Ontology based Multi-Agent System for the Handicraft Domain E-Bartering

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Abstract
The online supply requirement management within a heterogenous environment represents a real challenge. While the traditional e-purchase is widely adopted, the e-barter seems to be an ambitious alternative. It is mainly solicited when suppliers might be unavailable or the delivery timeouts are important. Moreover, it reinforces the communication between the producer and his professional network. In this paper, we propose an emulation of the handicraft women e-procurement process based on the power of multi-agent paradigm and ontology formalism. Indeed, we establish an e-barter framework which targets to recommend in real time, under different circumstances and regarding the handicraft woman situation the suitable exchange partners. Likewise, we established several producing rules in order to deduce automatically the best sourcing moment. Furthermore, the handicraft woman which is the decision maker might drive an e-barter auction (e-BA) process in order to choose the best exchange opportunities and
then minimize her expenses. We consider the e-BA as a new concept merging the barter and auction notions.

**Keywords:** E-procurement, E-barter, E-auction, multi-agent system, recommender system, handicraft domain, business ontology

## 1 Introduction

HanDicraft Women (HDWs) within developing countries constitute an important workforce. However, they encounter different issues during their business activities. This paper is project-driven which targets to improve the HDWs socio-economic level dealing with their heterogeneous environment and different contexts. Indeed, they can be expert or beginner, illiterate or cultivated, autonomous or dependant, integrated or isolated etc. To handle these issues, we should understand HDWs needs to better fit their requirement.

The recommendation of suitable supply opportunities promotes significantly the producing process aspects. Dealing with highly demanding users such as HDWs within a heterogeneous and inconstant environment, leads us to look for suitable suppliers in order to meet their expectations. Different researches evoked the best suppliers selection within the context of traditional e-procurement such as (Lee et al. 2009; Wang et al. 2012; Seungsup Lee et al. 2013). We are based particularly on (Dhaouadi et al. 2014a), where the authors treated the supply chain agentification in order to automatically recommend suitable suppliers for the HDWs communities during their business activities. The e-barter alternative can improve the HDWs satisfaction mainly when different issues may arise such as the suppliers' unavailability, the far delivery deadlines, the rare and seasonal raw material nature. These circumstances may affect critically the stock state and then threaten the producing activities progress. Indeed, an under-storage and/or over-storage situations may emerge. The over-storage phenomenon occurs when the raw material quantity exceeds the recommended level. This situation causes probably a poor workshop space management and a raw material quality degradation over time. The under-storage means that a particular raw material is out of stock. If the raw material in question is hardly procured (rare or non available), the situation will be increasingly unfavourable for the producing tasks. Taking into account these issues, the raw material exchange (e-bartering) within the professional network will be hence very efficient.

In this paper, we aim at providing consistent procurement opportunities via suitable exchange peers. The proposed e-barter system is considered as an extension of a previous proposed traditional e-commerce system in (Dhaouadi et al. 2014a). In fact, the barter is "an exchange of two items" (Küpçü and Lysyanskaya. 2012). According to our case, it consists in exchanging raw materials among handicraft network members. Similarly to (Núñez el al. 2005), we adopt the multi-agent paradigm so to model the e-barter system. The latter is considered as "A set of agents performing exchanges of products" (Núñez el al. 2005).

The recommendation of exchange peers is not a trivial task. It takes into account the HanDicraft Woman (HDW) situation such as her locality. In fact two relevant barter peers have to reach an agreement about the raw material to exchange and have to be also situated in
adjacent localities. Besides, in real world, the HDW, which is the barter initiator, may deals with different exchange alternatives where she has to opt for the best choice. In this paper we define a new concept "barter auction" (e-BA) merging the barter and the auction notions. Note that a classic auction operation consists in trading an item between a seller and different buyers. The seller is considered as the auction initiator and is expected to precise a starting price (Christidis et al. 2013). The buyers compete against each other in real time by proposing several bids. Each bid should be higher than the previous one. In our research work, we define the barter auction as an exchange operation between the different HDWs. It targets to facilitate the procurement process without the implication of money. The barter auction initiator (HDW) seeks to acquire an expected raw material and give back the less useful one. She is hence able to minimize her expenses by opting for the best exchange offer.

