Big Data and Information Analytics
doi:10.3934/bdia.2017022
©American Institute of Mathematical Sciences
Volume **2**, Number **3&4**, July & October **2017**
pp. **255–264**

CERTONTO: TOWARDS AN ONTOLOGICAL REPRESENTATION OF FAIR TRADE CERTIFICATION STANDARDS

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Abstract. The global fair trade movement, to secure fair deal for producers, has been supported by the labeling initiative, which promotes sales of fair-trade products by expanding their distributions into major consumer segments through product-labeling. Fair-trade certifications, practised in compliance with the fair trade standards set by Fairtrade International (FLO), are carried out at the producer end of the supply chain. Given the varieties of products and producers, however, these certification activities are subject to ambiguous or inconsistent interpretation of the FLO standards. In this paper, we propose an ontological representation of the standards called CertOnto. We aim at defining eventually a set of ontological vocabularies for describing the concepts of actors and their roles, the compliance criteria, producers, products, activities, context and situations, all of which are involved into a basic decision problem for CertOnto: Given a producer, or a product, should it be fairtrade-certified or not? With regard to this problem, we emphasize the difficulties of verifying the accuracy of information captured by CertOnto-FLO, and show that, from technical perspective, computing with CertOnto-FLO in general is challenging (at least NP-hard).

1. **Introduction.** Product labeling provides more information to the consumers to help them making informed purchasing decisions. Historically product labeling were controlled by specific government departments at different levels, and it played a significant role for indirect government market intervention for economical efficiency. Starting from 1970s, environmental and social issues caused by activities of product producing receive increasing attentions. Environmental and social labeling and certification are usually voluntary to the market actors, that is, organizations complying with the requirement are allowed to label their products on their own to signify their credibility. In addition, the practise of labeling and certification is managed by third-party organizations, and guided by corresponding market-based standards. For example, fair-trade certifications, performed by FLO-CERT, and

2010 *Mathematics Subject Classification.* Primary: 03B42, 03B70, 03B80; Secondary: 68T27, 68T30.

Key words and phrases. Fair-trade, certification standards, ontological processes, Situation Calculus, Description Logics.

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practised in compliance with the fair trade standards set by Fairtrade International (FLO), are exercised at the producer end of the supply chain.

Labels on products should be able to help consumers to identify products, produced by organizations that are in compliance with certain environmental and social practice claims. As such, credibility of these labels are important. In fact labeling scheme providing a seal of approval based on the verification of attributes by independent third-party certifiers or verifiers, is supported by the standard ISO 14024. Governance of third party certifiers and the assessment processes, however, depends on the availability to define and describe entities and relationships within certification and labeling systems.

An ontology provides a rigorous way for conceptualizing the domain knowledge of certification systems [29]. Additionally, ontological approaches improve the shareability and provide a mathematically rigorous framework for validating the certification cycles. This paper investigates the applicability of ontological approach to certification system representation and reasoning by working particularly on fairtrade certification. We present specifically the fairtrade certification ontology (CertOnto). We define a set of ontological vocabularies for describing the concepts of actors and their roles, the compliance criteria, producers, products, activities, contex and situations, all of which are involved in the basic decision problem that CertOnto is designed to address: Given a producer, or a product, should it be fairtrade-certified or not?

The reminder of this paper is organized as follows. In the following section (Section 2), we define a set of ontological vocabularies for describing the concepts of actors and their roles, the compliance criteria, producers, products, activities, context and situations.We then conclude the paper with several remarks (Section 3).

2. **Fairtrade certification ontology.**

A fairtrade certification framework is a shared decision making architecture, designed to promote producing of products in accordance with environmental, labor, and developmental standards. The standards of fairtrade are set by Fairtrade International (FLO), which oversees a certification body, FLO-CERT. Certification process is composed in particular of independent auditing of product producing to ensure that the standards are met by the operators being audited.

For the rest of this section, we discuss several related themes in CertOnto: concepts that define individual and collective actors and their associated attributes; concepts that defines compliance criteria (translated from Fairtrade standards) that are used for fairtrade certification; concepts of producers and products as defined by FLO; the concept of context, which defines the preconditions and effects of certification activities; and the concept of situation.

