Towards Temporal Conviviality Measures

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Abstract

In agents systems, conviviality measures quantify interdependence in social dependence relations, representing the degree in which the system facilitates social interactions. Moreover, a normative system is a mechanism to change conviviality by changing social dependencies, for example by creating new obligations. With the pervasive development of socio-technical systems, modelling such social settings has become increasingly important. We distinguish design time from run time measures. At design time, roughly, more interdependence increases conviviality among groups of agents or coalitions, whereas larger coalitions may decrease the efficiency or stability of these involved coalitions. At run time, we consider the extension to temporal dependence networks, that is, sequences of dependence networks. We distinguish dominance, volatility and entropy requirements for conviviality measures. We illustrate the use of our conviviality measures with examples from gaming.

1 Introduction

As software systems gain in complexity and increasingly mesh with the human social environment, models that can express the social characteristics of complex systems are more and more needed. For example, the composition of complex services in ambient intelligence applications, is often based on the dynamic agreements among groups of autonomous agents, or coalitions, which may collaborate at different levels and times [14].

In this paper, we are interested in two issues. The first one is the interdependence among the agents of a system, for example when service-oriented applications facilitate the exchange of business services among participants and established conviviality between them. Using dependence networks, such a transaction is represented by a simple cycle of two agents, each depending on the other for the exchange. In general, cycles represent possible ways to cooperate, indicating degree of choice or freedom to engage in coalitions. conviviality requirements measure interdependence in social dependence relations, representing the degree in which the system facilitates social interactions. The second issue we focus on is normative dependence networks, where some of the dependencies reflect obligations. For example, in strategic dependency diagrams, two crucial questions are raised regarding who are the relevant stakeholders and what are their obligations to other actor. Normative systems are mechanisms to obtain better system behavior. A normative multiagent system is a multiagent system together with normative systems in which agents on the one hand can decide whether to follow the explicitly represented norms, and on the other the normative systems specify how and in which extent the agents can modify the norms [4].

We distinguish design time from run time [1]. At design time, roughly, more interdependence increases conviviality among groups of agents or coalitions, whereas larger coalitions may decrease the efficiency or stability of these involved coalitions. Moreover, a normative system may adapt social dependencies, for example masking such dependencies by hiding power relations and social structures, and conviviality measures the increase in social interactions. At run time, we consider the extension to temporal dependence networks, that is, sequences of dependence networks [8].

Research question How to define conviviality measures for normative dependence networks?

We measure conviviality of a norm change by measuring the conviviality before the change, and afterwards, and taking the difference. In general, for a sequence of dependence networks, we could take the average of the conviviality of the individual dependence networks. However, there is no apparent reason to do so, since we could take the maximum or the minimum as well. Moreover, such an approach does not take into consideration that it may be relevant whether the same cycles persist over time, or cycles destroy and new cycles are created. A more in depth analysis is clearly wanted here. The challenge of measuring conviviality breaks down into the following subquestions:

1. What are the requirements for conviviality measures?
2. How to define conviviality measures?

The main challenge in defining conviviality measures is to make assumptions about the sequence. For example, we can leave out one dependence network from a sequence, or introduce multiple copies of the same dependence network. How this affects the conviviality in the sequence depends on the underlying assumptions. In [8] we do not say how the temporal dependence networks were constructed, so it may seem arbitrary. Moreover, we recall that we abstract tasks and resources from our definition of a dependence network, hence our time sequencing is done on goals which are chronologically ordered. We distinguish the following requirements for conviviality measures: Dominance, volatility and entropy. We illustrate the use of our conviviality measures with examples from gaming.

The layout of this paper is as follows. In Section 2 we discuss the assumptions and requirements of conviviality measures, and in Section 3 we introduce the conviviality measures.

2 Assumptions and requirements

2.1 Single transition case

With a single transition dependence network, we aim at analyzing the state of a dependence network and conviviality at design time. Some coalitions in the network provide more opportunities for their participants to cooperate with each other than others. To represent the interdependencies among agents in the coalitions, we use dependence networks. First, abstracting from tasks and plans we define a dependence network as in Definition 2.1 from [6]. We then review our conviviality measures assumptions and requirements.