The remainder of this paper is organized as follows: Section 2 represents related works. Then, section 3 introduces the proposed e-barter system. A case study is then undertaken in order to validate our proposal in section 4. Finally, we conclude this paper in section 5.

2 Related Works

In the literature, different research works have undertaken multi-agent systems when dealing with the e-barter process. In (Cavalli & Maag. 2004), the authors present a formal specification of an e-barter system based on intelligent agents. The proposed formalization uses the utility function to represent customer preferences and considers the transaction and shipping costs. They also validated their proposal via the test generation method application which reduces the design ambiguities and errors. In (Haddawy et al. 2005), an emulator for trade brokers practices is developed. The proposed system aims at matching buyers and sellers. Besides it uses the greedy heuristic to reduce the sellers number affected to a buyer regarding a particular product. Their solution is modeled as an optimization problem which targets to maintain the trade balance. However, the authors assume that the barter entries are already existent. Effectively, the implemented algorithm deals with real exchange demands taken during a week. Barter data is structured as a requirements matrix where the rows represent the trade members, the columns represent the product nature and the matrix content represents quantities to buy or to sell. The commercial barter problem is considered hence as the minimum cost circulation problem within a network. In despite of the method efficiency, it handles static data picked in a previous period of time. Nevertheless, the online treatment of the barter exchange demands is interesting. Furthermore, the proposed system proposes many suppliers in order to meet one good need which is far to be feasible in real life. (Küpçü & Lysyanskaya 2012) provide an efficient optimistic p2p fair exchange mechanism for bartering digital files using cryptology primitives. The system is able to be used in real bartering applications with high competence level. Most of the time, it is functional without the implication of a third party (Arbiter). However, when a conflict arises, the implication of a trustworthy arbiter is recommended.

In the other side, multiple papers handled the e-sourcing process based on the auction transactions. Effectively, there is a rising interest concerning the adoption of auction
mechanism during the procurement process. In (Lin et al. 2011) the authors propose an agent-based price negotiation system for online auctions. Mainly, three agents are used in the study: seller agent, buyer agent and mediator agent. The proposed system helps sellers and buyers to personalize their price negotiation strategies based on the fuzzy rules. (Huang et al. 2013) present a hybrid mechanism for e-supply procedure including two phases. The first phase concerns a multi-attribute combinatorial auction. The second consists in bargaining with the auction winners. The system improves the transactional social surplus. In (Pla et al. 2014), an auction mechanism is introduced. It considers different attributes such as price, service time, quality tolerance in order to better fit the auctioneer expectations.

In this research, a multi-agent system framework is proposed in order to facilitate the barter and auction transactions of raw materials within the professional handicraft networks. Indeed, it enables the complainant HDW firstly to search for suitable exchange alternatives and secondly to conduct an exchange auction if the proposed barter candidates are competitors. Our proposed system considers the benefits of existing scientific works in this regard. In fact, it recommends online and automatically the best trade alternatives. The recommendation is based on the exchange pairs preferences and profiles matching. Actually, the product nature in need and the geographic proximity are fundamental parameters during the barter opportunities suggestion. Hence, the selection process decreases the HDWs exchanged messages number (since the addressed community of interest is reduced) which is an important aspect in multi-agent paradigm. Likewise, we deal with several issues presented previously such as the necessity of a trustworthy arbiter which is no longer needed. In fact, the e-bartering pairs are communicating together without a mediator agent during the exchange and auction transactions. In order to maximize the HDW (barter initiator) benefit, a barter auction procedure is performed where she is able to select the best exchange offer. From another perspective, our system promotes the HDWs communication within the same professional network. Actually, the proposed system enables the HDWs to elaborate professional communities collaborating together. However, the system does not consider the shipping costs resulted from the exchange operation. It reduces only the delivery expenses since it takes into account the barter peers geographic adjacency.

