP: Actor grasping an object (clutch)
- INGEST: Actor ingesting an object (eat)
- Etc.

Example: Juan drinks water



Ejemplo: Juan compró un libro



Advantages

- Sentences are divided in elements that do not depend on the language
- A limited set of primitives allow us to:
  - associate knowledge and representation in just one way
  - design an interpreter that performs inferences
- Inferences capacities:
  - *It affirms conditions*: Juan exists and filete exists
  - *It may guess causes / intentions*: “Juan pidió el libro a Marta” ⇨ “Marta tenía un libro” y “Juan quería ese libro”.
  - *It deducts results*: “Juan comió un filete” ⇨ “Filete dejó de existir”.

Drawbacks

- More primitives lead to an efficiency reduction
- Critiques to using primitives:
  - The meaning of a phrase depends on the language it is formulated
  - The graphs represent a too detailed situation. Simple sentences ⇨ Complex graphs
  - How to determine the number and meaning of the primitives needed?
  - It focus the attention on verbs

Drawbacks of Relational Graphs

- There are sentences that can be represented by logic, but not by relational graphs
  - You can not represent the universal quantifier
- It is difficult to represent the interaction of propositions:
  - Night comes and temperature falls (two actions at the same time)
  - If it is night and foggy, it is dangerous to drive (It can not be represented)

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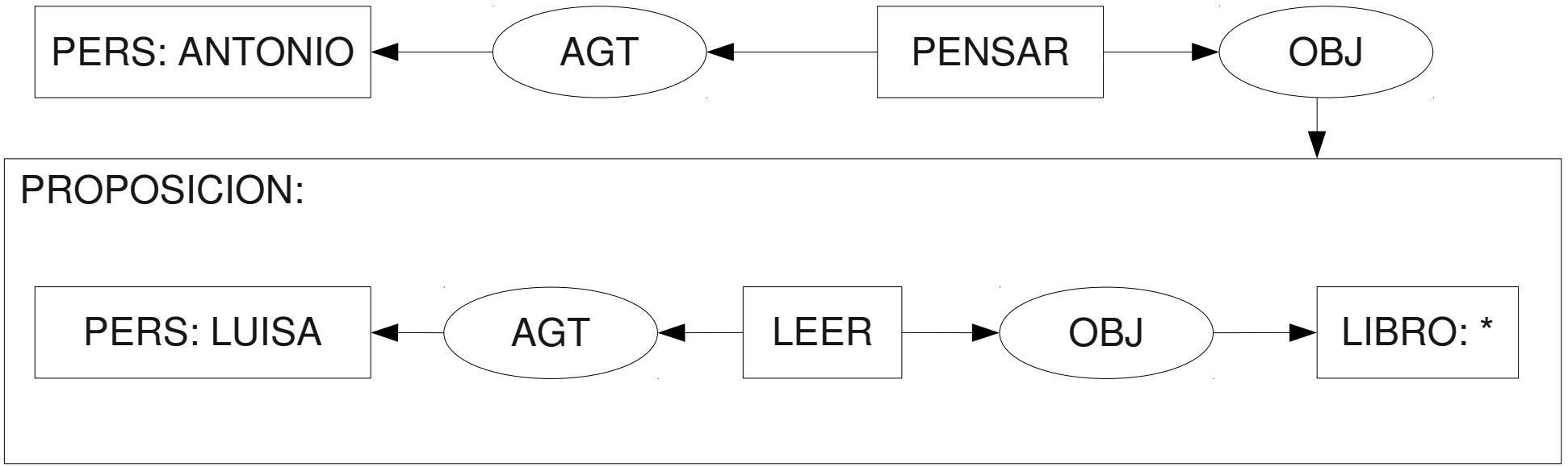
Sowa's Conceptual Structures

- They can draw contextual situations gathering up nodes in rectangles



Linear Notation

- Shapiro's nets and conceptual structures can be expressed in a linear notation:

[PENSAR] -
→ (AGT) → [PERS: Antonio]
→ (OBJ) → [PROPOSICION: [LEER] -
→ (AGT) → [PERS: Luisa]
→ (OBJ) → [LIBRO]]

Linear Notation Examples

- Un río: [RÍO: *] ≡ [RÍO]
- Un río caudaloso: [RÍO] → (ATR) → [CAUDALOSO]
- Algunos ríos: [RÍO: {*}]
- Tres ríos: [RÍO: {*}@3]
- El río (uno específico): [RÍO: #]
- ¿Qué río?: [RÍO: ?]
- El río Ebro: [RÍO: Ebro]
- Los ríos Duero y Tajo: [RÍO: {Duero, Tajo}]
- Todo río, todos los ríos: [RÍO: ∀]
- Cinco litros de agua:

  [AGUA] → (MEDIDA) → [CANTIDAD: 5L.]

Linear Notation Examples

- Las 10 de la mañana: [HORA: 10 a.m.]