Definition 2.1 (Dependence networks) *A dependence network is a tuple $\langle A, G, dep, \geq \rangle$ where: A is a set of agents, G is a set of goals, $dep : A \times A \rightarrow 2^G$ is a function that relates with each pair of agents, the sets of goals on which the first agent depends on the second, and $\geq$: $A \rightarrow 2^G \times 2^G$ is for each agent a total pre-order on sets of goals occurring in his dependencies: $G_1 >_{(a)} G_2$.*

In this work, the cycles identified in a dependence network are considered as coalitions. These coalitions are used to evaluate conviviality in the network. Cycles denote the smallest graph topology expressing interdependence, thereby conviviality, and are considered as atomic relations conveying interdependence. When referring to *cycles*, we are implicitly signifying *simple cycles* (as defined in [10]), also discarding self-loops. Moreover, when referring to conviviality, we always refer to potential interaction not actual interaction.

In our second assumption, we consider the conviviality in a dependence network to be evaluated in a bounded domain, i.e., over a $[min; max]$ interval. This allows to read the values obtained by any evaluation method.

The first requirement for our conviviality measures concerns the size of coalitions. This requirement is captured by the statement that there is more conviviality in larger coalitions than in smaller ones. We express this requirement through the following two cases. First case, a dependence network DN_i with a coalition of size n is better for conviviality than a DN_j with coalition of size $m = (n-\alpha)$, where $m < n$. For example, consider a coalition for peace in the world. The more countries participate, the better it is. Second case, a dependence network DN_i with a coalition of size n is more conducive to conviviality than a dependence network DN_j with two coalitions, one of size k and the other of size l, such as that $k + l \leq n$, ceteris paribus. This is motivated by the fact that having one large coalition eliminates the risk of being exposed to potential competition from other coalitions, which may be looking for the same resources.

Our second requirement concerns the number of coalitions. It is captured by the statement that the more coalitions in the dependence network, the higher the conviviality measure (ceteris paribus). This requirement is motivated by the fact that a large number of coalitions indicates more interactions among agents, which is positive in term of conviviality according to our definition based on interdependence.

2.2 Temporal case: definitions and assumptions

With temporal dependence networks, we aim at analyzing the evolution of dependence networks and conviviality at run time. Definition 2.2 formalizes how the dependence networks can be modified such that time evolution can be expressed in the dependencies between agents and captured in the network itself. Therefore, instead of performing a global analysis on the whole network, as with single transition dependence networks, or on internal changes as with dynamic dependence network, the network can be divided up into time sequences and analysis performed on each sequence. This allows for local analysis of the network and is less computationally intensive.

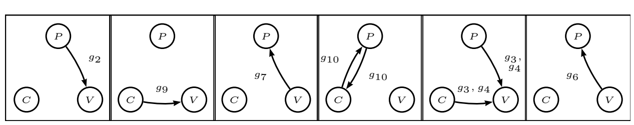
Definition 2.2 (Temporal dependence networks) *A temporal dependence network is a tuple* $\langle A, G, T, dep \rangle$ *where:* A *is a set of agents* G *is a set of goals* T *is a set of natural numbers denoting the time units or sequence number* $dep : T \times A \times A \rightarrow 2^G$ *is a function that relates with each triple of a sequence number, and two agents, the set of goals on which the first agent depends on the second.*

To illustrate how the temporal dependence networks are obtained, we now introduce the example of a virtual child adoption on Second Life. The process involves parents listing themselves to advertise their profile to prospective children who, if they like the parents, can select them. The agency then, matches children and parents to organize a trial period. Once parents and children have taken their decision, i.e., whether to adopt/be adopted, they either cancel or confirm the adoption and get from the agency an adoption certificate and the plan for a ceremony.

Table 1: List of goals.

