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Towards uBPMN-Based Patterns for Modeling Ubiquitous Business Processes

Alaaeddine Yousfi, Marcin Hewelt, Christine Bauer and Mathias Weske

***Abstract*—Ubiquitous business processes are the new generation of processes that pervade the physical space and interact with their environments using a minimum of human involvement. Although they are now widely deployed in the industry, their deployment is still ad hoc. They are implemented after an arbitrary modeling phase or no modeling phase at all. The absence of a solid modeling phase backing up the implementation generates many loopholes that are stressed in the literature. Here, we tackle the issue of modeling ubiquitous business processes. We propose patterns to represent the recent ubiquitous computing features. These patterns are the outcome of an analysis we conducted in the field of human-computer interaction to examine how the features are actually deployed. The patterns' understandability, ease-of-use, usefulness and completeness are examined via a user experiment. The results indicate that these four indexes are on the positive track. Hence, the patterns may be the backbone of ubiquitous business process modeling in industrial applications.**

***Index Terms*—Ubiquitous Business Process, Ubiquitous Business Process Modeling, uBPMN, Ubiquitous Computing.**

I. Introduction

Thanks to the technological advances that have blossomed in recent years, systems are currently more sophisticated than ever. On a typical day, we can now go for a run with wearables that track and share our location, heart rate, burned calories and speed (e.g., FitBit[1]). We can also play games using gesture and spoken commands rather than a game controller (e.g., Microsoft Kinect[2]). We can even order a song by just providing an audio excerpt of it (e.g., Shazam[3]) rather than trying to find it through its lyrics. All these examples and much more fall under the scope of ubiquitous computing (ubicomp).

Ubiquitous computing finds its roots in the vision of Mark Weiser [1]. It denotes the third generation of modern computing where one person owns and operates multiple computers. This discipline stands on the principle that computing pervades our physical space by taking place everywhere. Ubicomp brings up many benefits. It proposes a panoply of solutions [2] to bridge the gap between virtual systems and the physical environment in which they appear (i.e., Internet of Things [3]). The discipline also broadens the human-computer interactions by offering state-of-the-art input technologies [4], [5] to pleasantly interact with any kind of systems. Ubicomp is currently fueling research in Industry 4.0 [6].

When ubiquitous computing meets business process management (BPM) [7], we speak of ubiquitous business processes. *A ubiquitous business process is a location-independent business process that turns its business environment into a source of data and/or a target of outcome with the least of human interventions* [8]. Ubiquitous business processes carry a myriad of ubiquitous computing features such as automatic identification and data capture, context awareness, augmented reality, sustainability and ambient intelligence.

Although ubicomp features are now widely deployed in industry, their deployment is still ad hoc [9]. And while ubicomp was coined in the early 1990s, the discipline is still understudied when it comes to BPM. So far, recent contributions in the BPM field are limited to listing the theoretical benefits of ubicomp (e.g., [10]) or some of its features (e.g., context-awareness [11]). To date, the literature does not provide answers for representing the ubicomp features at the process level. The standard BPMN v2.0 (Business Process Model and Notation) itself cannot properly depict those. This situation has pushed organizations to implement and deploy ubiquitous business processes with no [solid] models backing up the code. While this solution can have ephemeral benefits, many references stress how detrimental the practice of jumping to code without designing sound models can be (e.g., [12], [13]). The build-and-test approach is too costly in terms of time and money.

Throughout this paper, we propose an approach to bridge the gap between ubiquitous computing and business process modeling. Our approach helps represent the recent ubicomp features within the process flow, in a straightforward manner, and without having a deep knowledge about them. Therefore, the remainder of the paper is structured as follows: in Section II, we examine related work, stress its shortcomings and position our ideas for overcoming them. In Section III, we briefly describe a ubiquitous extension of BPMN (i.e., uBPMN), that we use to put forward our approach. Based on that work, Section IV lays out the core contribution of our paper – our pattern approach –, while Section V describes its evaluation. Afterwards, we use Section VI to propose a comprehensive example and Section VII to conclude this paper, discuss its results and outline future work.

II. Related Work

Since its inception, ubicomp has aroused many research interests from numerous disciplines. In business process management, researchers were interested in leveraging its findings

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[1]https://www.fitbit.com

[2]https://developer.microsoft.com/kinect

[3]http://www.shazam.com

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to further improve business processes and enable them to keep up with the recent technological trends. For instance, Jung et al. [14] propose service integration to allow a ubiquitous business process management. Giner et al. [15] take a model driven approach. They argue that the dynamism of business processes and the complexity of ubiquitous computing require an adequate method for the construction of ubiquitous systems and propose a systematic model-driven development method. Wamba et al. [16, p. 279] propose an approach to enable "smart business processes" by means of RFID (Radio Frequency IDentification) integration.