- Todos los seres humanos son mortales:
  [PERS: ∀] → (ATR) → [MORTAL]

- Algún ser humano es mortal:
  [PERS] → (ATR) → [MORTAL]

- Él no ha venido:
  (NEG) ← [PROPOSICIÓN: [VENIR]
  → (AGT) → [HOMBRE: #]
  → (PASADO)]

Linear Notation Examples

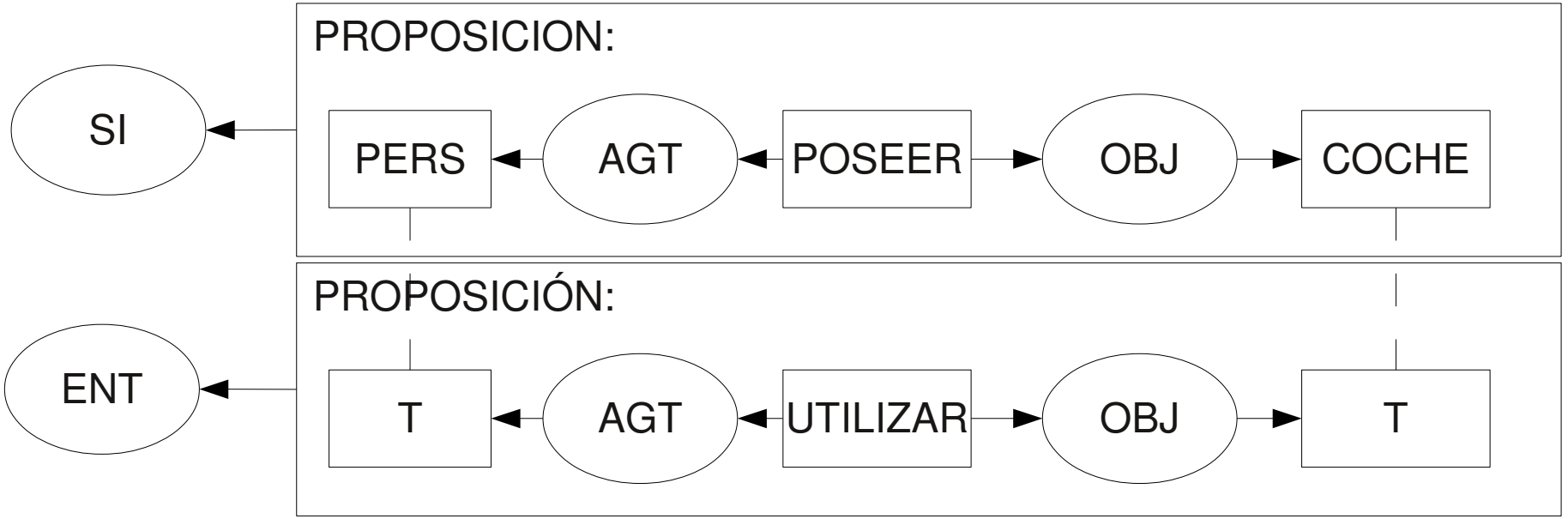
- Probablemente iré mañana:
  [PROBABLE] ← (MOD) ← [PROPOSICIÓN: [IR]
  → (AGT) → [PERS: #yo]
  → (TIEMPO) → [DÍA: #mañana]

- ¿Quién es el profesor de Luis?:
  [PERS: ?] → (PROFESOR-DE) → [PERS: Luis]

- ¿Dónde está tu libro?:
  [LUGAR: ?] ← (LOC) ← [LIBRO: #] → (POS) → [PERS: #tú]

Variables

CONDICIONAL



[CONDICIONAL:
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→ (AGT) → [T: *x]
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Variables

[DECIR]
→ (AGT) → [PERS: Ana]
→ (RCP) → [PERS: #él]
→ (OBJ) → [PROPOSICIÓN: [SUSPENDER]
→ (OBJ) → [CLASE: #] *y]
→ (PASADO)

[COMENTAR]
→ (AGT) → [#él]
→ (RCP) → [PERS: Luis]
→ (OBJ) → [*y]
→ (PASADO)

Summary

Conceptual Structures consist of three types of elements:

- ***Generic concepts:*** BOOK, PERSON, THINK
- ***Individual concepts:*** [PERSON: #me]
- ***Conceptual relations:***
  - Unit: PAST, NEG, etc
  - Binary: AGT, OBJ, RCV, ATTR, LOC, MEASURE, MOD, TEMP, THEACHER-OF etc
  - Ternary: BETWEEN

Inference Engine

- **Specialization:** To obtain a particular proposition from a general one by specializing some elements.
- **Generalization:** Opposite to specialization.
- **Union and simplification:** It is similar to the resolution principle in logic

Inference Examples

G1: [PERS:∀] ← (AGT) ← [BEBER] → (OBJ) → [AGUA]

specialization

G2: [PERS: Marta] ← (AGT) ← [BEBER] → (OBJ) → [AGUA]
G3: [NIÑA] ← (AGT) ← [BEBER] → (OBJ) → [AGUA]

specialization

G4: [NIÑA: Marta] ← (AGT) ← [BEBER] → (OBJ) → [AGUA]