$\mathbf{g_1}$: *Adopt child*	$\mathbf{g_5}$: *Provide adoption*	$\mathbf{g_8}$: *Get adopted*
$\mathbf{g_2}$: *Advertise profile*	$\mathbf{g_6}$: *Get paid*	$\mathbf{g_9}$: *Select profile*
$\mathbf{g_3}$: *Plan ceremony*	$\mathbf{g_7}$: *Match profile*	$\mathbf{g_{10}}$: *TryOut match*
$\mathbf{g_4}$: *Get certificate*		

For readability, we present in Table 1, the list of goals for the three stakeholder-agents `Parent`, `Child` and `Virtual Agency`. The temporal dependence network on root goals is trivial as it consists of the three goals g_1, g_5 and g_8. We therefore model the constituent goals: $g_2, g_3, g_4, g_6, g_7, g_9$ and g_{10}. Figure 1 visualizes the use of this structure to model the process.This figure should be read as follows: six dependence networks are constructed based on the sequential performance of each goal – `plan ceremony` and `get certificate` occur simultaneously and have been grouped together.



(a) TDN^1_{SL} (b) TDN^2_{SL} (c) TDN^3_{SL} (d) TDN^4_{SL} (e) TDN^5_{SL} (f) TDN^6_{SL}

Figure 1: Dependence network sequences.

More formally, let TDN^j_i refer to the temporal dependence network TDN_i where $j \in T$ and denotes the j^{th} sequence. In TDN_{SL} (Fig. 1), P refers to `Parent`, C to `Child` and V to `Virtual Agency`.

In the first sequence of dependence networks, TDN^1_{SL} there are 3 agents ($A = \{P, C, V\}$), 10 goals ($G = \{g_1, g_2, g_3, g_4, g_5, g_6, g_7, g_8, g_9, g_{10}\}$), 6 individual DNs ($T \in [1; 6]$), and 1 dependence ($dep(1, P, V) = \{g_2\}$) reflecting that the parent P depends on the virtual agency V to achieve goal g_2, e.g. advertise its profile. The individual DNs TDN^2_{SL} to TDN^6_{SL} are similarly formalized.

The process of constructing the sequences is the following. First, we define a temporal order on goals: $g_1 \succ g_2$, meaning that goal g_1 must be satisfied before g_2. (Alternatively we can define a temporal limit on g such that: $g_1 \succ_i$, i.e. g_1 must be satisfied before sequence i, or in sequence i; where $i \in \mathbb{N}$). This temporal order can follow the logical constraints of the process, e.g., by causality, a child will not have an adoption ceremony before it publishes its profile. However, in case there are no definite logical constraints, the temporal order can also be the explicit specification of norms and processes, such as contracts or the rules of a game.

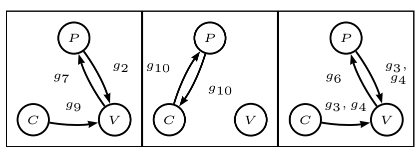
Let's assume in our example that the temporal order on goals for agents P, V and C is the following: $P : g_2 \succ g_{10} \succ g_4 \succ g_3 \succ g_1$; $V : g_7 \succ g_6 \succ g_5$; $C : g_9 \succ g_{10} \succ g_4 \succ g_3 \succ g_8$. We note that, for each agent, the last goal on the list is the root goal, meaning that when all preceding goals have been satisfied, the root goal is satisfied.

The partial order on each agent's goals is compared with the others to establish a correlation between goals. For example, the parent must advertise its profile and a potential child must have selected it before the agency can match parent and child. Therefore the following sequence is obtained: $g_2 \succ g_9 \succ g_7$, and the first temporal dependence network sequence, TDN^1_{SL}, is produced. Using our formalism, this sequence reads as follows: $TDN^1_{SL} = \langle A, G, T, dep \rangle$, where: $dep(1, P, V) = \{g_2\}$: in sequence 1, the parent P depends on the virtual agency V to reach its goal g_2, e.g. advertise its profile. $dep(1, C, A) = \{g_9\}$: in sequence 1, the child C depends on the virtual agency V to reach its goal g_9, e.g. select the profile of a parent. $dep(1, V, P) = \{g_7\}$: in sequence 1, the virtual agency V depends on parent P to reach its goal g_7, e.g. match a child with the parent's profile.

