

---

# Consensus in Group Decision Making and Social Networks

**Enrique Herrera-Viedma**  
**Agora University of Oradea,**  
**May 14, 2020**

# Outline

---

- **Group decision making: Consensus**
- Social networks
- Consensus approaches in social networks
- Challenges

# Group Decision Making: Consensus

---

## Definition: Group Decision Making

Selecting the best alternative (or alternatives) from a finite set of feasible alternatives for the problem taking into account the preferences of a group of experts

## Main Components

- 1 Set of feasible alternatives for the problem:  
 $X = \{x_1, \dots, x_n\}, n \geq 2$
- 2 The solution set of alternatives (the best ones):  
 $S \mid S \subset X, S \neq \emptyset$
- 3 Group of experts:  $E = \{e_1, \dots, e_m\}, m \geq 2$
- 4 Preferences of the experts:  $\{P^1, \dots, P^m\}$

# Group Decision Making: Consensus

## Preference Representation Formats

### Several Possibilities

- ① Selection set of alternatives
- ② Preference orderings
- ③ Utility values
- ④ Preference relations
  - **Fuzzy Preference Relations**
  - Multiplicative preference relations
  - Interval-valued preference relations
  - Linguistic preference relations

# Group Decision Making: Consensus

## Fuzzy Preference Relations

### Definition:

A fuzzy preference relation  $P$  on a set of alternatives  $X$  is a fuzzy set on the product set  $X \times X$ , i.e., it is characterized by a membership function

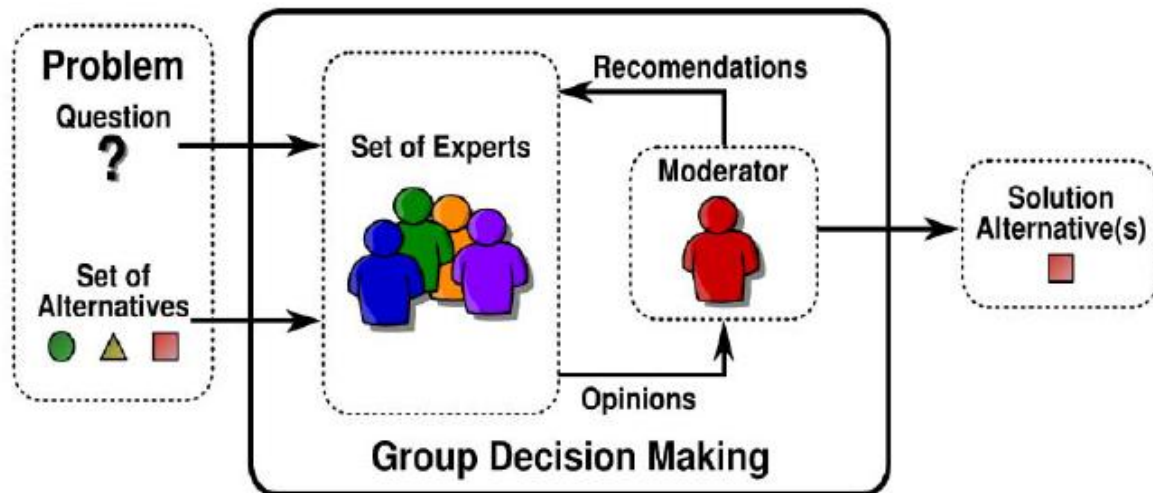
$$\mu_P: X \times X \longrightarrow [0, 1]$$

When cardinality of  $X$  is small,  $P$  may be represented by an  $n \times n$  matrix  $P = (p_{ij})$ , being  $p_{ij} = \mu_P(x_i, x_j) \forall i, j \in \{1, \dots, n\}$ .

- $p_{ik} = 1/2 \rightarrow$  indifference between  $x_i$  and  $x_k$  ( $x_i \sim x_k$ )
- $p_{ik} = 1 \rightarrow x_i$  is absolutely preferred to  $x_k$
- $p_{ik} > 1/2 \rightarrow x_i$  is preferred to  $x_k$  ( $x_i \succ x_k$ )

# Group Decision Making: Consensus

Consensus is an important subject in decision making processes with a group of individuals that want to make a decision together : **Group Decision Making (GDM)**