While the aforementioned approaches address ubiquitous computing in business processes as a whole, there are also many publications that focus on how ubicomp capabilities may be represented in process diagrams. Gao et al. [17] add sensors and smart device business functions to the BPMN diagrams to shrink the information gap between the physical world and the processes. Similarly, the authors of [18] and [19] extend BPMN to represent wireless sensor networks. Appel et al. [20] dedicate their work to the processing of event streams from the Internet of Things and extend BPMN accordingly to depict this capacity. With all that being said, the literature still runs short in offering an approach to model ubiquitous computing features (e.g., automatic identification and data capture, context awareness, augmented reality, sustainability and ambient intelligence) at the process level. For instance, how should one model context-awareness? So far, this question remains unanswered even though ubicomp is sought more than ever before. However, because the discipline is more than thirty years old, ubicomp is not easily approachable by the current process personnel in industry (i.e., process owner, manager, participant, analyst and engineer [21]) who come from different backgrounds.

Still, one might argue that ubiquitous business processes are widely embraced in industry [22], (particularly in Industry 4.0 [23]) and question why the representation of the recent ubiquitous computing features in process diagrams might matter in practice. The answer is simple, but has a large impact: today in industry, ubiquitous business processes are typically implemented without any models that could back the code. As a result, important parts of the process life cycle such as conformance and compliance remain neglected. The reason behind this is that modeling languages such as the BPMN v2.0 fall behind in representing ubiquitous business scenarios. Consequently, organizations have to design models on their own, digressing from the standard or sometimes going directly into operationalization. The negative impacts are twofold. First, it leads to a gap between the diagrams and the code. The literature is abundant about the weaknesses that emerge from jumping to code without having any straightforward modeling phase (e.g., [12], [13]). Second, we have to keep in mind that process models are considered a communication medium among the process personnel. Non-complying or non-exact diagrams negatively impact this communication, therefore, leading to misunderstandings that cost more time and money.

In a nutshell, the literature lacks an approach to model the various ubicomp features of automatic identification and data capture, context awareness, augmented reality, sustainability and ambient intelligence. Hence, we propose an approach to catch up on this deficiency. It builds on the work presented in [8], [24] where a new notation to depict ubiquity in business processes was introduced. Here, we employ that notation (summarized in Section III) and address the issue of representing those features using patterns.

III. uBPMN in Brief

In this section, we summarize the basics of Ubiquitous Business Process Model and Notation (or uBPMN), which builds the basis for our pattern approach introduced in Section IV. uBPMN is a conservative extension of BPMN v2.0 to depict ubiquity in business processes [24], [8]. The extension is conservative because everything true about BPMN v2.0 persists within uBPMN. It was accomplished in accordance with the OMG guidelines [25] and what has been already established in the literature (e.g., [26]).

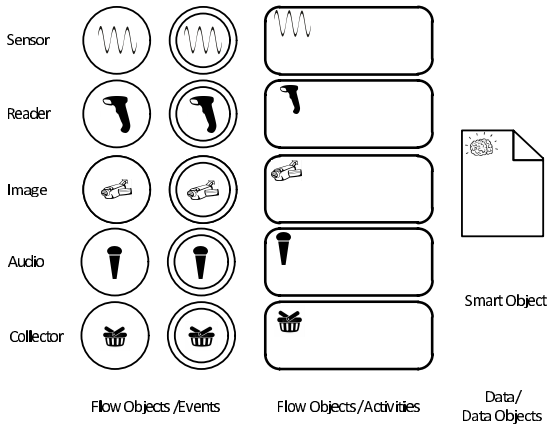

Fig. 1. uBPMN additional modeling elements

From a modeling standpoint, uBPMN was introduced to represent the recent ubicomp input technologies. These are sensors that quantify the physical data (e.g., temperature, position), smart readers that read data represented in standardized fashion (e.g., barcode, NFC), cameras, microphones and collectors that gather information from remote or local files (e.g., Cloud, Internet Packets) or proxy devices. Thanks to the newly added elements, uBPMN lays the groundwork for representing the latest ubicomp features of automatic identification and data capture, context-awareness, augmented reality, sustainability and ambient intelligence. As shown in Figure 1, three categories of BPMN v2.0 elements were targeted by the extension; Flow Objects/Events, Flow Objects/Activities and Data/Data Objects. For each input technology, five types of Events (five Start Events and five Intermediate Catch Events) were introduced in the first category, five types of Tasks in the second and one type of Data Object (i.e., Smart Object) in the third. Note, a Smart Object is a physical object that can report its state with the least of human interventions. For instance, a bottle is a physical object. However, a bottle with a barcode tag is a smart object because the barcode tag can report the state of the bottle, with the least of human interventions (e.g., scanning the barcode of the bottle and ordering it instead of typing its

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brand name and searching for it exhaustively). Hereafter, we use uBPMN to model those features.