Once, parent and child are matched, a trial period is allowed during which they spend time together and get to know each other. If this common goal g_{10} between parent and child is not reached, e.g. the matching of parent and child is not successful, then the process returns to TDN^1_{SL}. If the goal is reached, then the outcome is the continuation of the process. As a decision point, this sequence is modeled as a single temporal dependence network; it constitutes the second sequence, visualized in Figure 2 as TDN^2_{SL}.

We now consider the three remaining goals g_3, g_4 and g_6, that is `plan ceremony`, `get certificate` and `get paid`. There is no indication allowing a clear ordering of these goals, therefore, several possibilities open up. This is typically where a contract should clarify the situation and explicitly set the order in which these goals should happen, having direct consequences on the conviviality measures.

The individual DN TDN^3_{SL}, Figure 2, reflects the case where g_3, g_4 and g_6 happen simultaneously, i.e., parent and child get the ceremony planned and their certificate, and the virtual agency gets paid at the same time. More examples and further discussions are provided in [6]



(a) TDN^1_{SL} (b) TDN^2_{SL} (c) TDN^3_{SL}

Figure 2: Temporal dependence network sequences.

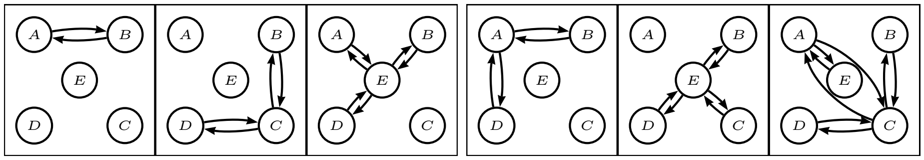
2.3 Temporal case: requirements

We now present the conviviality requirements for temporal cases. To provide an intuition of the concepts we introduce a gaming example. The game consists of finding the answer to a mystery by asking questions to the other players. It develops over three phases, each having a specific goal. During the first phase, the goal is to find the name of the agent who knows the answer to the mystery; for example, agent E has the answer. During the second phase, the goal is to find the location of this agent. During the third and final phase, the goal is to get the answer from the agent who knows it. In the following three examples, each illustrating one requirement, we consider two teams of five agents interacting with each other over the three phases of the game. In each phase, represented by a distinct individual dependence network, the agents must seek to reach the goals from the particular phase they are in by interacting with each other.

Let $|TDN_1|$ and $|TDN_2|$ be the length of these temporal dependence networks (in number or sequence). Let $|A_1|$ and $|A_2|$ be the number of agents in TDN_1 and TDN_2 respectively. We recall that $|A_1|$ and $|A_2|$ are constant over the individual dependence networks.Let TDN^j_i denote the j-th individual dependence network of the temporal dependence networks TDN_i.

Requirement 1 (Dominance) *A temporal dependence network has more conviviality than another one if, ceteris paribus, each individual dependence network of the former has more conviviality than the corresponding (same sequence number) individual dependence network of the latter.*

Fig. 3 illustrates the Dominance requirement: TDN_l has more conviviality than TDN_k. In each corresponding phase of the game, there are more interactions among the agents in team l than in team k. For example, in phase 1, three agents from team l interact, namely A, D and B, to form two coalitions, whereas in the same phase, only two agents from team k interact, namely A and B, to form a single coalition.