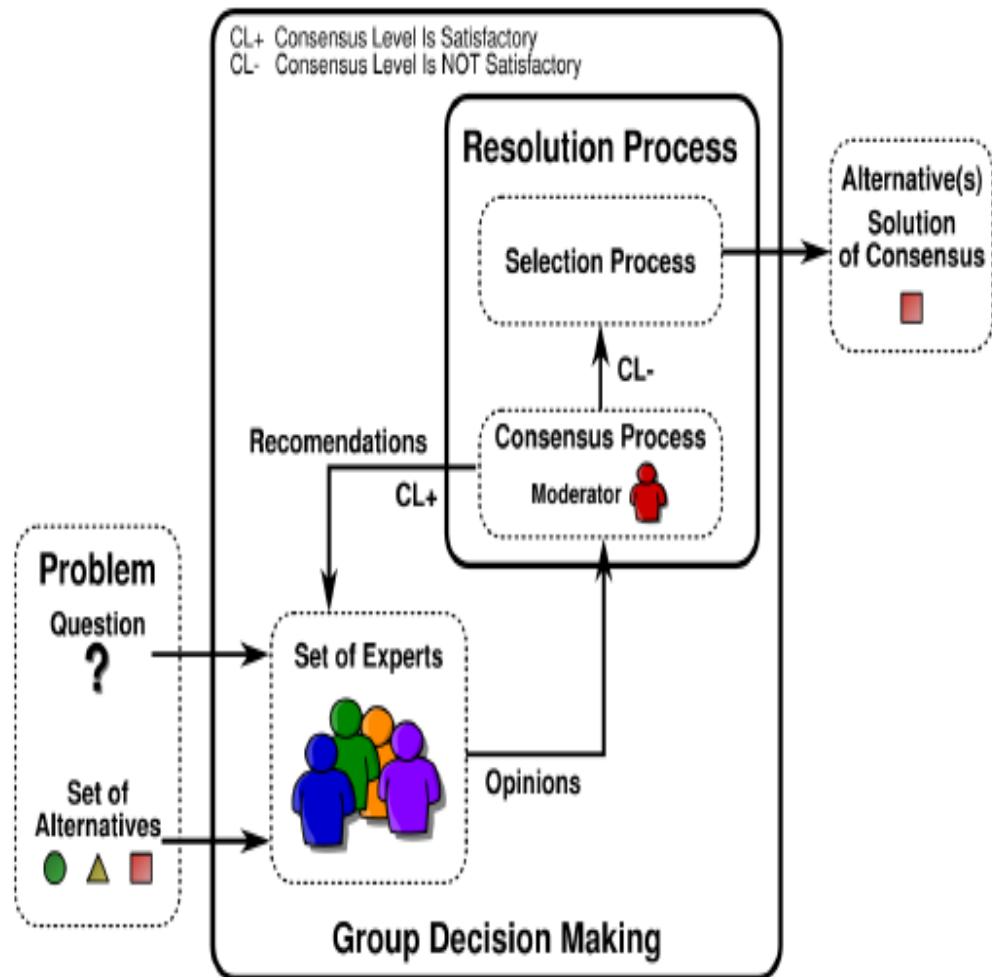


# Group Decision Making: Consensus

## Resolution Processes of GDM Problem:

**-Consensus Process:** To get the maximum agreement degree among experts' opinions

**-Selection Process:** To get the solution set of alternatives from consensus opinions



# Group Decision Making: Consensus

**Consensus reaching process**, is a discussion and deliberation process that includes a **multi stage negotiation**.

It is usually guided by means of **consensus measures**:

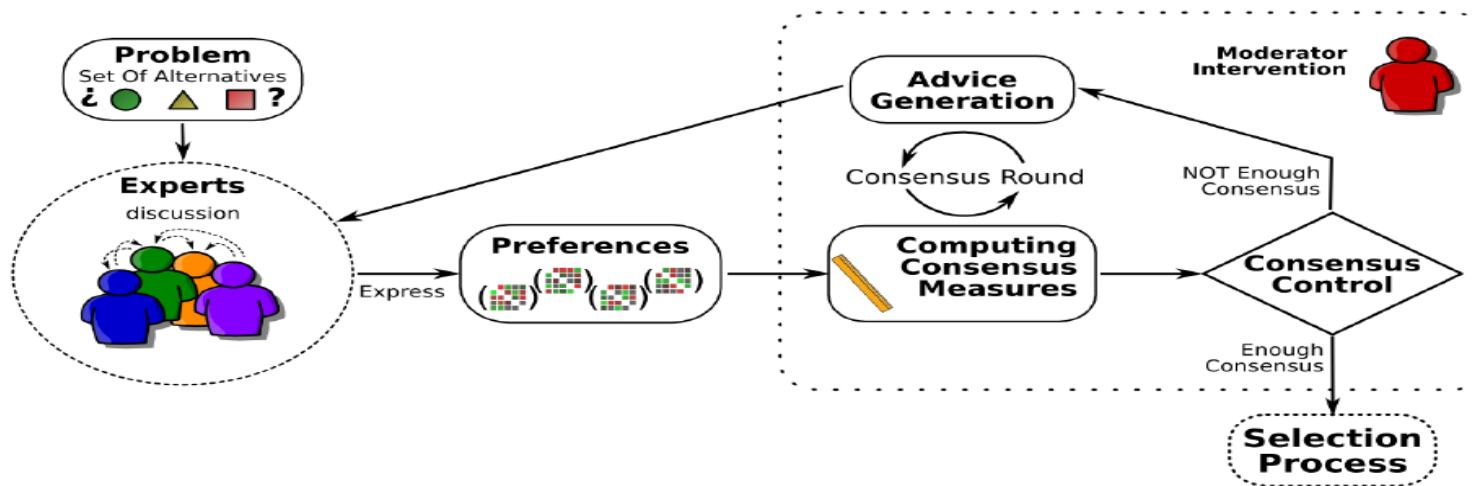


Figure 4.3: Consensus Process Scheme



# Group Decision Making: Consensus

---

## -Usual decision making contexts:

Users, alternatives, parameters, and algorithms of the decision making model **do not suffer changes** during the negotiation period developed in the different consensus rounds (STATIC DECISION FRAMEWORKS)

## -NEW DECISION MAKING CONTEXTS:

-Users interconnected in anywhere and anytime, e.g., using Web 2.0 tools. (**Dynamic contexts**)

-Users connected **in social networks** with additional information **TRUST**

# Outline

---

- Group decision making: Consensus
- **Social networks**
- Consensus approaches in social networks
- Challenges

# Social networks (SN): Definitions

---

1. A SN is a **theoretical construct useful in the social sciences** to study relationships between individuals, groups, organizations, or even entire societies
2. A SN is an **association of people** drawn together by family, work or hobby
3. In GDM a SN is like a **platform where users disseminate information and communicate with each other**, and we can study relationships among users using **Social Network Analysis**