3 E-barterering Within The Handicraft Domain

During her business activities, the HDW has to explore different supply alternatives in order to acquire the desired raw materials. Usually, she looks for suitable suppliers providing the needed good with lowest price and highest quality. Besides, when it is necessary, she is allowed to exchange several products with another member from her professional network. The exchange target is to get the desired product and in return providing another. Once the required raw materials are available, the HDW deals with the production. She may collaborate with other HDW in the purpose of satisfying the customer command. As seen, the HDW environment is open, heterogeneous, dynamic and distributed. Thus, the multi-agent paradigm adoption looks to be appropriate to the problem modeling. Indeed, we handled the e-procurement process agentification (Figure 1). Here, the HDW receives the customer command (1). Then she checks her stock state through the Stock Notifier (2). If the necessary
quantities are not yet available then the HDW might ask the Purchase and Barter agents (3) to search for the suitable supply opportunities. As decision maker, she is then able to select radically the convenient procurement alternative.

Our proposed system deals with HDW from different handicraft fields. It targets to recommend relevant supply opportunities in spite of the HDW context heterogeneity. That is why the specification of the handicraft domain via an ontology formalism is necessary. Moreover, the integration of the ontology enables agents to better represent knowledge (Wang et al. 2012). Likewise, it facilitates their interoperability and coordination (Thanh et al. 2004) and reinforces their confidence (Rosaci & Sarné, 2014). In the following, we introduce more details about the agents as well as the implemented ontology.

3.1 The Agent Specification

We defined different agents dedicated to the agentification of the HDW professional network. The next table summarize the different roles played by each agent.

<table>
<thead>
<tr>
<th>Agent</th>
<th>Behavior</th>
</tr>
</thead>
<tbody>
<tr>
<td>HDW</td>
<td>The HDW is the decision maker and the final user of the recommender system. In order to satisfy her clients and minimize her expenses, the HDW must check the available quantities within her stock. In the presence of an over or under-storage, she orders the barter and the purchase agents to call for the best e-procurement opportunities.</td>
</tr>
<tr>
<td>Interface</td>
<td>The interface agent is considered as a middleware between the HDW agent and the remaining agents. It facilitates their interactions.</td>
</tr>
</tbody>
</table>
Customer

It transmits a command to the HDW agent. The command includes one product or plus with different quantities.

Stock Notifier

It is the stock manager. It manages the entrees of new raw materials and updates their quantities if it is necessary. Whenever an under or over-storage case emerges, it notifies the HDW continuously.

Purchase

Once receiving the HDW order, it looks for suitable suppliers based on three levels: selecting only providers disposing of the required goods, then only those having a seller profile successfully matched with the HDW one and finally selecting the trustworthy ones.

Supplier

Once definitively selected by the HDW, the supplier agent is called to negotiate with her about the required good quantity, quality, costs and delivery timeout.

Barter

It broadcasts exchange demand within the professional network of the HDW in question. Indeed, it calls for HDW potentially interested in this specific exchange and of course satisfying the current HDW preferences. Likewise, it is attentive to the circulation of the diverse exchange initiatives. It means that it examines the received exchange demands from other HDW and selects the interesting ones (those meeting the current HDW needs).

<table>
<thead>
<tr>
<th>Table 1: Agents' behaviours definition</th>
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<tbody>
<tr>
<td>Customer</td>
</tr>
<tr>
<td>Stock Notifier</td>
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<tr>
<td>Purchase</td>
</tr>
<tr>
<td>Supplier</td>
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<tr>
<td>Barter</td>
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</tbody>
</table>

In the purpose to cover the handicraft domain details and thus facilitate the agents interactions, the business knowledge formalization is required. In fact, several business ontologies are implemented so to represent the handicraft business particularities. In the next subsection, we take as example the tapestry business ontology design.

3.2 The Handicraft Domain Specification

In order to join the handicraft woman expectations, we need to specify her business environment. A suitable way is to represent her professional world via the ontology formalism. An ontology is defined as a part of the real-world knowledge representation (Guarino 1998). The adoption of an ontology within the e-barter system ensures a successful communication between its agents and enables their interoperability and coordination (Sadeh et al. 2003). Actually, we integrated different business ontologies related to different handicraft areas such as tapestry, ceramic, embroidery etc. Every business ontology identifies and highlights the concepts and relationships specific to a particular handicraft field (Dhaouadi et al. 2014b).