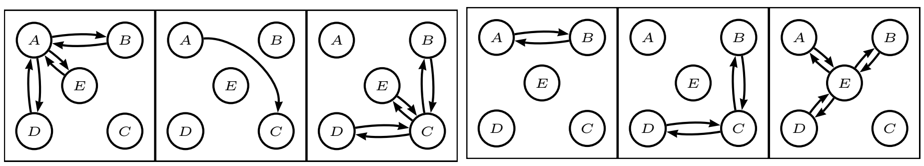


(a) TDN_k^1 (b) TDN_k^2 (c) TDN_k^3 (a) TDN_l^1 (b) TDN_l^2 (c) TDN_l^3

Figure 3: Illustration of Dominance

Requirement 2 (Volatility) *A temporal dependence network has more conviviality than another one if, ceteris paribus, the conviviality measures of all individual dependence networks in the former shows less volatility than in the latter.*

Fig. 4 illustrates the Volatility requirement: TDN_k has more conviviality than TDN_m. Team k players change their interactions more gradually over the tree phases, whereas changes in team m are more erratic, going from many interactions in phase 1 to no interaction in phase 2, to many interactions again in phase 3.

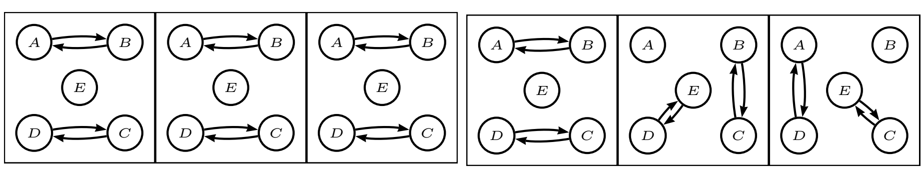


(a) TDN_m^1 (b) TDN_m^2 (c) TDN_m^3 (a) TDN_k^1 (b) TDN_k^2 (c) TDN_k^3

Figure 4: Illustration of Volatility

Requirement 3 ((Micro-organizational) Entropy) *A temporal dependence network has higher conviviality than another one if, ceteris paribus, the dependence topology in the former shows more variations than in the latter, i.e., if the agents have the opportunity to interact in a greater variety of coalitions.*

Fig. 5 illustrates the (Micro-organizational) Entropy requirement: TDN_i has more conviviality than TDN_j. Team i players change partners more ofter, allowing all players to interact, whereas in team j the same players keep interacting with each other and one player is never involved.



(a) TDN_j^1 (b) TDN_j^2 (c) TDN_j^3 (a) TDN_i^1 (b) TDN_i^2 (c) TDN_i^3

Figure 5: Illustration of Entropy

3 conviviality measures

3.1 Single transition case

It is shown that interdependence measures, introduced in [7], allow the evaluation of conviviality in dependence networks with respect to the proposed requirements. The basic idea is that since the atomic structure reflecting conviviality is a pair of reciprocating agents, the conviviality measures should also be based on the pairing relations in the dependence networks. Therefore, for each pair of agents, we count the number of cycles that contains this pair. These measures are normalized to be in $[0; 1]$ and allow for the sensible comparisons of any two dependence networks in terms of conviviality. Equation 1 is the general formula to express the pairwise conviviality measure $conv(DN)$ of a dependence network.

$$conv(DN) = \frac{\sum coal(a,b)}{\Omega} \tag{1}$$

$$\Omega = |A|(|A|-1) \times \Theta \tag{2}$$

$$\Theta = \sum_{L=2}^{L=|A|} P(|A|-2, L-2) \times |G|^L \tag{3}$$

Where $|A|$ is the number of agents, $|G|$ is the number of goals, L is the cycle length, P is the usual permutation defined in combinatorics, and $coal(a, b)$ is the number of cycles that contain both a and b. Then, Θ (Eq. 3) denotes the maximum number of cycles, whereas Ω (Eq. 2) denotes the maximal number of pairs of agents in cycles (which produces the normalization mentioned above).

3.2 Temporal case

Conviviality in Temporal Dependence Network can be measured on at least two separate scales: the micro organizational and the macro-organizational scales. Measurements at the macro-organizational scale will focus on the evaluation and comparison of the conviviality measures of each sequential DN, whereas micro-organizational measurement reflects topological aspects within each sequential DN. For instance, when we state our first Req. 1, we compare conviviality measures of sequential DNs, thus a measure at the macro-organizational is done. The same holds when we say that the conviviality measures should be equally distributed (Req. 2).