# Social networks: SN Analysis (SNA)

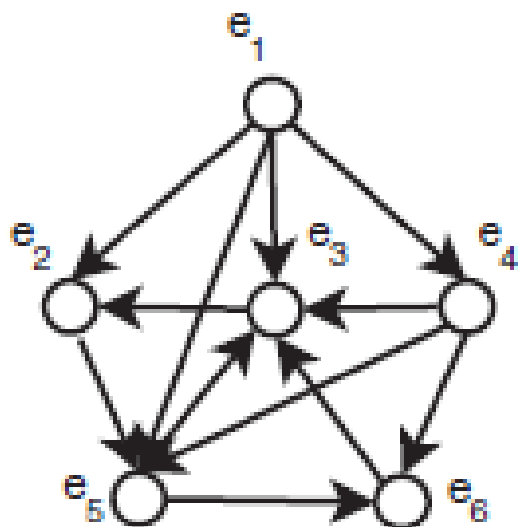
---

-**SNA** is the process of investigating social structures through the use of networks and graph theory. It characterizes a SN in terms of **nodes** (individual actors, people, or things within the network) and the **ties, edges, or links** (relationships or interactions) that connect them.

-**SNA** studies the structural and locational properties including centrality, prestige, structural balance, **trust relations** in a SN.

# Social Networks: Representation

Different notations in social network analysis.



Graph

$E_1 R E_2$     $E_4 R E_3$   
 $E_1 R E_3$     $E_4 R E_5$   
 $E_1 R E_4$     $E_4 R E_6$   
 $E_1 R E_5$     $E_5 R E_3$   
 $E_2 R E_5$     $E_5 R E_6$   
 $E_3 R E_2$     $E_6 R E_3$

Algebraic

$$A = \begin{pmatrix} 0 & 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 1 & 1 \\ 0 & 0 & 1 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 & 0 & 0 \end{pmatrix}$$

Sociometric

## Social networks:

# Properties that may influence a GDM context

---

### 1. Large user base:

- Richer and diverse knowledge, i.e., better decisions
- Large number of evaluations, i.e., difficult exploitation

### 2. Heterogeneous user base:

- Different representation formats and expression domains

### 3. Low participation and contribution rates:

- Many SN members are observers, i.e. non-cooperative behaviours, incomplete information

### 4. Intermittent contributions:

- Over time many SN members cease their contributions and new members join the GDM process

## Social networks:

# Properties of SN that may influence a GDM context

---

### **5. Real-time communication:**

-SN members can take part in the GDM process by means of mobile devices from any where and at any time, avoiding delays.

### **6. Difficulty of establishing trust relations:**

-SN members use mobile devices and do not know each other in person, i.e., greater difficulty in calculating trust or establishing voting delegation methods

# Outline

---

- Group decision making: Consensus
- Social networks
- **Consensus approaches in social networks**
- Challenges



# Consensus approaches in SN: Managing Trust Degrees and Relations

1. EXPERTS
2. PREFERENCE MODELLING
3. CONSENSUS REACHING PROCESS

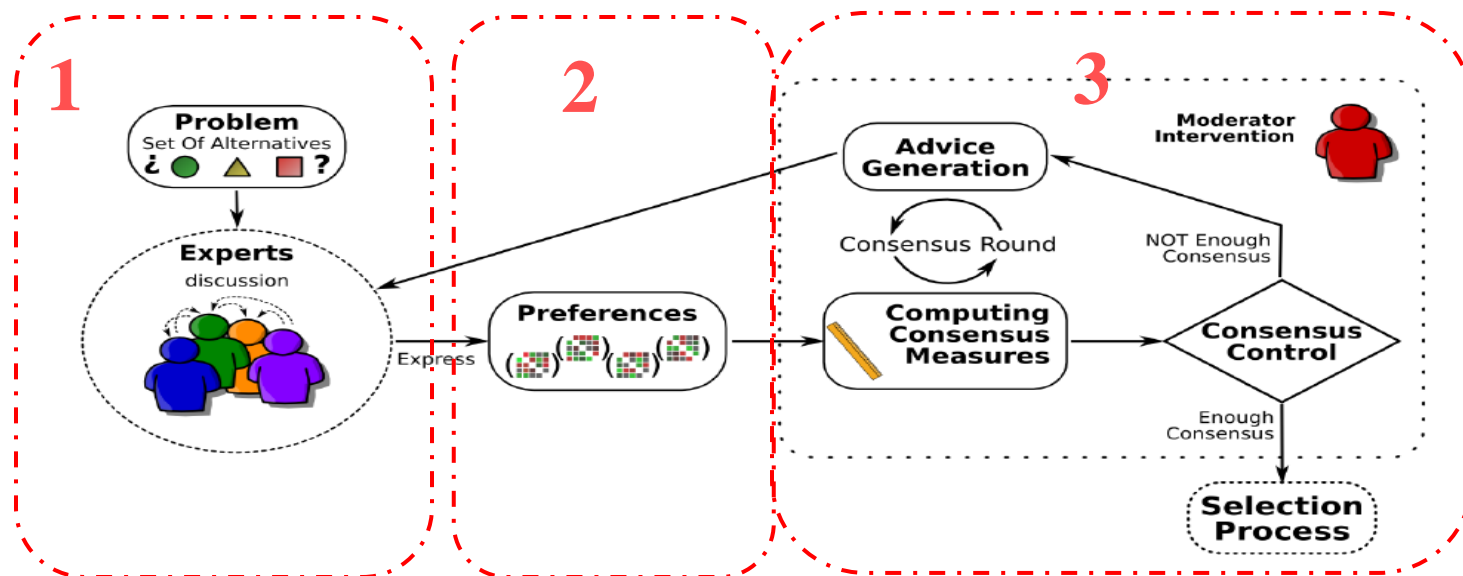
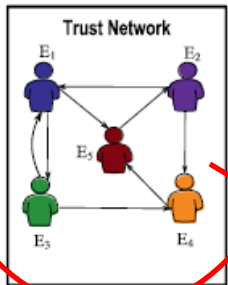