G5: [NIÑA:Marta] ← (AGT) ← [BEBER] → (INSTR) → [VASO]

union and simplification

G6: [BEBER]
→ (AGT) → [NIÑA: Marta]
→ (OBJ) → [AGUA]
→ (INSTR) → [VASO]

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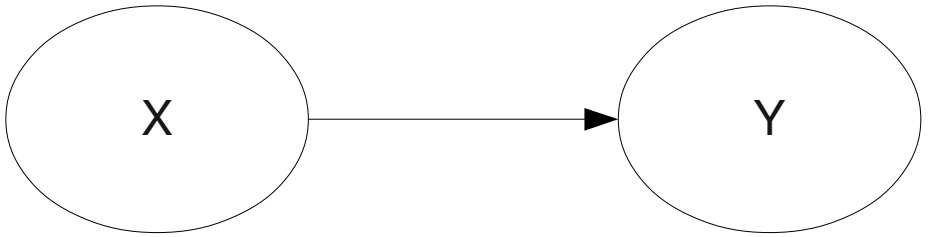
Causal Networks

- They consist of:
  - Nodes = variables
  - Links = ***influence relations*** between variables
- Often used in diagnostic problems



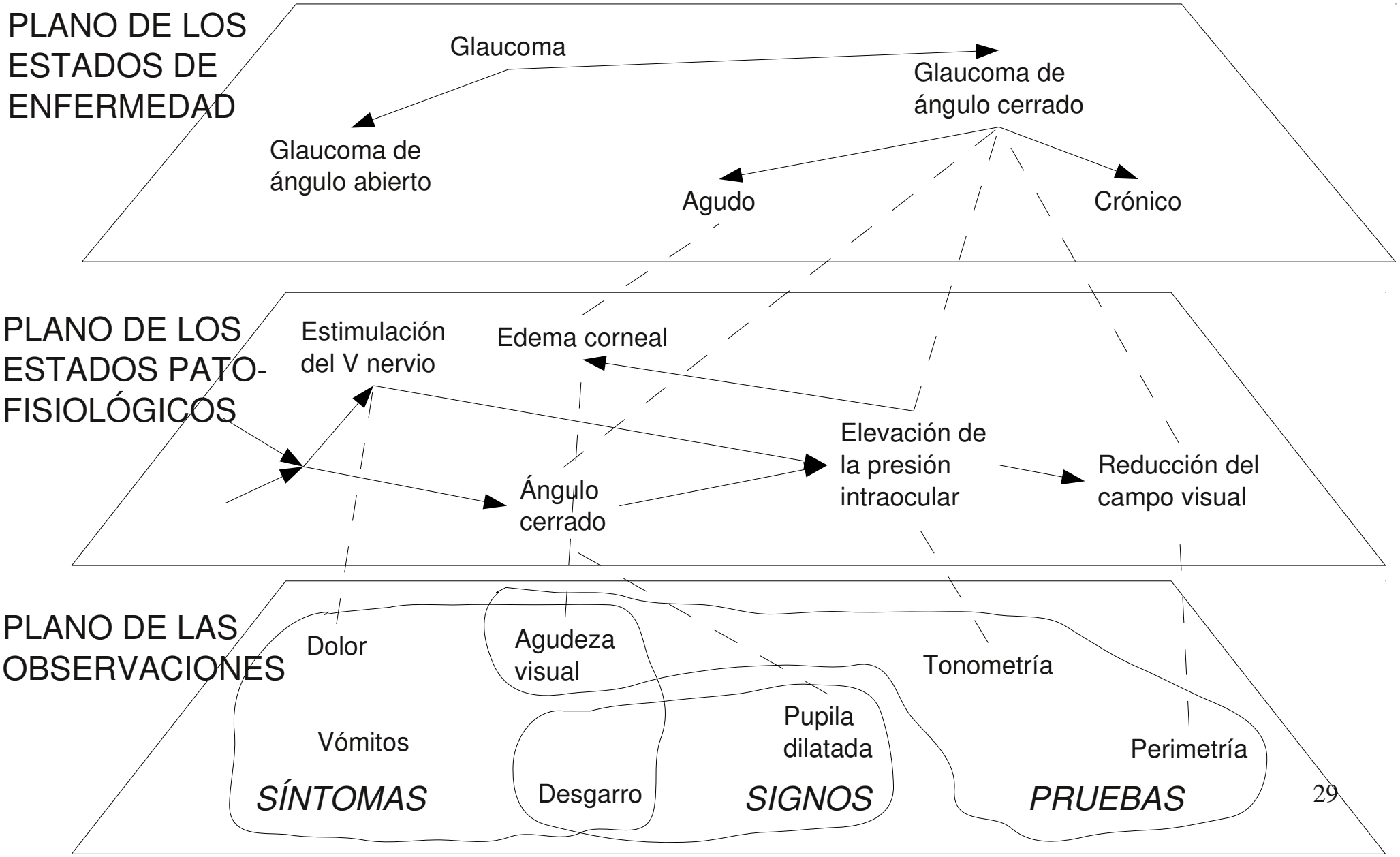
CASNET

- Casual Associational NETwork, 1970.
- Objective: to help when diagnosing and treating glaucoma and ***eye diseases***
- Advantages over other expert systems:
  - ***Temporal reasoning:*** it takes into account the evolution of the disease
  - ***Multiple diagnostic***
  - ***It explains its conclusions***