In contrast, to be able to compare the entropy within two sequential DNs, and evaluate the requirement Req.3, we need to study the TDN at a micro-organizational scale.

We now introduce our fine-grained conviviality measures for TDNs. Let TDN_1 and TDN_2 be two temporal dependence networks.

Definition 3.1 (Req. 1 formally) *Let*
$|TDN_1|$ = $|TDN_2|$. *If* $\forall TDN_1^j$ $conv(TDN_1^j) \geq conv(TDN_2^j)$*, then* $conv(TDN_1) \geq conv(TDN_2)$.

In Fig. 3 we can assume that each cycle consists of the same two goals reciprocation in a given individual DN. For instance in TDN_k^2, C depends on B for g_1 and reciprocated by g_2, similarly C depends on D for g_1 and reciprocated by g_2. This reflects the fact that the game is turn based, and all players have similar goals at a given phase of the game (i.e., in a given individual DN). Then, there are a total of 2 goals in each individual DNs of our examples (Fig. 3 to Fig. 5). The following variables are then constant over all the computation section for each individual DN (Eqs. 1-3):

- $|A| = 5$, $|G| = 2$
- $\Theta = \sum_{L=2}^{L=5} \frac{(5-2)!}{(5-2-(L-2))!} \times 2^L = 116$
- $\Omega = 5 \times (5-1) \times 116 = 2320$

The conviviality computation of each individual DN displayed on Fig. 3 is presented in Table 2. For instance, the conviviality of TDN_k^2 is $\frac{4}{\Omega}$ because (B, C), (C, B), (C, D), and (D, C) each belong to a cycle of length 2. We see that the computed conviviality for each individual DN is lower in TDN_k than in TDN_l. In each phase of the game, the group of players has more interactions.As a conclusion and per Req. 1, TDN_k has less conviviality than TDN_l.

Table 2: Computations for TDN_k and TDN_l, Fig. 3

$conv(TDN_k^1) = \frac{2}{\Omega}$	$conv(TDN_k^2) = \frac{4}{\Omega}$	$conv(TDN_k^3) = \frac{6}{\Omega}$
$conv(TDN_l^1) = \frac{4}{\Omega}$	$conv(TDN_l^2) = \frac{6}{\Omega}$	$conv(TDN_l^3) = \frac{8}{\Omega}$

For the second requirement, we use the notion of standard deviation, σ, which reflects the volatility in a set of measures. A low standard deviation indicates that the data points tend to be very close to the mean, whereas high standard deviation indicates that the data are spread out over a large range of values. We note $\sigma(TDN_i)$ the standard deviation over the individual DN s belonging to TDN_i. We also need to fix the conviviality mean of TDN_1 and TDN_2, respectively noted $\mu(TDN_1)$ and $\mu(TDN_2)$. In our case, x_i is the conviviality measure for TDN_i.

Definition 3.2 (Req. 2 formally) *Let*
$|TDN_1| = |TDN_2|$*, and* $\mu(TDN_1) = \mu(TDN_2)$*. If* $\sigma(TDN_1) < \sigma(TDN_2)$*, then* $conv(TDN_1) > conv(TDN_2)$.

We can now evaluate the conviviality of the TDNs illustrated Fig. 4 according to the previous requirement. First, we have to compute conviviality for each individual TDN : $TDN_m^1 = \frac{6}{\Omega}$, $TDN_m^2 = 0$,

$TDN_m^3 = \frac{6}{\Omega}$, $TDN_k^1 = 2$, $TDN_k^2 = 4$, and $TDN_k^3 = 6$. The respective means are then $\mu(TDN_m) = \frac{4}{\Omega} = \mu(TDN_k)$. But their standard distribution are $\sigma(TDN_m) = \sqrt{\frac{8}{\Omega^2}}$ and $\sigma(TDN_k) = \sqrt{\frac{8}{3\times\Omega^2}}$, i.e., $\sigma(TDN_m) > \sigma(TDN_k)$. Therefore, TDN_m has less conviviality than TDN_k (according to Req. 2). Let δ_T be the number of different coalitions over all sequences of the temporal dependence network T.