Figure 4.3: Consensus Process Scheme

# Consensus approaches in SN: Managing Trust Degrees and Relations

## 1. EXPERTS

Computing Trust degrees:  
**PROPAGATION**



Dynamic GDM processes:  
**VOTING DELEGATION**

Clustering of experts based on trust

Computing importance degrees using SN structural metrics:  
**CENTRALITY**

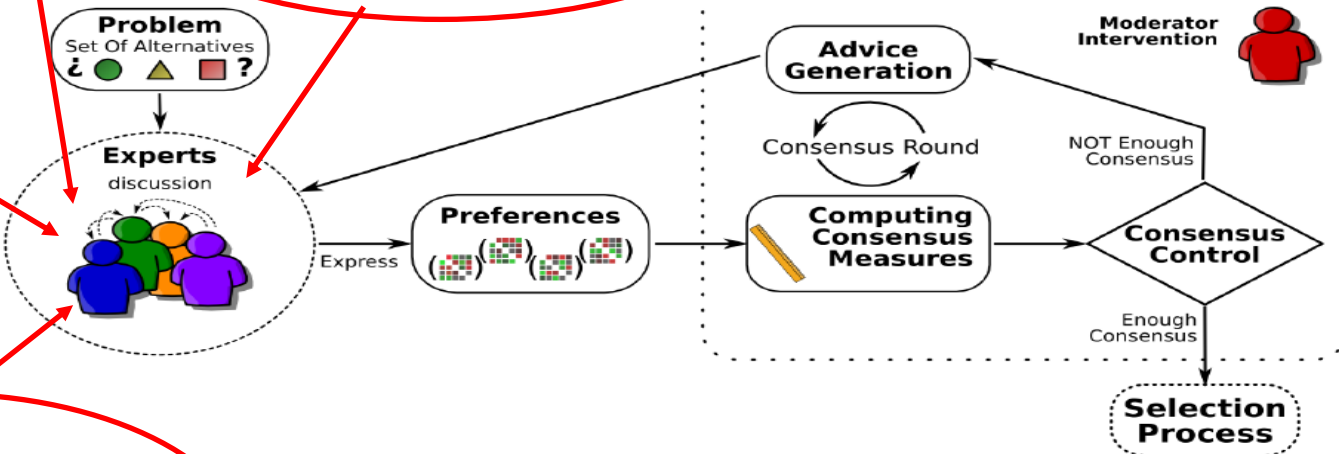


Figure 4.3: Consensus Process Scheme



## Managing Trust Degrees and Relations

---

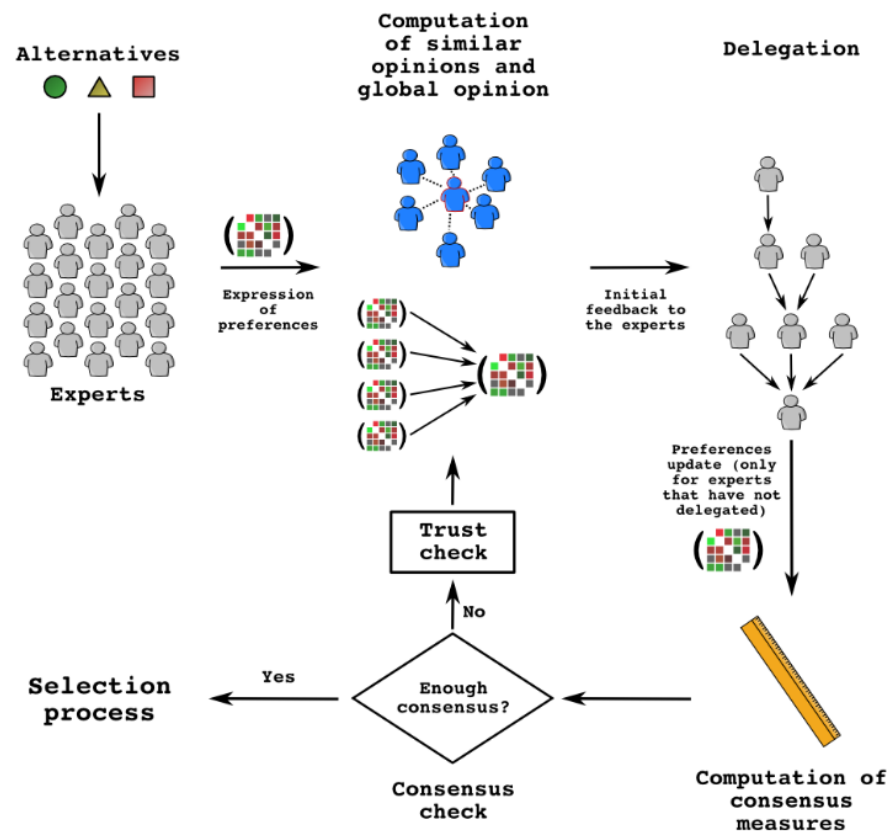
### 1. EXPERTS

- a) **Dynamic consensus models in SN-GDM:**
- b) **Computing trust degrees in SN-GDM:**
- c) **Computing importance degrees in SN-GDM:**
- d) **Clustering based consensus models in SN-GDM:**

# Consensus approaches in SN: Managing Trust Degrees and Relations

## -Dynamic consensus models in SN-GDM:

Alonso et al. in 2009, proposed a **delegation mechanism** that allows to update the experts set at each consensus stage using trust degrees.