2.1. **Actors and roles.**

Actors in CertOnto are entities that are capable of executing certain activities, that are purposely guided by the intentions or goals of these entities. An actor in the system is either an individual (human or software agent) or a collective (groups of people or software agents), but not both. Certification organizations, producers, traders, importers, and manufacturers are collective actors. Auditors, evaluators, and certifiers are individuals. Knowledge of actors is captured axiomatically by the following sentences

$$(\forall x)(actor(x) \equiv (individual(x) \vee collective(x)) \wedge (individual(x) \supset \neg collective(x)));$$

$$(\forall x)(organization(x) \vee producer(x) \vee trader(x) \vee importer(x) \vee manufacturer(x) \supset collective(x));$$

$$(\forall x)(auditor(x) \vee evaluator(x) \vee certifier(x) \subset individual(x)).$$

Actors are responsible for acting out roles (e.g., works, hired labors, auditors and operators) to perform activities, whereas the concepts of workers and hired labors are equivalent.

$$(\forall x)(role(x) \equiv actor(x) \wedge (worker(x) \vee hiredLabour(x) \vee auditor(x) \vee operator(x));$$

$$(\forall x)(worker(x) \equiv hiredLabour(x))$$

2.2. **Compliance criteria.** FLO-CERT established the Compliance Criteria (CC) by translating Fairtrade Standards requirements and FLO-CERT certification policies into verifiable control points that can be evaluated during the certification process.

A compliance criterion can be major, core, regular, or development:

$$(\forall x)(criterion(x) \supset major(x) \vee core(x) \vee regular(x) \vee dvlpmt(x)).$$

A particular core criterion is that: the average score of the development criteria is equal or above 3.0. This criterion (DCC) is axiomatized as

$$(\forall optr)(compliantWith(optr, DCC) \equiv (\forall c_1, \ldots, c_k, n_1, \ldots, n_k, ave)$$
$$((dvlpmt(c1) \wedge rank(optr, c1, n1) \wedge \ldots \wedge dvlpmt(c_k)$$
$$\wedge rank(optr, c_k, n_k) \wedge ave = average(n_1, \ldots, n_k)) \supset ave \geq 3.0)).$$

That is, an operator *optr* is in DCC iff, given all development criteria from c_1 to c_k and their ranks n_1 to n_k, the average of their ranks *ave* is above or equal to 3.0.

2.3. **Producers and products.** Classification of producers as described in this section is based on Section 1.3.2 of [5]. A Glossary of products can be found in [8]. FLO-CERT classifies producer setups [5] into four categories: Small Producer Organisations, Single Plantation, Multi-Estate, and Contract Product Projects:

$$(\forall p)(producerOrg(p) \equiv spOrg(p) \vee singleOrg(p) \vee multiOrg(p) \vee contractPP(p)).$$

Small producers are further classifies into 1st grade, 2nd grade, 3rd grade, and mixed structure:

$$(\forall p)(spOrg(p) \equiv firstGrd(p) \vee secondGrd(p) \vee thirdGrd(p) \vee mixed(p)).$$

A first grade organization contains exclusively members of small producers; A second grade contains exclusively first grade organizations; A third grade contains exclusively second grade organizations; A mixed Structure contains at least two different organizational setups, and its members can only be a small producer, a first grade affiliate or a second grade affiliate.

$$(\forall org, p)containsMember(org, p) \wedge firstGrd(org) \supset sp(p);$$

$$(\forall org, p)containsMember(org, p) \wedge secondGrd(org) \supset firstGrd(p);$$

$$(\forall org, p)containsMember(org, p) \wedge thirdGrd(org) \supset secondGrd(p);$$

$$(\forall org, p)containsMember(org, p) \wedge mixed(org) \supset$$
$$(\exists p_0)(p0 \neq p \wedge containsMember(org, p0)) \wedge$$
$$(sp(p_0) \wedge firstGrd(p)) \vee (sp(p) \wedge firstGrd(p0)) \vee$$
$$(sp(p_0) \wedge secondGrd(p)) \vee (sp(p) \wedge secondGrd(p0)) \vee$$