Definition 3.3 (Req. 3 formally) *Let* $|TDN_1| = |TDN_2|$, *and* $\mu(TDN_1) = \mu(TDN_2)$, *and* $\sigma(TDN_1) = \sigma(TDN_2)$. *If* $\delta_1 > \delta_2$, *then* $coal(TDN_1) > coal(TDN_2)$.

In Fig. 5, $\mu(TDN_j) = \mu(TDN_i) = \frac{4}{\Omega}$, and $\sigma(TDN_j) = \sigma(TDN_i) = 0$. In this case, a simple counting will suffice to obtain : $\delta_{TDN_j} = 2$ and $\delta_{TDN_i} = 6$. Therefore, TDN_j is less convivial than TDN_i (according to Req. 3).

4 Related research

The present work takes as a starting point an abstract notion of dependence graphs initially elaborated by Conte and Sichman [17]. The notions of dependence graphs and dependence networks were further developed by the authors and with a more abstract representation similar to ours, in Boella et al. [3] and Caire et al. [5] in the context of the concept of conviviality defined as reciprocity. Dependence based coalition formation is analyzed by Sichman [16], while other approaches are developed in [15, 11, 2].

Moreover, we build on the notion of social dependence introduced by Castelfranchi along with concepts like groups and collectives [9]. Castelfranchi brings such concepts from social theory to agent theory to enrich agent theory and develop experimental, conceptual and theoretical new instruments for social sciences.

Similarly to Grossi and Turrini [12], our approach brings together coalitional theory and dependence theory in the study of social cooperation within multiagent systems. However, our approach differs as it does not hinge on agreements.

Finally, works emphasizing agents' interdependence as a critical feature of multiagent systems, particularly for the design of systems involving joint interaction among human-agent systems such as in Johnson and Bradshaw et al. "coactive" design [13].

5 Summary

In agents systems, conviviality measures quantify interdependence in social dependence relations, representing the degree in which the system facilitates social interactions. Moreover, a normative system is a mechanism to change conviviality by changing social dependencies, for example by creating new obligations. With the pervasive development of socio-technical systems, modelling such social settings has become increasingly important. We distinguish design time from run time measures. At design time, roughly, more interdependence increases conviviality among groups of agents or coalitions, whereas larger coalitions may decrease the efficiency or stability of these involved coalitions. At run time, we consider the extension to temporal dependence networks, that is, sequences of dependence networks. We distinguish three requirements for conviviality measures: **Dominance requirement:** A temporal dependence network has more conviviality than another one if, ceteris paribus, each individual dependence network of the former has more conviviality than the corresponding (same sequence number) individual dependence network of the latter. **Volatility requirement:** A temporal dependence network has more conviviality than another one if, ceteris paribus, the conviviality measures of all individual dependence networks in the former shows less volatility than in the latter. **Entropy requirement:** A temporal dependence network has more conviviality than another one if, ceteris paribus, the dependence topology in the former shows more variations than in the latter, i.e., if the agents have the opportunity to interact in a greater variety of coalitions.

Finally, we define conviviality measures that satisfy these three requirements, and illustrate them with an example from gaming. A topic of further work is to define measures of temporal dependence networks for other interpretation of the temporal sequence, and to define conviviality measures for dynamic dependence networks. The difference between temporal and dynamic dependence networks is that in dynamic dependence networks the dynamics is represented in the dependence network itself. This has been used to define conviviality masks [5], and thus the measures of dynamic dependence networks will lead to measures of conviviality masks. However, we expect that the proposed measures do not apply in a straightforward way, but that new measures will be needed to capture further views of conviviality.

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