# Consensus approaches in SN: Managing Trust Degrees and Relations

---

## -Computing trust degrees in SN-GDM:

**Wu et al.** in 2017 and 2016 proposed several **novel trust propagation method** to obtain trust relationships using **Induced OWA operators and Uninorms**, respectively.

*Wu, J., Chiclana, F., Fujita, H. & Herrera-Viedma, E. (2017). A visual interaction consensus model for social network group decision making with trust propagation. **Knowledge-Based Systems**, 122, 39-50.*

*Wu, J., Xiong, R. & Chiclana, F. (2016). Uninorm trust propagation and aggregation methods for group decision making in social network with four tuple information. **Knowledge-Based Systems**, 96, 29-39.*



## Managing Trust Degrees and Relations

---

### -Computing importance degrees in SN-GDM:

-**Brunelli et al. in 2014** proposed to compute the importance of the users in relation to their influence strength in a social network using a **centrality metric based on trust degrees**.

-**Wu and Chiclana in 2014** proposed to compute the user importance degrees by combining **both a consensus level and trust degrees**.

*Brunelli, M., Fedrizzi, M. & Fedrizzi, M. (2014). Fuzzy m-ary adjacency relations in social networks analysis: Optimization and consensus evaluation. **Information Fusion**, 17, 36-45.*

*Wu, J. & Chiclana, F. (2014). A social network analysis trust-consensus based approach to group decision-making problems with interval-valued fuzzy reciprocal preference relations. **Knowledge-Based Systems**, 59, 97-107.*



## Managing Trust Degrees and Relations

---

### -Clustering based consensus model in SN-GDM:

**Shang in 2017 and Han et al 2013** proposed both **clustering based consensus models by using trust relations** to establish different clusters of experts and showed that it is possible to achieve a much faster consensus.

*-Shang, Y. (2017). Finite-time cluster average consensus for networks via distributed iterations. **International Journal of Control, Automation and Systems**, 15(2), 933-938.*

*-Han, Y., Lu, W. & Chen, T. (2013). Cluster consensus in discrete-networks of multiagents with inter-cluster nonidentical inputs. **IEEE Transactions on Neural Networks and Learning Systems**, 24(4), 566-578.*