In the following, we propose a short overview on the business ontology dealing with the tapestry production. In the following figure (Figure 2), three business processes are depicted namely procurement, producing and commercialization processes. The procurement process, for instance, may be achieved through an eventual E-purchase or E-barter procedures. Each one includes different activities. Indeed, the E-barter has the "Need Specification", "Peer Selection", "Barter Auctions" and finally the "exchange procedure" as activities. Regarding the producing process, it comprises different phases such as "Raw Material Preparation" and "Realization". Each producing phase may be divided into diverse activities which each requires
the use of several "Tools" (e.g. Loom) and has as input diverse "Raw Materials" (e.g. Colorant, Wool).

Figure 2: The business ontology related to the tapestry production

3.3 The E-Barter Interaction Protocols

In this subsection, we highlight the agents' interactions through the introduction of several communication protocol diagrams. The next figure (Figure 3) depicts the impact of a new customer command arrival.

Figure 3: Communication protocol diagram for the stock checking

In order to satisfy the client demand, the HDW would like to check automatically the available quantities within the stock. The interface agent plays the role of middleware between the HDW and the Stock Notifier. The latter is responsible of the checkout of the recommended raw materials for the production. Indeed, one interesting aspect in our work is to deduce automatically the supply requirement. Note that the under/over-storage verification is executed continuously and is not only expected when a new command is received. Different
business rules are used to infer an over or under-storage situations. These rules are considered as input of the Stock Notifier verification technique. More details about this technique are presented in the Algorithm 1. Before moving to the latter, several basic notions will be defined in the following:

**Definition 1 (Minimal stock).** The minimal stock includes the raw materials quantities necessary for the production. \( \text{MinQ}_j \) for instance, represents the minimal quantity relatively to the raw material \( R_{M_j} \).

**Definition 2 (Safety stock).** The safety stock represents the extra stock level necessary for the production sustainability under critical circumstances. Particularly, \( SQ_j \) depicts the safety quantity of the raw material \( R_{M_j} \).

**Definition 3 (Maximal stock).** The maximal stock represents the maximal raw materials quantities able to be stored. The producers target to respect the maximal stock level due to the storage cost and the raw materials degradation over time. \( \text{MaxQ}_j \) for example, expresses the maximal quantity regarding the raw material \( R_{M_j} \).

**Definition 4 (Customer command).** The customer command includes different artisanal products with the respective quantities. It is formulated as follows:

\[
\text{C} (\text{customer}_i) = \text{NB}_{P_1} \times P_1 + \ldots + \text{NB}_{P_n} \times P_n
\]

With :
- \( \text{C} (\text{customer}_i) \) : is the command related to the customer \( i \).
- \( P_i \) : is the product of category "i".
- \( \text{NB}_{P_i} \) : is the number of pieces of the product \( P_i \).

**Definition 5 (Business Rule).** The business rule, in our context, expresses approximately the involvement degree of the different raw materials within an artisanal product fabrication. These rules are extracted from the HDWs answers when they are face to face interviewed.

Actually, we conducted an important number of interviews in the purpose to gather relevant producing techniques. Firstly, a questionnaire is performed by a sociologist which is a project member. The questionnaire includes different questions such as: "Who designs the products for you?", "What are the needed raw materials for your production and what are the recommended quantities?", "What are the needed tools for your production?", "Are there any procurement difficulties?", "What are the transformation process stages?" etc. As project members, we conducted about 100 interviews with HDWs having different profiles issued from Tunisia and Algeria. The HDWs answers provide however a good basis for the business rules extraction. A business rule is formulated as follows:

\[
\text{R} (P_i) = t_1 \times R_{M_1} + t_2 \times R_{M_2} + \ldots + t_j \times R_{M_j} + \ldots + t_m \times R_{M_m}
\]

With :
- \( \text{R} (P_i) \) : is the business rule related to the product \( P_i \) fabrication.
- \( R_{M_j} \) : is a particular raw material required for the product \( P_i \) fabrication
- \( t_j \) : is the involvement degree (needed quantity) of the raw material \( R_{M_j} \) within the product \( P_i \) fabrication.

**Example.** Let a business rule R1 regarding the product P1 creation:
\[ R1(P_j) = 5 \times RM_1 + 2 \times RM_2 + 0.25 \times RM_3 \]

Literally, this rule notes that 5 units of \( RM_1 \), 2 units of \( RM_2 \), 0.25 unit \( RM_3 \) must be available in order to produce \( P_j \). We introduce right now the check stock state algorithm which uses the terms previously defined.