TABLE 1. Terms to describe context and their possible values

Context	*Remark*
cycleType	Type of Cert. cycle: SixYear or ThreeYear
cycleRound	BeforeFirst, First, Second, ...
auditType	Type of audit: Initial, Renewal, Surveillance

$$(second(p_0) \wedge firstGrd(p)) \vee (second(p) \wedge firstGrd(p_0));$$

and

$$(\forall org, p) containsMember(org, p) \wedge mixed(org) \supset$$

$$(sp(p) \vee firstGrd(p) \vee secondGrd(p)).$$

The two major indicators used to define small producer are 1) the number of permanent workers hired on average per year and 2) the farm size. However, measurement and evaluation of these indicators subject to the geographical location of the producer and nature of the product the producer produces. As such, region and product dependent variants of definitions of small producers are provided by FLO-CERT. For example (drawn from [6]) any banana producer in Jamaica, which hires no more than two permanent workers per acreage and has farm size no bigger than 10 acreage, is a small producer.

$$(\forall x) producer(x) \wedge locatedIn(x, Jamica) \wedge produces(x, Banana) \wedge$$

$$permanentWorkerNum(x) \leq 2PerHa \wedge farmSize(x) \leq 10Ha) \supset sp(x).$$

2.4. **Context and situation.** Since the domain of certification involves multiple, distributed stakeholders (either collectives or individuals), it is desirable to include in CertOnto explicit specifications of context, i.e., the precise environment where certification activities are performed. As such, in CertOnto, we provide three terms *cycleType*, *cycleRound*, and *auditType*, for describing certification knowledge. Description of their possible values are listed in Table 1. Certain Constraints exist for these context. In particular, we know that there are two certification cycle types: The three year cycle type is the default one, whereas the six year cycle type is applied to operators who are small producers

$$(\forall x)(cycleType(x) \equiv x = SixYear \vee x = ThreeYear);$$

$$(\forall a, optr) audit(a, optr) \wedge smallProducer(optr) \supset cycleType(SixYear).$$

For each instance theory of CertOnto, each context term is assigned a unique value. Combination of these assignments defines a particular context, where the requirement for the activities in the ontology to occur legally, and the consequence of the occurrences of these activities to the systems, are determined unambiguously. As shown subsequentially in Section 2.5, three activities so far: audit, evaluate, and certify, are considered in the current version of CertOntoFLO.

Given a context, occurrences of activities change the status of the system. As such, CertOnto makes an explicit distinction between the concept of ontology context and that of ontology situation. A situation consists of a set of fluent conditions,

TABLE 2. Fluent Conditions to Characterize a Situation

Fluent	*Remark*
certified(x)	The operator x is certified
conformAllC(x)	x conforms to all criteria
confromAllMajorC(x)	x conforms to all major criteria
certRenewed(x)	The operator x is renewed
certConfirrmed(x)	The operator x is confirmed
certSuspended(x)	certification is suspended
certDenied(x)	certification application is denied
certSuspensionLifted(x)	The suspension on x is lifted
decertified(x)	x is decertified
majorCMSuggested(x)	Corrective measures (major) are suggested by x
majorOESubmitted(x)	Objective evidences (major) are submitted by x
majorCMFulilled(x)	CMs (major) are fulfilled by x
regularCMSuggested(x)	Corrective measures (regular) are suggested by x
regularOESubmitted(x)	Objective evidences (regular) are submitted by x
regularCMFulfilled(x)	CMs (regular) are fulfilled by x

which take Boolean values (Table 2). Assignments to all of the fluent conditions in the set define a complete specification of the system situation, whereas occurrences of activities update the current situation from one to the other, in a way specified in Section 2.5.

2.5. **Certification activities.** Continuing from the previous section: Activities change the value of fluents in the ontology thus moves the system from one situation to the other; and Certification activities include: audit, evaluate, certify. We give explanations in more details in this section.

An *audit* activity $(\forall a, optr)\ audit(a, optr)$ (auditor a audits operator optr) will further enable any compliance criterion (applicable in the given context), available in the resulting situation, through assigning a unique value to the rank. That is,

$$(\forall a, o, c) audit(a, o) \wedge (core(c) \vee major(c) \vee regular(c)) \wedge applicable(o, c) \supset$$

$$(\exists! n) rank(o, c, n) \wedge (n = 1 \vee \ldots \vee n = 5).$$

Thus, for *optr*, the rank of c is available.

$$(\forall optr, c)(\exists n) rank(optr, c, n) \wedge (n = 1 \vee \ldots n = 5) \supset (available(optr, c))$$

