ID3P: Iterative Data-Driven Development of Persona based on quantitative evaluation and revision

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***Abstract*—Personas are fictional characters used to understand users' requirements. Many researchers have proposed persona development methods from quantitative data (data-driven personas development), but practical issues about running a service have yet to be discussed. This paper proposes Iterative Data-Driven Development of Personas (ID3P). In particular, to detect a change in users' characteristics, our proposal includes an iterative process where the personas are quantitatively evaluated and revised in each iteration. ID3P helps service manager who are unfamiliar with UX techniques to understand about users on a web service quantitatively. Moreover, it provides a quantitative evaluation of business strategies based on GQM+Strategies and personas. To verify our proposal, we applied it to Yahoo!JAPAN's web service called Netallica.**

***Keywords*-Requirements engineering, Data analysis, Consumer behavior, Personas, GQM+Strategies**

I. INTRODUCTION

Persona, which is a fictional character designed to understand users' requirements, is a representative human-centered design method. Originally, personas were proposed by A.Cooper and created qualitatively. However, previous works noted some issues with personas including: 1) Personas differ from actual users when they are not based on users' data, 2) Personas are not used for decision making in design,etc. [1] [2] and 3) Meeting a persona's requirements does no guarantee achievement of a business goal [3].

With regard to the first issue, many works have proposed data-driven persona development methods using various types of data [4] [5] [6] [7] [8] [9] [10]. In 2016, data-driven development from users' clickstreams on a website, which is a certain type of big data was proposed [11].

However, these works do not describe practical problems of web services because their case studies were only applied to users at a specific point on a service; these problems are related to the second and third issues of personas. Some researches have reported the difficulty in decision-making [12] and proposals of human aspects [13] [14]. Specifically, a change in users' requirements, which is a practical problem of web services, is a serious challenge for service managers when promoting a service. Fluctuations in users' visit to a service make it difficult to plan an effective strategy, which must reflect the current users' requirements.

In connection with this problem, some previous works have proposed applying personas to Agile or Scrum [15] [16]. In addition, when data-drive persona development is considered as a big-data application, the relationship between Agile and big data [17] is a related work. Implementing practice personas in an iterative process has not been studied in detail. Moreover, previous works have not employed a case study.

Therefore, a simple combination of previous methods is not the solution to the above problem of data-driven persona development. To solve this problem, we proposed Iterative Data-Driven Development of Personas (ID3P) for practical applications of data-driven persona development on real services. Specially, we integrated data-driven persona development and evaluation into GQM+Strategies (GQM+S), which is a goal-oriented model to measure business goals. The contributions of ID3P are:

- It assists in understanding about users in a service via an iterative evaluation and revision of personas.
- It provides a quantitative analysis of persona characteristics to easily derive strategies.
- It employs a quantitative evaluation of a strategies based on personas to enhance the business decisions.

This paper describes ID3P. Section II reviews the basic concept behind ID3P. Section III explains ID3P. Section IV presents a case study, while section V analyzes our results. Section VI discusses related works, and section VII summarizes our conclusions and contributions.

II. BACKGROUND

A. Data-Driven Persona Development

A persona is a fictional character developed to understand users' requirements. It has some attributes like a real person (e.g., name, gender, job, characteristic, goal for its service, etc.). Initially, a persona is created qualitatively, but many researchers have reported that a persona can be based on actual users' data. To date, numerous types of data-driven construction approaches have been proposed [4] [5] [6] [7] [8] [9] [10]. In 2016, data-driven development from a certain type of big data was proposed [11]. However, issues about running a service in the long-term (e.g., changes in users' requirement) were not assumed.

B. GQM+Strategies

GQM+Strategies (GQM+S) is a measurement approach for business goals based on Goal-Question-Metrics (GQM). GQM+S is a hierarchy model of goals and strategies where each strategy is derived from a goal. In GQM+S, every business goals is measured by several metrics, which are derived by GQM approach, to determine whether or not a goal is achieved [18]. In connection with practical cases, previous works applied GQM+S to several types of real services and validated its effectiveness [19] [20] [21]. Additionally, other works demonstrated a method to improve the quality of GQM+S [22] [23] [24].

III. PROPOSAL

A. Overview

ID3P is assumed to be applied over multiple iterations. Our proposal includes: 1) a quantitative evaluation and revision of personas developed through a data-driven construction approach and 2) quantitative evaluation of business strategies or assumptions via the analysis of personas (Fig. 1).