**ALGORITHM 1. Check Stock State Algorithm**

**Input:** Node \{NB\_P1, NB\_P2,...NB\_Pi,... NB\_Pn\} // the commanded products numbers

\{SQ\_RM1, SQ\_RM2,...SQ\_RMi,... SQ\_RMn\} // the safety quantities of the raw materials \( RM_i \)

\{MaxQ\_RM1, MaxQ\_RM2,... MaxQ\_RMI,... MaxQ\_RMn\} // the maximal quantities of the raw materials \( RM_i \)

\{Q\_RM1, Q\_RM2,... Q\_RMI,... Q\_RMn\} // the current quantities of the raw materials \( RM_i \)

\{R (P_1), R (P_2),... R (P_i),... R (P_n)\} // the business rules regarding the product \( P_i \) production

**Output:** The notifications concerning raw material out of stock or on surplus with respective quantities;

*/ We initialize the minimal quantity MinQ\_RMj with the safety quantity SQ\_RMj value.*

\[
\text{for } j \text{ from 1 to } m \\
\quad \text{MinQ\_RMj } \leftarrow \text{SQ\_RMj} \\
\text{end for}
\]

*/ If a raw material \( RM_j \) is included into the commanded products \{P_1, P_2, ..., P_n\} fabrication then we compute its minimal quantity relying on the defined business rules and the demanded articles pieces number*/

\[
\text{for } i \text{ from 1 to } n \\
\quad \text{for } j \text{ from 1 to } m \\
\quad\quad \text{if } RM_j \in R (P_i) \text{ then}
\quad\quad\quad \text{QMin\_RMj } \leftarrow \text{QMin\_RMj} + t_j \ast \text{NB\_Pi} \\
\quad\quad \text{end if}
\quad \text{end for}
\quad \text{end for}
\]

*/ Check the presence of an under or over-storage situation regarding the raw material \( RM_j \)*/

\[
\text{for } j \text{ from 1 to } m \\
\quad \text{if } (\text{QMIN\_RMj} > \text{Q\_RMj}) \text{ then}
\quad\quad \text{Write ("Under-storage Alert concerning", RM} _j\text{, "Quantity in deficit is", QMIN\_RMj} - \text{Q\_RMj});
\quad \text{end if}
\quad \text{if } (\text{Q\_RMj} > \text{QMAX\_RMj}) \text{ then}
\quad\quad \text{Write ("Over-storage Alert concerning", RM} _j\text{, "Quantity in excess is", Q\_RMj} - \text{QMAX\_RMj});
\quad \text{end if}
\quad \text{end for}
\]

Once, the check stock state algorithm is executed, three alternatives may arise regarding each raw material namely available quantity, under-storage or over-storage cases as showed in the next diagram (Figure 4).
As illustrated in (Figure 4), the checking process is repeated for each raw material. For each process iteration, the Stock Notifier agent deduces and displays the state of the stored raw material on the HDW interface. If the quantity is available, the HDW can proceed for the producing phases normally. If an under-storage case is occurred, the HDW asks both the purchase and barter agents to search for relevant supply opportunities. However, if an over-storage situation emerges, the HDW is only allowed to look for exchange possibilities through the barter agent recommendations. As said before, we do not consider the procurement alternatives suggested by the purchase agent which are undertaken in (Dhaouadi et al. 2014a). Besides, in this paper, we deal particularly with the e-bartering scenarios. To do so, the barter agent is the responsible for driving the research process for suitable peers.