# Consensus approaches in SN: Managing Trust Degrees and Relations

## 2. PREFERENCE MODELLING

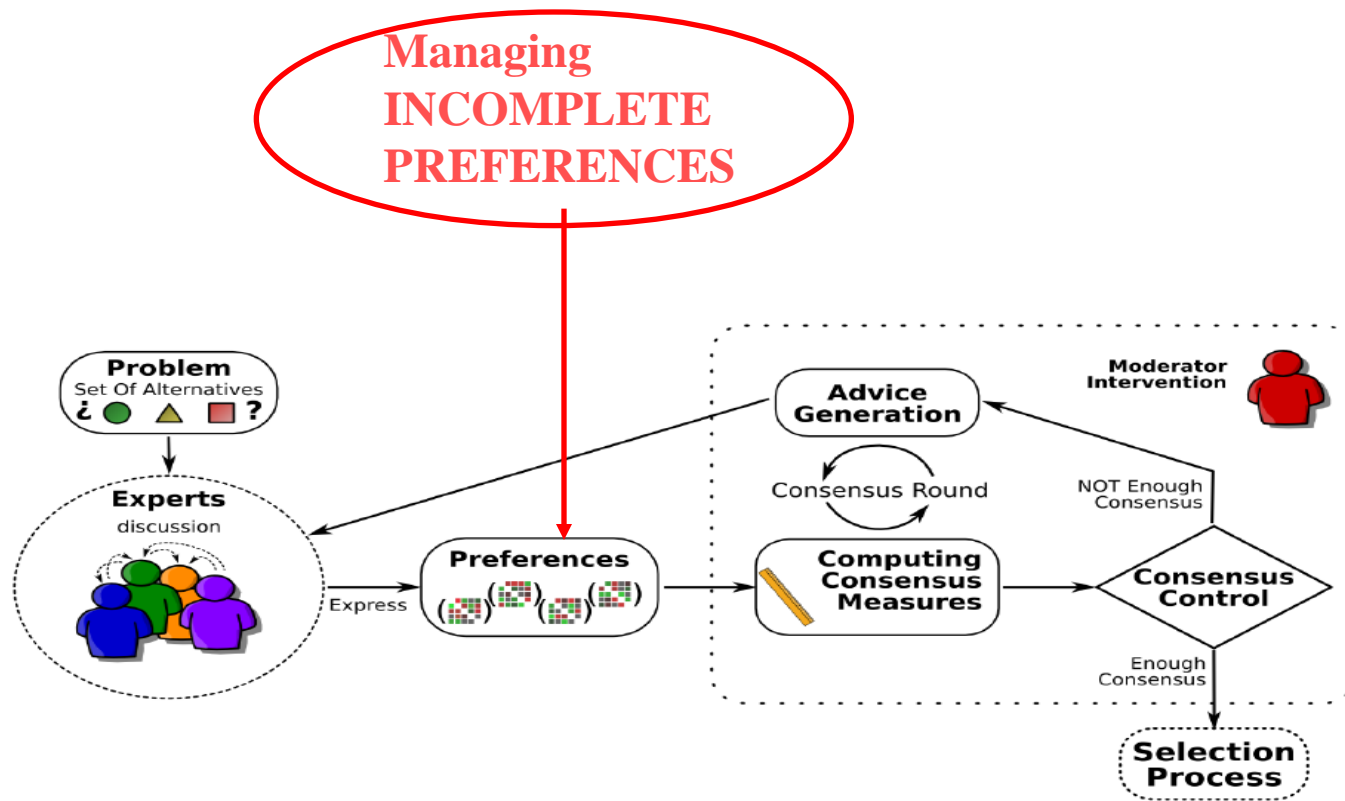


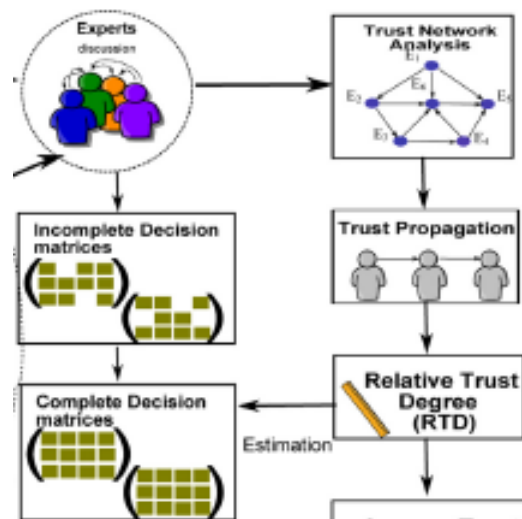
Figure 4.3: Consensus Process Scheme



# Consensus approaches in SN: Managing Trust Degrees and Relations

## Managing INCOMPLETE LINGUISTIC PREFERENCES:

Wu et al. in 2015 proposed a **new consensus model for GDM in SN for completing incomplete linguistic preferences using the trust relations existing among users.**



Wu, J., Chiclana, F. & Herrera-Viedma, E. (2015). Trust based consensus model for social network in an incomplete linguistic information context. *Applied Soft Computing*, 35, 827-839.