Diagnostic Network

- Nodes are placed in three levels:
  - **Observations:**
    - Symptoms (whatever patient feels)
    - Signs (whatever doctor perceives)
    - Results of laboratory tests
  - **Pathological states:** disfunction of organs
  - **Illness states:** structured by means of a taxonomic tree
- Inter-level and Intra-level links with associated ***causal factors***

CASNET


PLANO DE LOS ESTADOS DE ENFERMEDAD
Glaucoma
Glaucoma de ángulo cerrado
Glaucoma de ángulo abierto
Agudo
Crónico
PLANO DE LOS ESTADOS PATO-FISIOLÓGICOS
Estimulación del V nervio
Edema corneal
Elevación de la presión intraocular
Reducción del campo visual
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PLANO DE LAS OBSERVACIONES
Dolor
Agudeza visual
Tonometría
Pupila dilatada
Vómitos
Perimetría
Desgarro
SÍNTOMAS
SIGNOS
PRUEBAS

Diagnosis and Therapy

- There are two types of diagnosis:
  - Pathological states (simple).
  - Illness
- It also offer ***therapeutic recommendations*** in another plane where nodes are therapies and links can relate:
  - therapies with pathological or illness estates
  - therapies among them (interactions, toxicity and temporal dependencies)

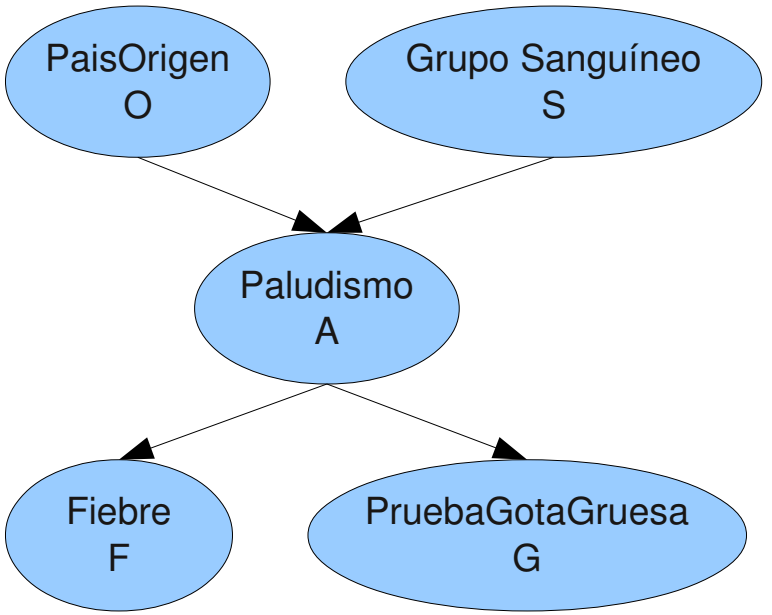
Bayesian Networks: Model

- It is a connex acyclic directed graph with an associated probability distribution on its variables, which fulfils graphical property of ***directed-separation.***
- For each node, designer has to provide the probabilities of its values conditioned to the values of its parent nodes

$$P(x_i) \qquad P(x_i | \{parents(x)\})$$

Example

- Let it be the following network with the following probabilities P(O), P(S), P(A | O, S), P(F | A), P(G | A)



- Conditional independence ⇨ P(F | A, O, S, G) = P(F | A)
- P(O,S,A,F,G) = P(O) P(S) P(A | O, S) P(F | A) P(G | A)

Directed Separation Property

- If two sets of nodes X and Y are d-separated in the graph by a third set Z, then, they are independent given the values of nodes in Z
- A path (undirected) is d-separated by set Z if:
  - it contains a chain i->m->j and m is in Z, or
  - a chain i<-m<-j and m is in Z
  - a chain i<-m->j and m is in Z
  - a chain i->m<-j and no descendant of m is in Z, neither m
- It allows to work with probabilities without the necessity of exponential amounts of information

Bayes' Theorem (1)

- Given the *a priori* probability of one hypothesis $P(B_i)$ and the conditional hypothesis $P(A|B_i)$, we can obtain the probability of the following hypothesis:

$$P(B_i|A) = \frac{P(A|B_i) \cdot P(B_i)}{P(A)} = \frac{P(A|B_i) \cdot P(B_i)}{\sum_{j=1}^{n} P(A|B_j) \cdot P(B_j)}$$

- If we have P(Flu) y P(Fever | Flu), P(Fever | Constipation) ..., we can infer P(Flu | Fever).
- $\{B_j \mid j = 1, ..., n\}$ forms a partition of the event space