IV. Modeling Ubiquitous Computing Features

To help embrace ubicomp within the process flow, we hereby share the guidelines for modeling the ubiquitous computing features of automatic identification and data capture, context-awareness, augmented reality, sustainability and ambient intelligence. Therefore, each subsection is dedicated to a feature and they all follow the same outline; we briefly define the feature, list examples from the business world to concretely stress its adoption, share the instructions to model it, then, provide a tangible example to consolidate the explanation.

A. AIDC

Automatic Identification and Data Capture (or AIDC) refers to the procedure of automatically identifying objects and collecting data about them [27]. Via this technology, the information is both identified and collected quickly, discretely and most of the time accurately [16], [28]. AIDC is key to overcoming the issue of Media Break [29] by reducing the dependency of processes on humans. A Media Break occurs when the process pauses and requires humans to transfer data for it to continue [8]. This is considered a issue because workflows are supposed to take place in real time and pausing them to purvey data goes against the foundational pillars of a workflow. In the business world, AIDC appears in a panoply of cases. Amazon[4] offers the technology to identify and order products from their barcodes or appearances (e.g., book cover). UPS[5] deploys it to sort the millions of packages that transit throughout its logistics system everyday. Shazam uses it to help identify and buy multimedia content. AIDC is also deployed in highways to deduct the toll and prevent long queues at the entrance and exit points.

Deploying AIDC consists of injecting a ubicomp input technology to identify and capture the information on the fly. To date, these are sensors, smart readers, collectors, microphones and cameras [24]. At the process level, they can exclusively be depicted via the uBPMN extension that we explained in Section III. Note, there is no general architecture for the depiction. To inject AIDC within the process flow, all one has to do is include the ubicomp input technology(ies) in accordance with the uBPMN specification. We recall that uBPMN is a conservative extension of BPMN. In other words, everything true about the former is also true about the latter.

Example: While approaching a highway's entry point, the RFID antenna scans the tag on the car's windshield and saves the car's start location. While approaching a highway's exit point, another antenna scans the tag on the windshield, infers the end location and leads to deducting the corresponding toll.

The corresponding model is shown in Figure 2. As portrayed, the process starts once the RFID tag is read at the highway entry point and ends once the toll is deducted - after the same tag is read at the highway exit point. Because Radio Frequency Identification is a ubiquitous computing technology, the tag is both identified and captured on the fly at the toll plazas. In doing so, the highway systems insure a fluidity of the traffic by avoiding long queues. Note, we use a Data Store to indicate the persistence of the data beyond the process scope.

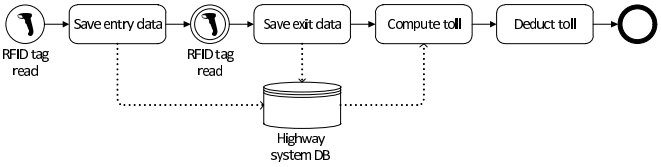

Fig. 2. AIDC example

B. Context-Awareness

Context-awareness is the ability of a system to rapidly adapt itself to the context of an entity [30]. The context of an entity is any information that characterizes it [31]. In ubiquity, this context is theoretically unbounded [1]. For instance, an entity book can have a plethora of contextual dimensions that characterize it such as its title, front cover and the number of pages it encloses. Even the title itself can exhibit a myriad of contextual information that goes beyond imagination, namely, its position, font, font size, font color, writing style (e.g., bold, italic, underlined) and writing mode (e.g., lower case, upper case, camel case). Currently, we can witness the presence of context-awareness across distinct domains. Netflix[6] and YouTube[7] deploy it to recommend videos with regard to a particular location (i.e., a contextual information) [32]. Context-awareness helps also determine the video quality. Depending on the Internet speed (i.e., a contextual information), the quality of the video played can range from 144p to 1080p. In the same vein, Google (e.g., AdSense[8], AdWords[9]) uses context-awareness to effectively run its Ad business.