# Consensus approaches in SN: Managing Trust Degrees and Relations

## 3. CONSENSUS REACHING PROCESS

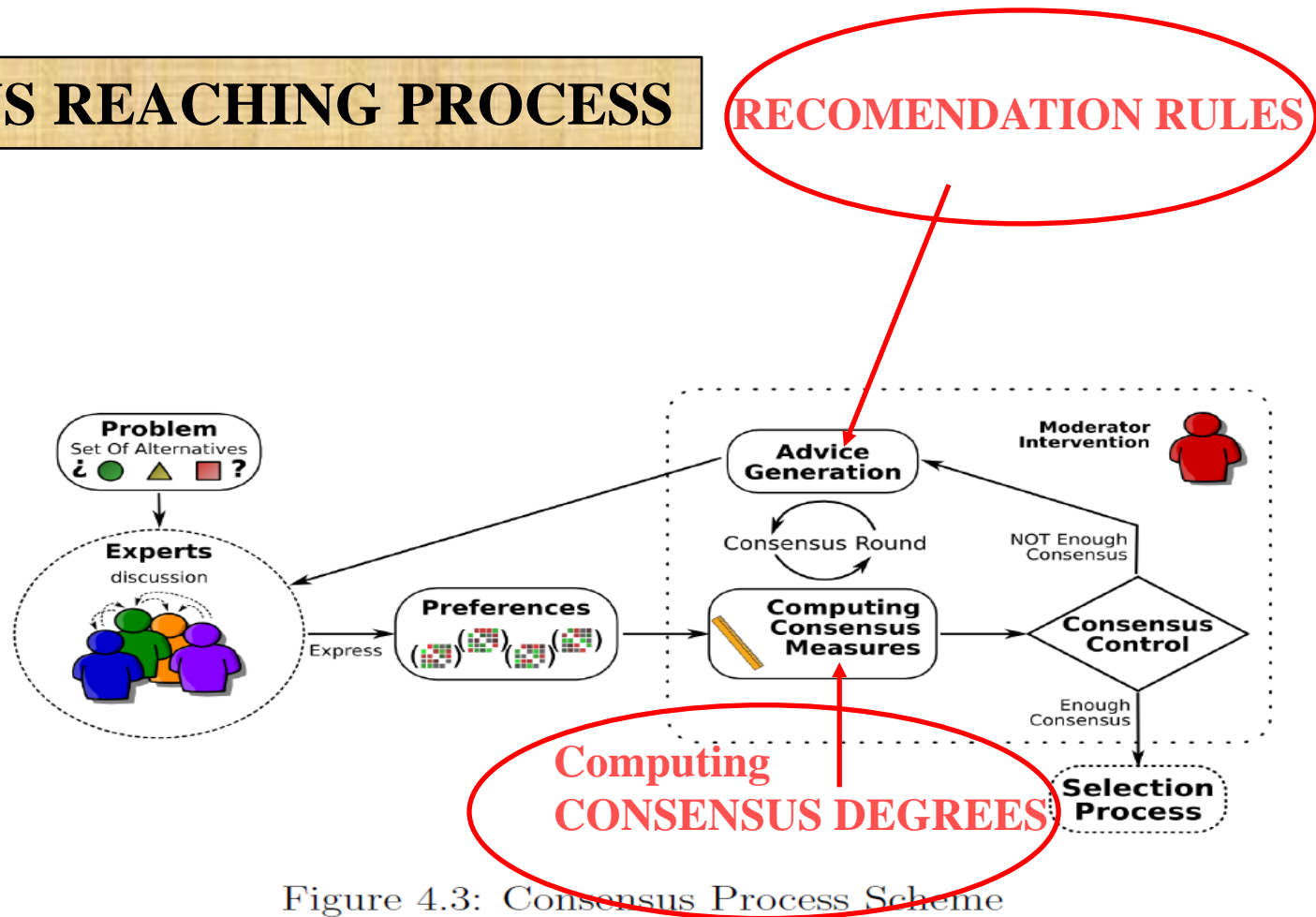


Figure 4.3: Consensus Process Scheme



## Managing Trust Degrees and Relations

---

### 3. CONSENSUS REACHING PROCESS

**a) Recommendation Mechanisms in SN-GDM:**

**b) Computing Consensus Degrees in SN-GDM:**

# Consensus approaches in SN: Managing Trust Degrees and Relations

---

## -Recommendation Mechanisms in SN-GDM (I)

1. Liu et al. in 2017 proposed a new trust induced recommendation mechanism that is focused on modifying inconsistent evaluations utilizing only assessments from the trusted users and not from the distrusted ones.
2. Li et al. in 2013 proposed a trust based recommendation tool that allows users exchange their judgments with their neighbours and move their judgments closer to each other if they have similar opinions.

*Liu, Y., Liang, C., Chiclana, F. & Wu, J. (2017). A trust induced recommendation mechanism for reaching consensus in group decision making. **Knowledge-Based Systems**, 119, 221-231.*

*Li, L., Scagllione, A., Swami, A. & Zhao, Q. (2013). Consensus, polarization and clustering of opinions in social networks. **IEEE Journal on Selected Areas in Communications**, 31(6), 1072-1083.*

# Consensus approaches in SN: Managing Trust Degrees and Relations

## -Recommendation Mechanisms in SN-GDM (II)

3. Dong et al. in 2017 proposed a new leadership based recommendation mechanism, i.e., the opinions are guided toward the leaders' opinions in the SN.

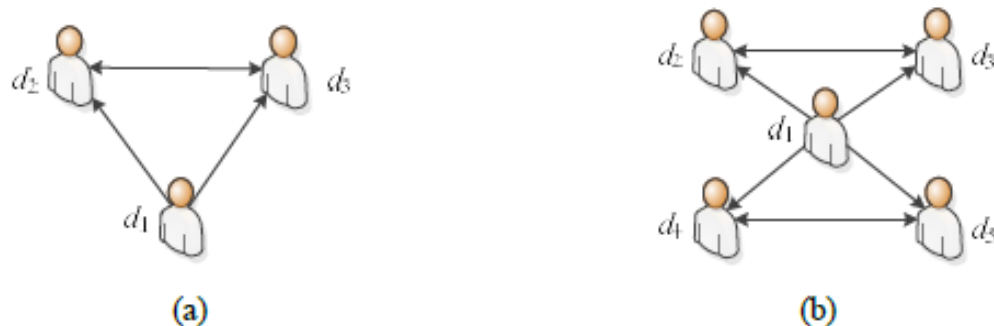


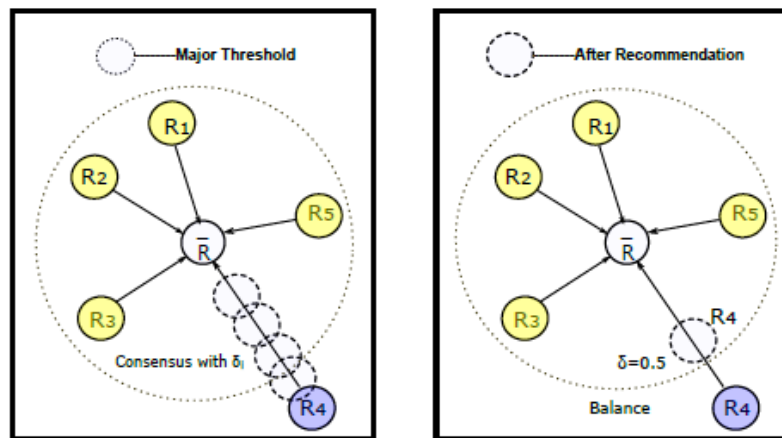
Fig.9. The opinion leaders in a social network

Dong, Y., Ding, Z., Martínez, L. & Herrera, F. (2017). Managing consensus based on leadership in opinion dynamics. *Information Sciences*, 397-398, 187-205.

# Consensus approaches in SN: Managing Trust Degrees and Relations

## -Recommendation Mechanisms in SN-GDM (III)

4. Wu et al. in 2017 proposed a trust based consensus model the visual recommendation mechanism that provides visual information representations by allowing users to choose their suitable feedback parameters to reach a balance between individual independence and group consensus.



(a) Visual recommendation simulation with  $\delta_i$

(b) Balance  $\delta_i$  between individual and group

Figure 5: Visual representation of consensus levels after implementation of recommended values

Wu, J., Chiclana, F., Fujita, H. & Herrera-Viedma, E. (2017). A visual interaction consensus model for social network group decision making with trust propagation. *Knowledge-Based Systems*, 122, 39-50.