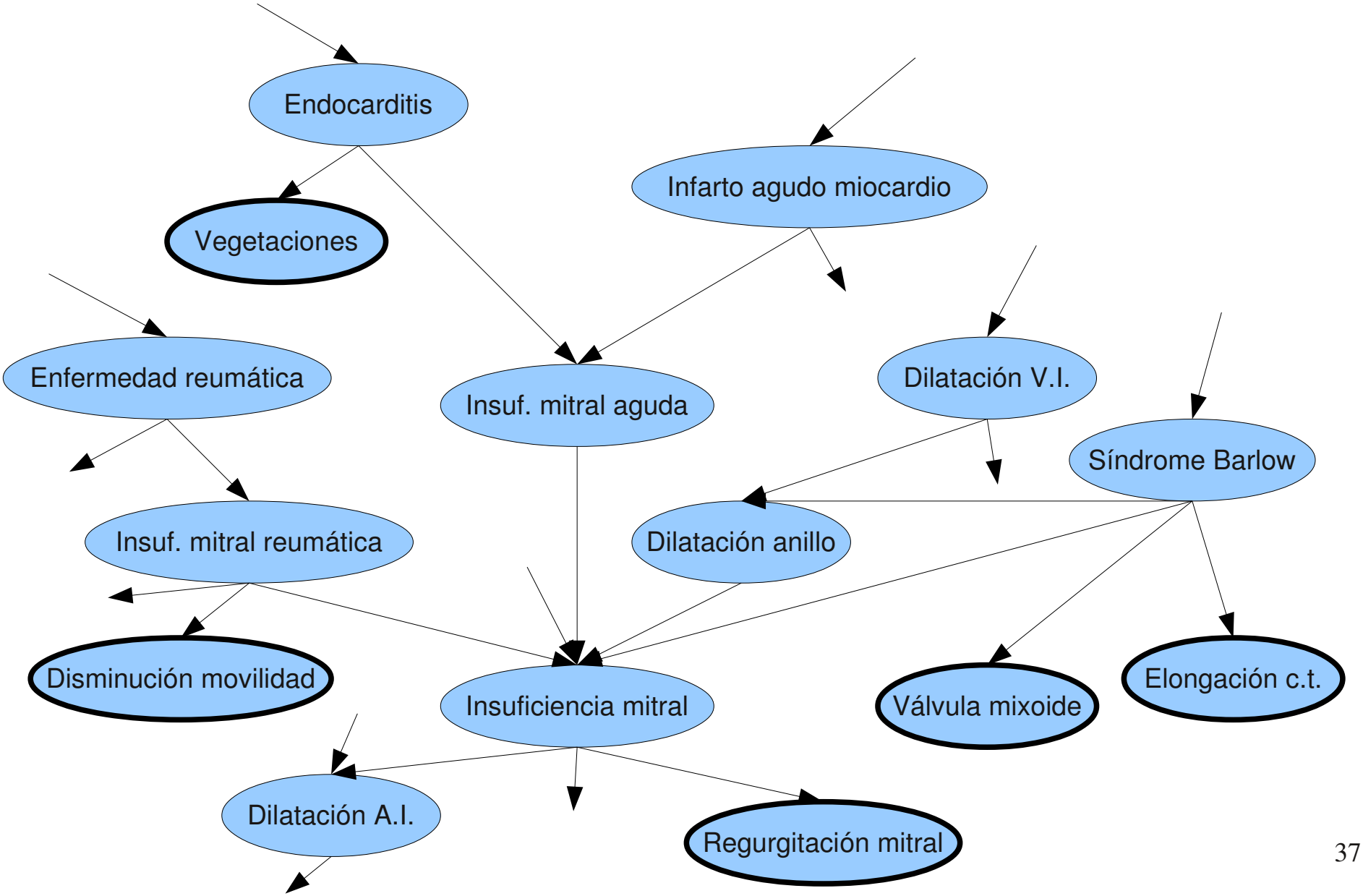
Bayesian Networks: Advantages

- They hold the advantages derived from the classic probabilistic model
- ***They efficiently computes probabilities***
- ***They did not include rare suppositions***
- They present a high modularity level, which allow them to locally compute probabilities

DIAVAL Expert System

- First Spanish Expert System
- It diagnoses heart diseases
- It takes into account:
  - Patient data
  - Antecedents
  - Symptoms and signs
  - Clinic tests' results (echocardiogram).
- It consist of 300 nodes

The Bayesian Network



Inference

- It consists in fixing the value of some nodes (observations) and computing the probability of the interesting variables (diagnostics)

- Example

Advantages of DIAVAL

- It stores a deep knowledge of the internal processes
- It can ***explain the causal chain of anomalies*** from the diagnosed illness to the observations
- It can perform ***three types of reasoning***:
  - *Adductive*: To diagnose from observations (upward).
  - *Deductive*: It takes into account inheritable diseases (downward).
  - Intercausal: It looks for some causes from another ones (horizontal).
- It is based on a solid probability theory