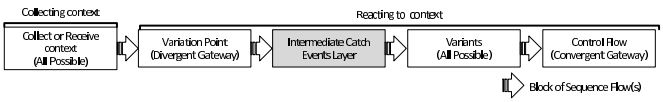

Fig. 3. Context-awareness pattern

To enable context-awareness, one has to (1) collect context, then, (2) react to it (e.g., [9], [33]). Hence, Figure 3 shows the pattern for representing context-awareness at the ubiquitous business process level. From left to right, there is the context collection part. Here, context can either be atomic or composite. The former refers to one piece of information (e.g., location) while the latter to many pieces (e.g., location, speed, time). Additionally, context can either be directly captured by the process participant, using a ubiquitous computing input technology, and/or received as a message from another/other participant(s). The second part is about reacting to the collected context. Here, we use the concept of

[4]https://www.amazon.com/gp/feature.html?docId=1000729231
[5]https://www.ups.com
[6]https://www.netflix.com
[7]https://www.youtube.com/
[8]https://www.google.com/adsense
[9]https://www.google.com/adwords

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variability [34], [35]. Variability is about efficiently modeling processes that have many commonalities yet exhibit some differences, by factorizing the commonalities and grouping the differences in a process of reference. Its relevance stems from the fact that context-awareness always deals with the predefined set (i.e., commonalities). What makes the difference from one case to another is the context and its follow-up. For instance, the Internet speed helps determine the video quality that always ranges from 140p to 1080p. Those options are generally common to each and every video (i.e., each and every process instance). However, the speed can have an abundance of values that theoretically range from 0Kbps to a value in Gbps (i.e., differences in Internet speeds). For that, we use a preexisting architecture that was published in [36], [37]. Its gist, as indicated in the figure, starts with a divergent Gateway that sets the cardinality of selecting the option(s) (i.e., variant(s) in variability terms). The variant selection depends on the branching condition linking it to the divergent Gateway (e.g., select 144p video if the speed is lower than 2Mbbps). Overall, a cardinality of *Monomial* is about selecting one option among the ones offered (i.e., 1) and is represented with an Exclusive Gateway. A cardinality of *Multiple* is about selecting some options among the ones offered and is represented with an Inclusive Gateway (i.e., 1..*) while a cardinality of *Optional* refers to the possibility of either selecting or skipping the available options (i.e., *) and is represented with an Inclusive Gateway as well. The Intermediate Catch Event layer shown in gray will only be applicable in case the preceding divergent Gateway is event-based. Otherwise, the layer is to be skipped. The variants can be a sequencing of uBPMN modeling elements as long as their placement goes by the specification. On the extreme right, there is a control-flow convergent data-based Gateway to insure a validity of the model. Its type (inclusive or exclusive) matches the one of the variation point.

Example: The quality of the video to play depends on the Internet speed.

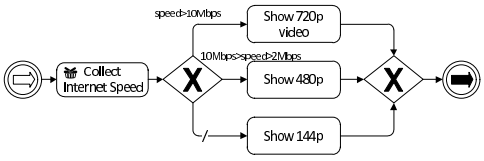

Fig. 4. Context-awareness example

From the example, we understand that collecting context is about capturing the Internet speed while reacting to it is about opting for the appropriate video quality with regard to the collected speed. Since we are talking about one piece of information, the context here is atomic. We also assume that it is captured by the same process participant via the Collector Task. Because only one video quality is allowed, we use a variability of type Monomial to depict the context reaction part. Hence, we place an exclusive Gateway as a variation point. Similarly, we place another one for control flow after the variants. For simplicity, we use only three variants that represent the video qualities of 144p, 480p, 720p. Their respective branching conditions are a collected speed lower than 2Mbps, between 2Mbps and 10Mbps and greater than 10Mbps. The corresponding model is shown in Figure 4. Note, we focus on the context-awareness segment and use Intermediate Link Events of type Catch and Throw to show it. We also follow the same style for the upcoming features.

C. Augmented Reality

Augmented reality's main goal is to supplement the real-world with computer-generated content [38]. It allows the real-time fusion of physical objects with virtual ones [39], [40]. The outcome appears to co-exist in the same space as the real world. This technology improves the user experience by enriching the physical environment with virtual systems [41] (e.g., enriching the view of a historical monument with information about its genesis). It simply gives an individual the power of seeing more than what others see. To date, augmented reality has been embraced by a wide range of disciplines such as entertainment [42], medicine [43] and education [44]. For instance, TryLive[10] offers this technology to try on apparel, HappyView[11] focuses solely on eyewear and Home Depot[12] provides it to help customers plan their home improvement(s) (e.g., change door, test furniture). Note, augmented reality usually takes place on the system's frontend.

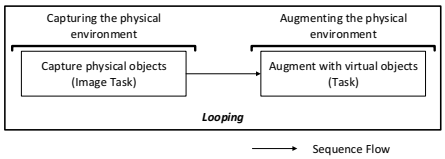

Fig. 5. Augmented reality pattern

From the previous examples along with what has been established in the literature (e.g., [45], [46]), we can conclude that an image input stream is mandatory for the deployment of augmented reality. It captures the physical objects and provides a background to superimpose the virtual ones. Within ubiquitous business processes, we use an Image Task. Note, a video is a sequence of images with a speed greater or equal than fifteen frames per second. Figure 5 shows the pattern for representing augmented reality. It is composed of two activities forming a sub-process. The first captures the physical environment while the second augments it with the virtual component(s). Both activities are looping to generate a video.