## Managing Trust Degrees and Relations

---

### -Computing Consensus Degrees in SN-GDM:

**Brunelli et al. in 2014, proposed a new soft consensus measure computed taking into account the influence strength of the users in line with their eigenvector centrality based on trust.**

*Brunelli, M., Fedrizzi, M. & Fedrizzi, M. (2014). Fuzzy m-ary adjacency relations in social networks analysis: Optimization and consensus evaluation. **Information Fusion**, 17, 36-45.*

# Outline

---

- Group decision making: Consensus
- Social networks
- Consensus approaches in social networks
- **Challenges**



# Challenges in Consensus in SN

---

- **To deal with different preference structures to facilitate the expression of evaluations to the users**
  - For example, using numerical and linguistic domains and also different fuzzy preference modellings as hesitant fuzzy sets.
- **To deal with experts who do not accept the advice**
  - Models to manage **non cooperative experts opinions**
  - Using some **tools of influence (psychology)** to persuade them
  - Including some **arguments to the expert's preferences**
- **To deal with trust and distrust like in recommender systems**

# Publications

---

*E. Herrera-Viedma, F.J. Cabrerizo, F. Chiclana, J. Wu, M.J. Cobo, K. Samuylov.* Consensus in Group Decision Making and Social Networks. *Studies in Informatics and Control* 26:3 (2017) 259-268.

*Y. Dong, Q. Zha, H. Zhang, G. Kou, H. Fujita, F. Chiclana, E. Herrera-Viedma.* Consensus Reaching in Social Network Group Decision Making: Research Paradigms and Challenges. *Knowledge Based Systems*, Vol. 162, 15 December 2018, Pages 3-13.

# Questions?

---



Enrique Herrera Viedma: *viedma@decsai.ugr.es*

# Consensus approaches in SN: Managing Trust Degrees and Relations

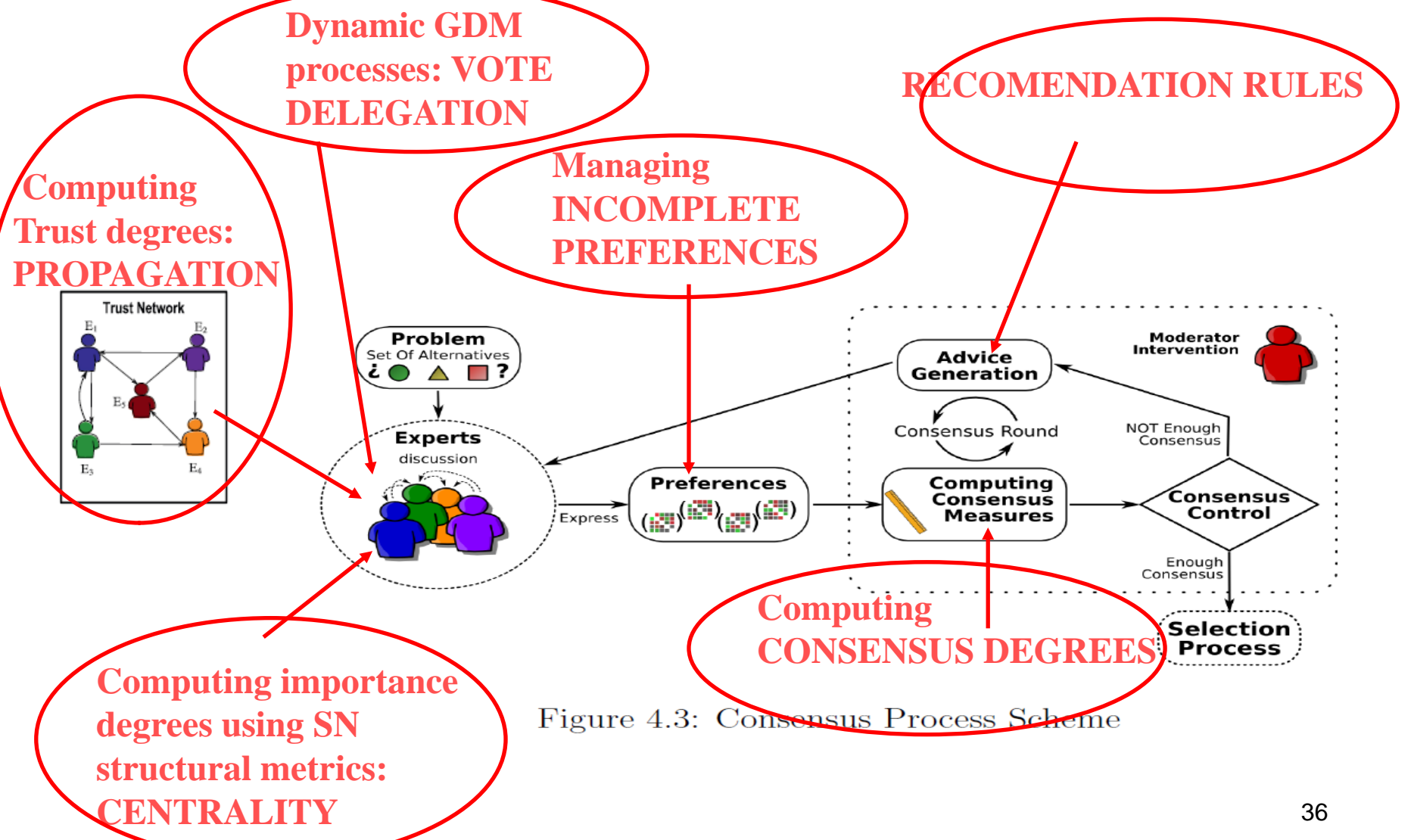


Figure 4.3: Consensus Process Scheme