Drawbacks of Bayesian Networks

- ***Limited range of applications***:
  - They are good diagnosing
  - They do not fit well planning, control or design problems
- They still a huge amount of information (probabilities)
- Loops complicate computing. Researchers propose stochastic simulation methods

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Basic primitives

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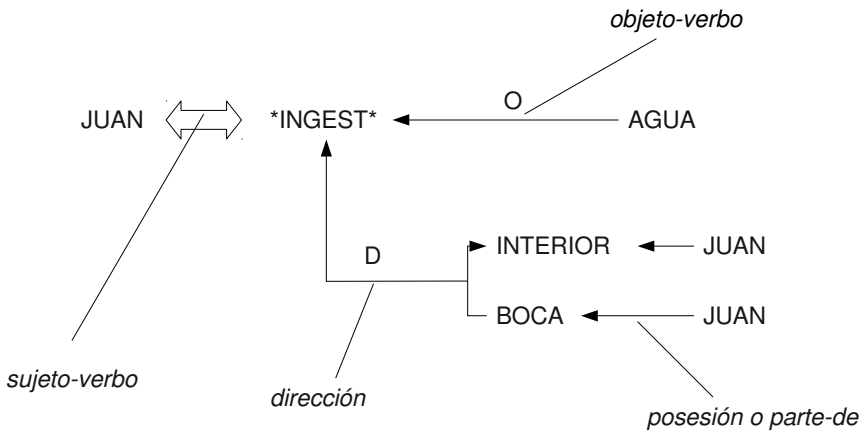

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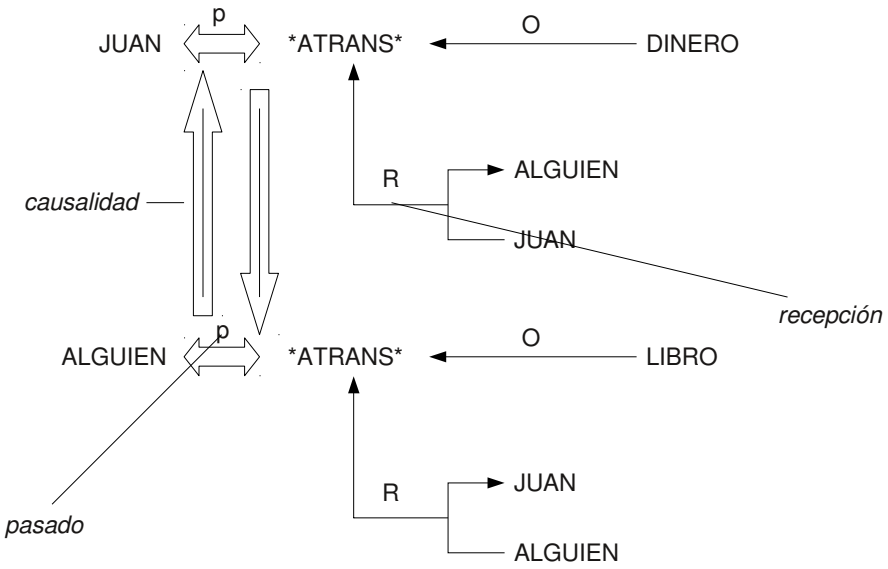

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Drawbacks of Relational Graphs

- There are sentences that can be represented by logic, but not by relational graphs
  - You can not represent the universal quantifier
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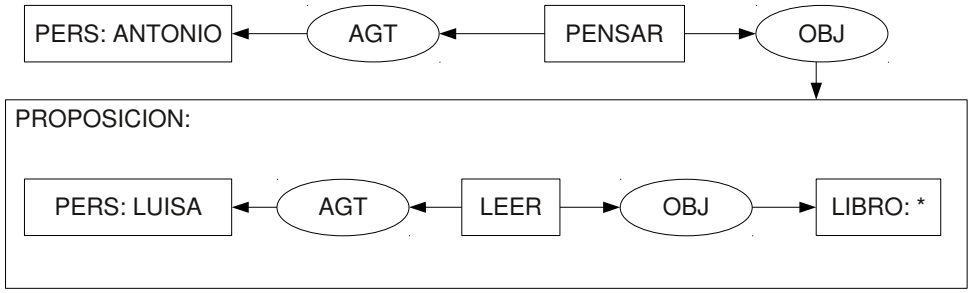

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- Todo río, todos los ríos: [RÍO: ∀]
- Cinco litros de agua:

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- Probablemente iré mañana:
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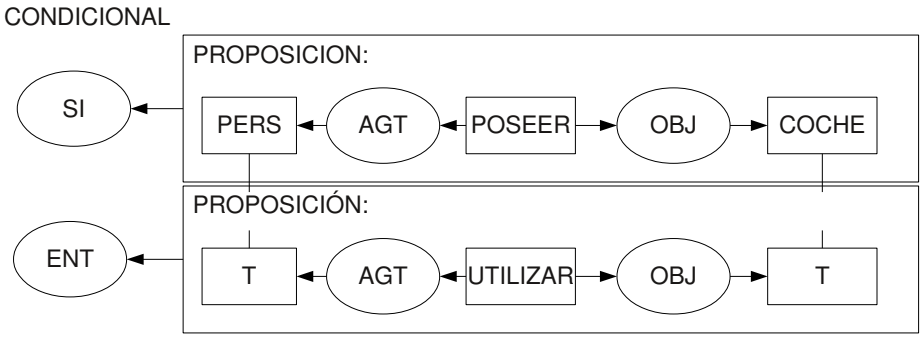
  → (AGT) → [PERS: #yo]
  → (TIEMPO) → [DÍA: #mañana]