Example: After choosing an eyeglass frame, the customer is prompted to virtually try it on via the device's camera.

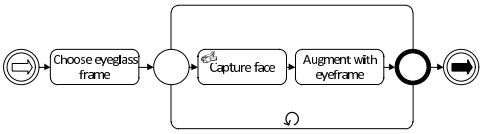

Fig. 6. Augmented reality example

[10]http://www.trylive.com/
[11]http://www.happyview.fr/
[12]http://www.homedepot.com/c/SF_Mobile_Shopping

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Figure 6 shows the proposed model of the example. The first Task models the action of choosing the frame while the sub-process depicts the augmented reality feature (i.e., capturing the face and superimposing the selected frame on it).

D. Sustainability

As its name indicates, sustainability is the ability to maintain a certain level in the long run [47]. This technology has been at the forefront of the research agenda because a sustainable system is basically one that persists for the longest possible life span [48]. Note, everything has a beginning and everything comes to an end - sustainable systems included. To date, we can observe sustainable systems in energy management [49], financial services [50], environment [51] and agriculture [52]. Sustainability is sought to preserve any type of resources. Google Fused Location[13] and Nest thermostat[14] are famous examples of sustainability in the world of ubiquitous computing. The former balances the advantages of enabling location-based services in a smartphone with the lifespan of the phone's battery. The latter reduces the energy consumption in a house by adapting the temperature to the behavior of its residents.

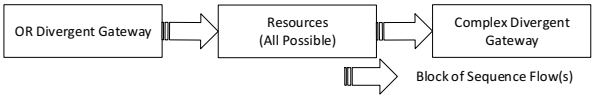

Fig. 7. Sustainability pattern

To represent sustainability at the ubiquitous business process level, we propose the pattern shown in Figure 7. It starts with an inclusive divergent Gateway. The Gateway portrays the possibility to opt for one, some or all available resources. These can be represented using different uBPMN elements as long as their alignment adheres to the specification. Each resource is chosen depending on the branching condition that links it to the Inclusive Gateway. Following the resources placement, there exists a convergent Complex Gateway. It allows selecting the optimal outcome. The selection rule varies with each situation. It can be represented in the same way the OMG did on page 361 of the BPMN v2.0 specification manual.

Example: To ensure a sustainability of energy within mobile devices, the process is configured to capture location using different mediums (i.e., GPS, Cell Tower, Wi-Fi, Bluetooth).

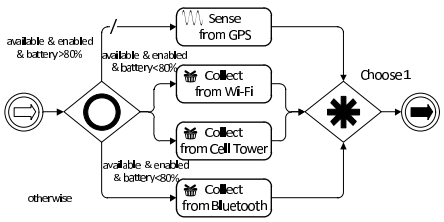

Fig. 8. Sustainability example

The corresponding model of the example above is shown in Figure 8. The four resources are delimited by an inclusive Gateway and a Complex one. The former gives the possibility of choosing the available resources while the latter determines the selection criteria of the outcome (e.g., select the location with the highest accuracy). This is one of the example that is currently in use within mobile devices to expand their battery life. What might vary from one case to another are the branching conditions of the inclusive Gateway and the selection criteria of the Complex one which we leave open.

E. Ambient Intelligence

As its name indicates, ambient intelligence brings intelligence to our everyday environments and makes them responsive to us [53]. Its main goal is to assist us throughout the complicated modern world [54] where we are asked to do more and more in the same twenty four hour time frame that we have always had. The interactions are indeed intuitive and attuned to our senses. An ambient intelligence system recognizes the people that it interacts with and unobtrusively renders its services in a sensitive way to meet their needs [55], [56]. It also has diverse social, economic and ethical implications (e.g., [57]). In the business world, Google Now[15], Amazon Echo[16], Microsoft Cortana[17], Apple Siri[18], and, recently, VIV[19] are among the prominent ones to date.

Before covering its modeling details, we have to highlight that ambient intelligence is theoretically composed of two major phases; a learning phase and an operation phase. The learning phase consists of collecting all sorts of relevant data in the user's environment (e.g., via email mining [58], activity sensing [59], location tracking [60]) in order to build her/his user model. The collection is accomplished using the different ubicomp input technologies and takes place mostly in the background. The operation, on the other hand, is either triggered by the user (e.g., saying "*OK Google*" then "*Flights to Dallas*" to Google Now - *OK Google* is the first command that intentionally triggers the system while *Flights to Dallas* is the second that highlights their wish) or by the system itself (e.g., sending an alert to the user about their upcoming flight with directions to the airport). Note, there is no definite sequencing of the two phases, also, since the learning phase is unpredictable, we focus on the operation phase only.