An *evaluate* activity $(\forall e, optr) evaluate(e, optr)$ (evaluator e evaluates operator *optr*) will decide the existence of non-conformity of *optr* from the rank values recorded in the auditing report prepared by the auditor. In particular, the activity *evaluate* will ensure that an operator *optr* is in compliance with a criterion c iff *optr* obtained a rank greater or equal to 3.0 from the audition.

$$(\forall e, o, c, n)((evaluate(e, o) \wedge (core(c) \vee major(c) \vee regular(c)) \wedge$$
$$available(o, c) \wedge rank(o, c, n) \wedge n \geq 3.0) \supset compliantWith(o, c))$$

Consequently, if the operator c is in compliance with all criteria, then there is no conformity; whereas if c is in compliance with all major criteria, then there is no major-conformity for o.

$$(\forall c, o)(available(o, c) \wedge compliantWith(o, c) \supset conformAllC(o));$$
$$(\forall c, o)(available(o, c) \wedge (core(c) \vee major(c)) \wedge compliantWith(o, c)$$
$$\supset conformMajorC(o));$$
$$(\forall o)(complicanceAllC(o) \supset complianceMajorC(o));$$

Based on the context of the audit type (i.e., the value of auditType(x)), the activity *certify* will decide whether certification for the operator o is approved, renewed, confirrmed, or suspended.

$$(\forall cert, o)(certify(cert; o) \wedge conformAllC(o) \wedge auditType(Initial) \supset certified(o));$$
$$(\forall cert, o)(certify(cert, o) \wedge conformAllC(o) \wedge auditType(Renewal)$$
$$\supset certRenewed(o));$$
$$(\forall cert, o)(certify(cert, o) \wedge conformAllC(o) \wedge auditType(Suverveillance)$$
$$\supset certConfirmed(o));$$
$$(\forall cert, o)(certify(cert, o) \wedge \neg conformAllC(o) \wedge conformMajor(o) \wedge$$
$$(auditType(Renewal) \vee auditType(Surveillance)) \supset certSuspended(o)).$$

Given a particular instance domain theory of CertOnto, it needs to be specified in its initial context and situation, that

1. The size of the operator. For example, if the operator *Optr* is a small producer, the context is initially set as follows:

   $$cycleType(SixYear), cycleRound(BeforeFirst), auditType(Initial);$$

2. All fluents are false $\neg certified(Optr)$, $\neg certRenewed(Optr)$, $\ldots$, $\neg regularCMFulfilled(Optr)$; and
3. The ranks of all criteria for *Optr* are unavailable $(\forall c) rank(Optr, c, `NA')$.

Actors are associated with goals, i.e., intentions to achieve, or stay in, their particularly favorite situations. Within CertOnto, goals can be stated formally. For example, depending on the context, an operator *optr* intends to have their application "$certified(optr)$", renewed "$certRenewed(optr)$", confirmed "$certConfirmed(optr)$", or to have the suspension that is currently applied on it lifted "$certSuspensionLifed(optr)$", in against to the suspension of the application "$certSuspended(optr)$", denial of its application "$certDenied(optr)$", or decertification "$decertified(optr)$".

Goals can be reduced into a combination of subgoals with logical connectives "$\wedge$", or "$\vee$", or "$\neg$". For example, the goal "$certified(optr)$" can be reduced into a conjunction of "$compliantWith(optr, c)$", for all compliance criteria that is applicable in the current context and situation.

3. **Concluding remarks.** The fairtrade movement has reached a global level of development, with participating countries from all over the world. Due to the facts that 1) a large, and growing, number of products are to be fairtrade certified and 2) the product producers are geographically distributed, the practise of fairtrade certification demands the availability of a formal/ontological fairtrade certification software system.

In this paper, we propose CertOnto, an ontology that is designed to respond the call. With explicit descriptions of key themes in the business of fairtrade certification, CertOnto and its future implementation would allow all actors involved in a certification process, either an individual as an auditor or certifier, or a collective small producer as an operator, to communicate effectively and efficiently. Building-up CertOnto, however, faces challenges on obtaining critical information and verifying its validity thereafter. For example, even though it is easy to define the concept of child labor:

$$childLabour(x) \equiv (labour(x) \wedge age(x) \leq 18);$$

in the real world, child labor employers generally intend to avoid disclosing this information to the public.