- ¿Quién es el profesor de Luis?:
  [PERS: ?] → (PROFESOR-DE) → [PERS: Luis]

- ¿Dónde está tu libro?:
  [LUGAR: ?] ← (LOC) ← [LIBRO: #] → (POS) → [PERS: #tú]

Variables



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Variables

[DECIR]
- → (AGT) → [PERS: Ana]
- → (RCP) → [PERS: #él]
- → (OBJ) → [PROPOSICIÓN: [SUSPENDER]
  - → (OBJ) → [CLASE: #] *y]
- → (PASADO)

[COMENTAR]
- → (AGT) → [#él]
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- → (OBJ) → [*y]
- → (PASADO)

Summary

Conceptual Structures consist of three types of elements:

- ***Generic concepts:*** BOOK, PERSON, THINK
- ***Individual concepts:*** [PERSON: #me]
- ***Conceptual relations:***
  - Unit: PAST, NEG, etc
  - Binary: AGT, OBJ, RCV, ATTR, LOC, MEASURE, MOD, TEMP, THEACHER-OF etc
  - Ternary: BETWEEN

Inference Engine

- **Specialization:** To obtain a particular proposition from a general one by specializing some elements.
- **Generalization:** Opposite to specialization.
- **Union and simplification:** It is similar to the resolution principle in logic

Inference Examples

G1: [PERS:∀] ← (AGT) ← [BEBER] → (OBJ) → [AGUA]

specialization

G2: [PERS: Marta] ← (AGT) ← [BEBER] → (OBJ) → [AGUA]
G3: [NIÑA] ← (AGT) ← [BEBER] → (OBJ) → [AGUA]

specialization

G4: [NIÑA: Marta] ← (AGT) ← [BEBER] → (OBJ) → [AGUA]

G5: [NIÑA:Marta] ← (AGT) ← [BEBER] → (INSTR) → [VASO]

union and simplification

G6: [BEBER]
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- They consist of:
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  - Links = ***influence relations*** between variables
- Often used in diagnostic problems

CASNET

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- Objective: to help when diagnosing and treating glaucoma and ***eye diseases***
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- Nodes are placed in three levels:
  - **Observations:**
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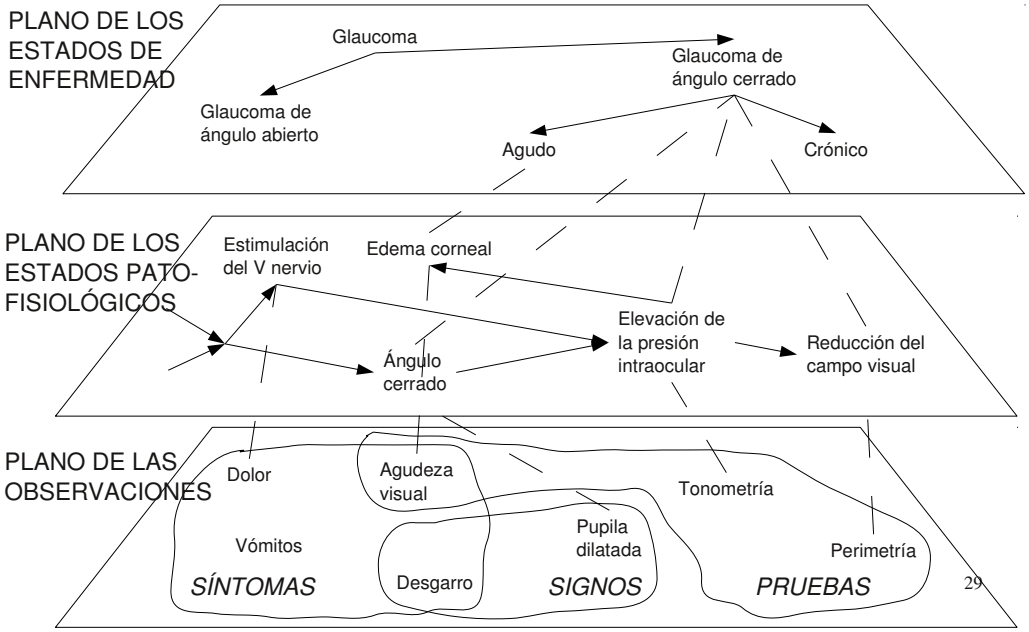
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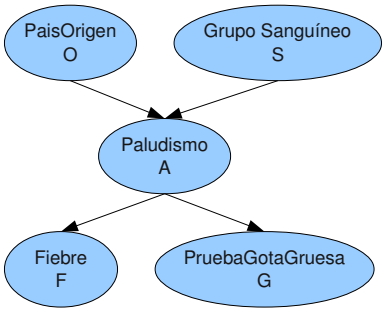
Example