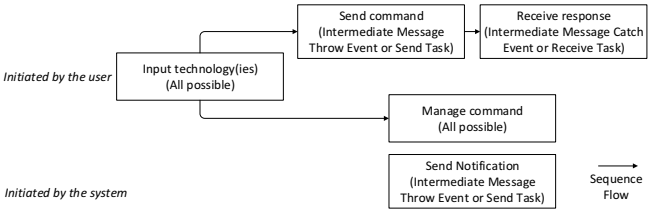

Fig. 9. Ambient intelligence pattern

As explained previously, ambient intelligence interactions can be initiated by either the user or the system itself.

[13]https://developers.google.com/android/reference/com/google/android/gms/location/FusedLocationProviderApi

[14]https://nest.com/thermostat/meet-nest-thermostat/

[15]https://www.google.com/landing/now/

[16]http://www.amazon.com/Echo

[17]https://www.microsoft.com/en/mobile/experiences/cortana/

[18]http://www.apple.com/ios/siri/

[19]http://viv.ai/

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Therefore, we introduce two patterns as shown in Figure 9. The top one generically represents interactions initiated by the user. It starts with one or a sequence of input technologies to capture the command(s). These can be Events (Start or Intermediate Catch) or Tasks. Once captured, the command(s) are either sent and executed on the system's backend (e.g., *OK Google*, then *Flights to Dallas* goes to the backend to get a listing of available flights) or handled locally (*OK Google*, then, *Add milk to my shopping list* is saved on the phone). For interactions initiated by the system (bottom), the modeling is much simpler as it consists only of sending a message (Message Intermediate Throw or Sender Task) to the user.

Example: Via Google Now, the user can get a listing of the available flights by sequentially firing up the audio commands of OK Google, Flights to San Francisco.

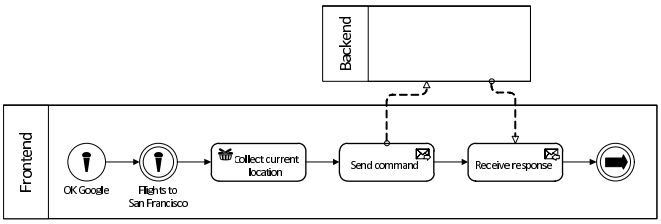

Fig. 10. Ambient Intelligence example

The example presents an ambient intelligence interaction initiated by the user. *OK Google* is the initiator command while *Flights to San Francisco* is the main one. The latter command is sent and processed in the backend where a global distribution system can be queried to get the list of available flights (e.g., Amadeus[20]). Note, the main command implicitly requires a collection of the current location. This is a primary information as it is the start point to search for airports in its vicinity instead of asking to provide that information manually (e.g., type the name of the airport). As we explained in the previous section, location can be captured in a sustainable way. Here, we only use a Collector Task to represent a location collection from the device IP. Overall, there are three input technologies that capture the necessary information to properly perform the ambient intelligence interaction.

V. Evaluation

The evaluation examines the quality of our proposed patterns with respect to modeling ubiquitous business processes. To attain this objective, we employ a single-case mechanism experiment as suggested by the Design Science Research methodology guidelines [61]. We use this approach because we evaluate and test artifacts, which, in our case, are the uBPMN patterns. These are evaluated in the simulated context of a classroom experiment. However, this context resembles the real-world context in which the patterns are expected to be applied. The resemblance stems from the fact that our participants are business process experts and the scenarios are borrowed from the industry. Overall, for each modeling assignment, our participants were asked to model two business scenarios that exhibit features of ubiquity.

[20]http://www.amadeus.com/

The first scenario showcases context-awareness, augmented reality and sustainability. It is about a customer who wants to buy glasses from an online shop. Depending on the location, which can be captured using GPS, WLAN or the cell tower, certain glasses are on stock. These glasses can be tried on virtually by the customer using a connected camera.

The second scenario is about ambient intelligence. It describes a customer who issues audio commands to receive recommendations for nearby restaurants. To focus solely on ubiquity, participants were asked to ignore ordering and payment in both scenarios.

Measurement Design. Our knowledge goal is to study the patterns' understandability, ease-of-use, usefulness, and completeness. These are important indicators for the quality of a modeling language (or language extension in our case) [62] as well as the user acceptance [63]. If we find that the patterns are easy to understand, easy to use, complete, and useful, in reaching the modeling goal (our knowledge questions), this would support the claim that the patterns ease the modeling of ubiquitous business processes. Striving for our knowledge goal, we rely on self-reported data by the participants, collected using a questionnaire that was designed following Tullis and Albert [64]. Each knowledge question is represented in the questionnaire by a group of four or five statements, e.g., "I found the patterns easy to understand" or "I would recommend the patterns to a colleague". Each group contains one negative statement to check that participants answer carefully, e.g., "I found it complicated to use the patterns". We measure the level of agreement with the statements on a 5-point Likert scale, designed to be balanced and symmetric to support quantitative analysis. For analysis, the values are projected onto a numerical scale ranging from 0 to 4 (interpreted as complete disagreement/agreement), with 2 being the neutral position. To determine the value for each knowledge question, we average the single items in the corresponding group (negating the answer for the negative statement). Additionally, the questionnaire asks for the participants' experience with regard to BPMN and ubicomp.