From computational perspective, reasoning with CertOnto can be intractable. For example, as shown on the organizational structure in FLO, a particular individual in the Operations Department can fulfill the roles of certifier, auditor, or evaluator. However, due to the requirement on avoiding conflict of interests, temporal constraints, or other restrictions, it might not always be possible to assign a FLO-CERT staff to a particular task at a given time (in fact it is easy to show that such an task-assignment problem is NP-hard), meaning that there is no efficient algorithm, that is currently known to us, to compute the exact solution[1].

It is noted that for describing the taxonomy of producers and products in CertOnto, full employment of first-order logics as demonstrated in the paper is unnecessary and Description Logics [1], a computationally tractable fragment of the first-order logics, should be sufficiently expressive for that purpose, which means that highly optimized DL reasoners can be used to reason over this part of the ontology, on typical reasoning problems, such as product concepts subsumptions, or small producer membership check.

We remark that 1) in [20], a hybrid reasoning in unrestricted FOL extensions of the DL, which permits the integration of highly optimized FOL theorem provers and DL reasoners while maintaining soundness and refutational completeness, is proposed and is applied to investigate the application of an retail ontology, proposed in [31]; 2) the research reported in [2] indicates that the expressive power of Unified Modeling Language (UML) Class Diagrams is in essence equivalent to DLs, hence, conceptually, UML class diagrams offer a powerful alternative tool for Products

[1]Proof Sketch: We transform the NP-complete One-in-three SAT problem ([L04] of [9]) into the current problem. Note that it is remarked in [9] that the problem is NP-complete even if no clause $c \in C$ contains a negated literal. Given an instance of an One-in-three SAT problem, we treat each variable as an individual state, and each clause as a task. Hence, within the transformed instance, it is required that each task (clause) can be performed by one and only one of the three individuals (variables) that correspond to the clause. It is the case that there exists an assignment to satisfy the One-in-three SAT problem instance iff there exists an assignment for exactly one state to each task in the transformed instance. Hence in CertOnto, for example, deciding the existence of an available state to audit a particular operator $Optr$ (i.e., verifying $\mathcal{T}_{certOnto} \models (\exists a)(certify(a, Optr))$, where $\mathcal{T}_{certOnto}$ is the ontology CertOnto in the form of first-order-logic sentences, is at least NP-hard.

and Producers representation. Example use of class diagrams is provided in [14], where a conceptual description of an ontology for generic decision making ontology is presented.

In CertOnto, we conceptually axiomatize the activities that serve to achieve objectives and goals that actors in the system attempt to achieve. Similar approach was taken earlier in [3], where an OWL based conceptual ontology is presented for pervasive computing environments. Nevertheless, as pointed out in [4], an activity representation framework should aim at answering "what is going to be done, who is going to do it, when and where it will be done, how and why it will be done, and who is dependent on its being done".

With our current CertOnto, answering all these questions will inevitably require direct and intense involvement of manual efforts, thus we believe it is necessary to extend CertOnto in ways where execution dynamics could be captured completely. As such, we propose an application of Situation Calculus [19] to describing activities in the system. Situation Calculus is a logical language for representing actions and changes in a dynamical domain. It was first proposed by McCarthy and Hayes in 1969 [18]. The language L of Situation Calculus as stated by [19] is a second-order many-sorted language with equality. Situation Calculus has been used to describe dynamic systems and complicated processes [11, 12, 10, 23, 13], to axiomatize graphical process formalisms including Petri Nets [22, 24], Clinical Practise Guidelines [25], UML Activity Diagrams [26], and Business Process Model and Notation (BPMN) [27]. Among many other applications of Situation Calculus, it is used in [15] to serve as foundational formalism for business process modeling and analysis. Supply chain events decompositions are represented using Situation Calculus in [28].

As part of possible future work, one could extend the CertOnto to include additional activities associated to certifications [7]. For example, we might need to consider appealing, review requests, allegate and complaint which are submitted to FLO and are investigated by the quality management representatives in FLO. This study can be combined with analysis of online reviews in particular [16, 17, 30].

Acknowledgments. A considerable part of this research was carried out when the first author was a Postdoctoral Research Fellow with Professor Theresa Pardo at the Center for Technology in Government, University at Albany. We sincerely thank all members in our "I-Choose" (Building Information Sharing Networks to Support Consumer Choice [21]) collaborative research team under the NSF Award Number: 0955935. We also gratefully acknowledge the support by ORF-RE (Ontario Research Fund - Research Excellence)[2] Award in BRAIN Alliance[3].

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