In order to initialize the exchange process (Figure 5), the barter agent calls for exchange opportunities within the HDW network. It addresses accurately the different barter agents relative to the remaining HDWs. Note that Barter[i] and HDW Interface[i] mean respectively the barter and the HDW interface agents related to the HDW i-th instance. Once the exchange demand is received and displayed in her interface, the HDW may refuse or accept it. In the second case, the acceptation is propagated until the initial barter agent. The latter has to rank the received positive answers through the execution of the matching profile algorithm. The proposed algorithm adopts different rules which guides the selection of suitable barter peers. In fact, two HDWs having similar profile parameters, such as living at the same locality, are disposed to be relevant exchange peers. The ranked list is then communicated to the current HDW.
As shown in (Figure 6), three cases may arise relying on the number of received positive answers. If the ranked list is empty (answers number = 0), thus the current HDW has the choice to look for new procurement opportunities. If only one positive response is received (answers number = 1), then the HDW responsible for the decision making is able to initialize a negotiation procedure with the proposed exchange candidate. The negotiation begins with a call for proposal from the current HDW to the eventual exchange peer (HDW [i]). The latter proposes the properties of the good to exchange and can ask for another in return. Of course, the proposal is propagated until the current HDW. If she disagrees with this proposal, it does not mean the negotiation is failed. Nevertheless, the negotiation steps will be repeated until the mutual satisfaction of both barter peers occurs. This loop is broken when the HDW in question accepts or refuses the proposal definitively. The third scenario occurs when the number of received positive answers exceed 1 (answers number > 1). Here, the HDW bids on the barter auction in order to select the best exchange offer. As a barter auction initiator, the HDW targets to acquire the needed raw material and give back the less useful one. In the opposite side, each HDW, which seems to be an eventual barter candidate, sends her proposal towards the barter initiator (Figure 6). When the proposal list is displayed within her interface, the HDW opts for the promising alternative. Sometimes, she calls for proposal for a second or third time until receiving a convenient offer: an offer which maximizes the needed raw material quantity and minimizes the quantity of the asked raw material. In other words, the barter auction scenario (frequent in real life) maximizes considerably the HDW (barter initiator) benefit. Likewise, it affords her more flexible and relevant choices.
In order to validate the proposed approach, we emulate several e-bartering scenarios. The simulation objective is to show the real scenarios feasibility. First-of-all, we settled up different business ontologies related to tapestry, ceramic and embroidery productions based on Protégé software. We specified likewise, several business rules as extracted from the interviews where each rule is dealing with a specific product regarding its nature as well as its characteristics (dimensions, weight etc.). The system as described above is implemented using the jade platform under eclipse tool. Moreover, the bean ontology generator plug-in is used to generate the Java files representing the developed ontologies (easily used by the jade environment). During the simulation, we created 2 customer agents in addition to a community of 10 HDW agents having different profile parameters (geographic locality, handicraft domain) and their respective barter, purchase and interface agents. The agent communication is ensured via the FIPA-ACL language. The Contract-Net Protocol is followed during the bidding and negotiation procedures. In the following, we expose a simulation scenario (Figure 7) where The interfaces express the process evolvement.
"Sofia" (a HDW agent), received a customer command (Interface 1) asking for the fabrication of the "margoum" product with precise dimensions (2 meters of length and 1.5 meters as width). The "margoum" is a wool weaving used as floor carpet whose origins are Arab-Berber. After the automatic stock checking (Interface 2), it has been found that the "wool" (required raw material) is out of stock. Hence, the HDW looks for suitable procurement opportunities. Effectively she receives different supply alternatives from both barter and purchase agents (Interface 3). Since the HDW is rather interested in an exchange procedure, she focuses on the ranked list of the eventual exchange peers recommended by the barter agent. The list comprises 2 tapestry makers (HDWs) namely Sarah and Linda which are living at the same locality as "Sofia". A barter auctions scenario is held then (Interface 4). While Sarah proposes the "colorant" raw material in exchange for "wool", Linda asks for cotton. The colorant is less interesting according to Sofia that is why she opts for Sarah as the interesting exchange peer.

Figure 7: The HDW interactions with the system

5 Conclusion

We proposed a recommender system which assists the HDW during the procurement process. It offers her relevant supply opportunities through suggesting suitable barter partners. The trade peers suitability relies on their profile similarities and their expenses minimization. The e-barter system is recurrent supply solution which replaces or extends classical procurement transactions. E-bartering consists in exchanging goods between a network members without the implication of money. Our approach proposes online solutions. It guarantees also the barter initiator (HDW) benefit on two levels. The first level reinforces her relationships with the network members. The second level promotes her economic profit via the barter auctions.
module. In further research we propose to test our approach in real context where data regarding profile parameters and preferences are learned automatically. Likewise, we propose to define new ways for assessing the bartered goods values.

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