Experiment Setup. To ensure that the selected individuals are a good representation of the intended future users of the uBPMN patterns, we asked for their experience with BPMN and ubicomp. Hence, we recruited 4 PhD students working on BPM and 13 master students who major in business process management. The PhD students have both published and reviewed papers in BPM. The master students were about to graduate and some of them have already secured jobs in the industry. Number-wise, our 17 participants have previous experience with BPMN, ranging from 0.5 to 10 years, with a median of 3.5 years. Their understanding of ubicomp averages at 1.77 on a scale from 0 (no understanding) to 3 (very good). Thus, the participants are to be considered a good proxy for the intended users of the uBPMN patterns, i.e., process personnel with basic understanding of ubicomp.

The experiment was conducted over a period of two weeks. In the first week, we asked the test subjects to perform a modeling task without the use of our approach. We also administered a questionnaire at the end of the assignment. After that, we held a lecture about our ubicomp approach

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(presented in Section IV). The participants were asked to think of a scenario of their own for each of the patterns to ensure their engagement. The experiment continued one week later, when participants were assigned a modeling task using our patterns, and a questionnaire afterwards. For both modeling assignments, the time was measured and limited to 15 minutes for the first and 10 for the second scenario.

Results. We found that all knowledge questions are answered positively. Figure 11 shows, from left to right, the results for understandability, ease-of-use, usefulness, and completeness. The patterns' understandability scored highest among the participants (median 3.2, mean 2.91), followed by ease-of-use (median 3, mean 2.88), and usefulness (median 2.8, mean 2.85). The completeness is rated slightly worse with a median of 2.25 and a mean of 2.44. It also has the highest number of disagreeing answers, i.e., answers with a value below 2. The usefulness has 3, understandability 1, and ease-of-use 2, completeness has 7 disagreeing answers, and hence its first quartile is below 2. The standard deviation is lowest for ease-of-use (0.66) and highest for usefulness (0.9), while understandability (0.87) and completeness (0.82) rank in between. There is only a slight correlation (r-value around 0.5) between ubicomp experience of participants and positive judgment of understandability, ease-of-use, and usefulness. Ubicomp experience and judging of completeness are not correlated. Modeling time is slightly lower for uBPMN, however, this can be explained by the fact, that the participants got familiar with the scenarios, when modeling with BPMN.

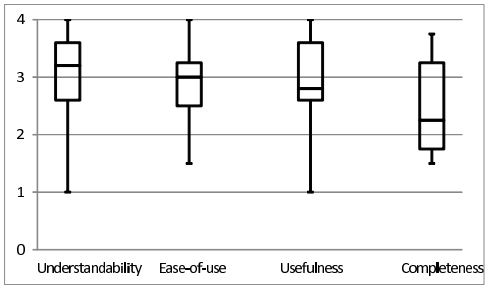

Fig. 11. Experimental results

Our participants closely followed the suggested uBPMN patterns when modeling, resulting in solutions similar to one another and to our own solution. Figure 12 shows a sample solution for the second scenario (selected for its readability). It is very similar to the exemplary use of the ambient intelligence pattern presented in Figure 10. Due to space limitations, we did not include further models created by the participants.

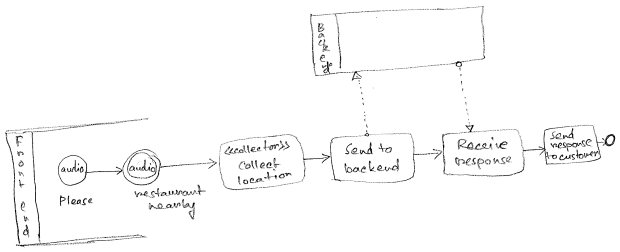

Fig. 12. Sample solution of a participant for scenario 2

Limitations. Since the evaluation was administered in a limited time frame (two weeks), the participants may have had a learning effect and were more likely to judge the patterns easy to understand and use. To mitigate this issue, we have refrained from offering any kind of assistance during the modeling assignments. We have also collected and thoroughly examined the feedback provided by our test subjects.