- Let it be the following network with the following probabilities P(O), P(S), P(A | O, S), P(F | A), P(G | A)



- Conditional independence ⇨ P(F | A, O, S, G) = P(F | A)
- P(O,S,A,F,G) = P(O) P(S) P(A | O, S) P(F | A) P(G | A)

Directed Separation Property

- If two sets of nodes X and Y are d-separated in the graph by a third set Z, then, they are independent given the values of nodes in Z
- A path (undirected) is d-separated by set Z if:
  - it contains a chain i->m->j and m is in Z, or
  - a chain i<-m<-j and m is in Z
  - a chain i<-m->j and m is in Z
  - a chain i->m<-j and no descendant of m is in Z, neither m
- It allows to work with probabilities without the necessity of exponential amounts of information

Bayes' Theorem (1)

- Given the *a priori* probability of one hypothesis $P(B_i)$ and the conditional hypothesis $P(A|B_i)$, we can obtain the probability of the following hypothesis:

$$P(B_i|A) = \frac{P(A|B_i) \cdot P(B_i)}{P(A)} = \frac{P(A|B_i) \cdot P(B_i)}{\sum_{j=1}^{n} P(A|B_j) \cdot P(B_j)}$$

- If we have P(Flu) y P(Fever | Flu), P(Fever | Constipation) ..., we can infer P(Flu | Fever).
- $\{B_j \mid j = 1, ..., n\}$ forms a partition of the event space

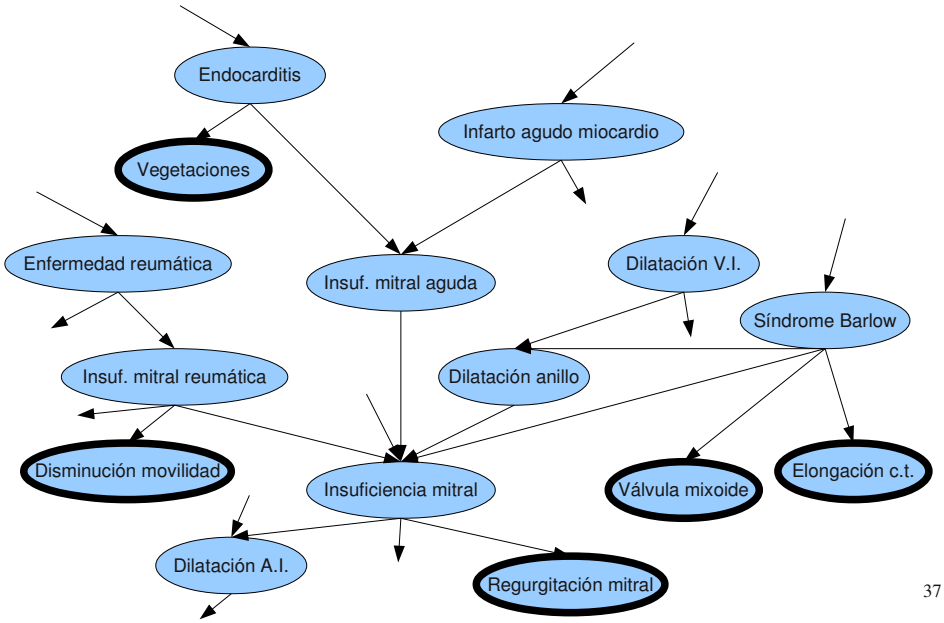
Bayesian Networks: Advantages

- They hold the advantages derived from the classic probabilistic model
- ***They efficiently computes probabilities***
- ***They did not include rare suppositions***
- They present a high modularity level, which allow them to locally compute probabilities

DIAVAL Expert System

- First Spanish Expert System
- It diagnoses heart diseases
- It takes into account:
  - Patient data
  - Antecedents
  - Symptoms and signs
  - Clinic tests' results (echocardiogram).
- It consist of 300 nodes

The Bayesian Network



Inference

- It consists in fixing the value of some nodes (observations) and computing the probability of the interesting variables (diagnostics)

- Example

Advantages of DIAVAL

- It stores a deep knowledge of the internal processes
- It can ***explain the causal chain of anomalies*** from the diagnosed illness to the observations
- It can perform ***three types of reasoning***:
  - *Adductive*: To diagnose from observations (upward).
  - *Deductive*: It takes into account inheritable diseases (downward).
  - Intercausal: It looks for some causes from another ones (horizontal).
- It is based on a solid probability theory

Drawbacks of Bayesian Networks

- ***Limited range of applications***:
  - They are good diagnosing
  - They do not fit well planning, control or design problems
- They still a huge amount of information (probabilities)
- Loops complicate computing. Researchers propose stochastic simulation methods