In addition, while our test subjects were recruited from academia, it does not undermine the quality of their feedback. The PhD students have previously published and reviewed papers about business processes. The master students majored in business process management and were on the verge of hitting the job market. Some of them have already secured positions in renowned firms. In fact, this practice of selecting test subjects can have a healthy effect on the evaluation of incipient approaches as stated by Gemino and Wand [65]. These authors confirm that practitioners can be biased towards their current established working styles. Students, on the other hand, will have a strong impact on the adoption and application of the approach in industry.

VI. Illustrative Example

To help assimilate using the patterns, let us consider the example of an online shopping process. The process starts with the user searching for the product and ends up with her/him checking out. Overall, the process has the following requirements:

RQ. 1 Users can vocally search for products (instead of typing the search strings).

RQ. 2 The products listed depend on the current location of the user (i.e., if a product is not sold in the user's location, it is not shown to her/him).

RQ. 3 Users can try the chosen products before buying them.

Table I outlines the corresponding ubiquitous computing technology(ies) to each and everyone of the aforementioned requirements. Enabling audio-driven commands (RQ. 1) means that the process holds an audio-driven AIDC. In the same vein, listing products depending on the location of the user (RQ. 2) implies that the process is context-aware. Here, context is atomic (i.e., location). Furthermore, location capture can be sustainable. As a result, we can use different mediums (e.g., GPS, Internet Packets) to acquire it. Last but not least, offering the possibility to try on the product before buying it (RQ. 3) can be guaranteed via augmented reality.

TABLE I
Requirements Matching

Requirement	Ubiquitous Computing Feature
1	AIDC (Audio)
2	Context-Awareness and Sustainability
3	Augmented Reality

In Figure 13, we propose a corresponding ubiquitous business process model. The process is initiated when the user articulates an audio command (i.e., audio-driven AIDC). After receiving the audio command, the current location of the user is obtained. Acquiring the location can be accomplished

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in a sustainable manner as represented by the sustainability fragment. The sustainability fragment also plays the role of the context collection part. The context reaction part lists the appropriate products based on the communicated location. The user can then try one of the listed items via the augmented reality fragment before checking out.

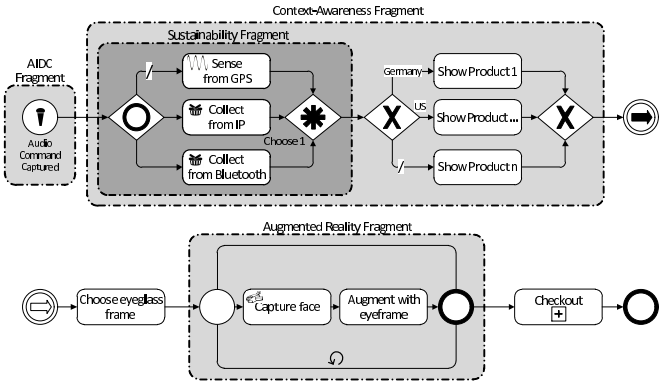

Fig. 13. Shopping ubiquitous business process model

To show how each fragment operates within the ubiquitous business process flow, we attach Figure 14. The figure represents a snapshot of the implemented process. On the upper side, the audio command is captured. The user is then geo-located and the list of available products is rendered. Once selected (via the *try* link), the user is prompted to try the item on via her/his camera as shown on the right side of the figure.

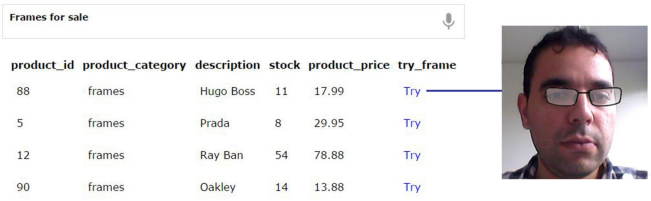

Fig. 14. Snapshot of the ubiquitous business process implementation

VII. Conclusion, Discussion and Future Work

In this paper, we propose an approach to model the recent ubicomp features. It is based on the concept of patterns. The proposed patterns are the outcome of a thorough analysis we conducted with regard to the features' deployments in the discipline of human-computer interaction (where they originated). The patterns aim to bridge the gap between the latest achievements in ubicomp and business process modeling. They also work as a ready-to-use gadget for a process personnel in industry that seeks ubicomp but lacks the basic knowledge to use it. An evaluation was conducted to examine the patterns' understandability, ease-of-use, usefulness, and completeness. The results are very promising. They show that the patterns are easy to understand and apply even with a shallow understanding of ubicomp. In addition, they are very useful in accurately depicting the ubicomp features.

To progress our ideas, we plan on scaling our testing phase across different industrial cases. We will examine the behavior of our patterns with regard to any industry-specific requirements or regulations that might emerge. We will also conduct a quantitative analysis of the performance metrics and their variations from one industrial case to another in order to set up benchmarks for the community.

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