In ID3P, to cope with an unpredictable change of the users, a persona is verified quantitatively in each iteration like Agile. Because the users on a web service change continuously. each iteration should involve a verification step of the previous persona. Thus, ID3P involves the following steps:

1) Initiate
2) Develop personas by a data-driven construction approach
3) Deduce the assumptions to plan strategies
4) Plan and execute strategies
5) Revise personas
6) Verify assumptions and evaluate strategies

B. Step 1: Initiate

In this step, a GQM+S model is constructed to quantitatively evaluate the strategy, and some metrics are selected as metrics defined in ID3P. Fig. 2 depicts the relationship among the attributes in ID3P.

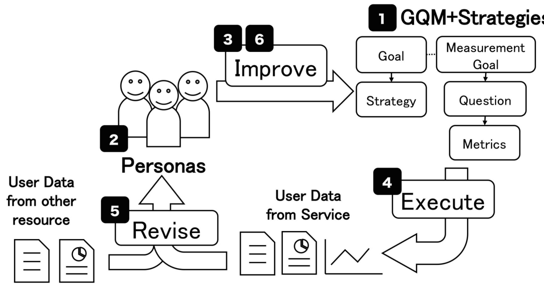

Fig. 1. Overview of an iteration in ID3P

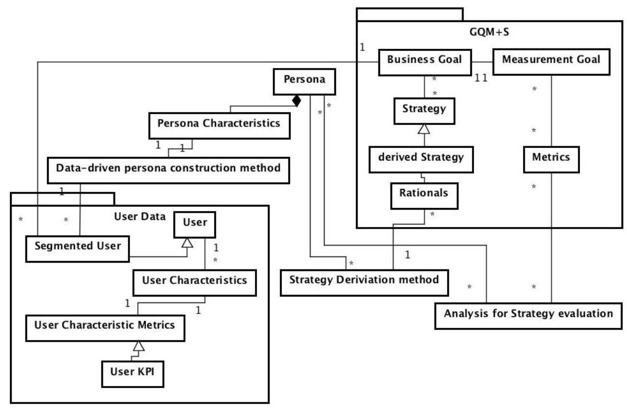

Fig. 2. Relations in ID3P

1) GQM+Strategies: To quantitatively evaluate a goal, all goals should be measurable. Therefore, the relationship between goal strategies should be clarified as a GQM+S model in ID3P. A goal is often related to the higher-level organization's goal. For example, in Fig 3, top-level organization's goal is *"increasing the number of users"*, and *"increasing the number of users in their 20s"* is defined as the service goal.

2) User characteristic metrics: User characteristic metrics are metrics used to develop a persona. These metrics must be reflected in each user's actions or characteristics (e.g., the clicks of each user on a web page in a web service). The service can track the logged-in user's click points on web page. In this case, a user's click log can be defined as a user characteristic metrics because each click corresponds to an action on the web service.

3) User KPI: In the user characteristic metrics, some metrics reflect on each user's satisfaction, effectiveness, or other usability aspects. In ID3P, such metrics are defined as the user KPI. For example, because the numbers of logins or login times reflects the user's intention of using a service, they can be categorized into the user KPI. Hence, the user KPI should be measured to investigate users' attitude and evaluate strategies.

C. Step 2: Develop Personas

In this step, personas are developed by a data-driven construction approach. In ID3P, we assume that the user characteristic metrics are relatively large or big data. There are several reasons why personas can be constructed from user characteristic metrics.

- User characteristics metrics reflect the users' behaviors.
- As previously reported, metric patterns are derived from the user characteristic metrics by data mining techniques.
- Metric patterns are summaries of users' behaviors, so users' behaviors can be derived from such metric patterns.

Some common patterns can be derived by clustering of click logs, which is one of the user characteristic metrics. When a pattern has a high frequency of clicks on the help page, this pattern can be defined as the action of watching the help page.

D. Step 3: Deduce Assumptions to Plan Strategies

Assumptions to plan strategies are derived based on the personas' characteristics and a GQM+S model. In ID3P, the following relationships between the behaviors of a persona, actual users, and other metrics are assumed:

- Each user corresponds to one of the user's behaviors derived from the user's characteristic metrics.
- Each user must also correspond to his or her own user KPI.

In ID3P, the difference in the user characteristic metrics is helpful to plan strategies. For example, the intention to use service can be measured by the login count indirectly. When one persona has longer login time than other persona, the reason for the difference can be assumptions for an effective strategy to promote user's login.

While taking action based on planned strategies, the assumptions are validated via the user characteristic metrics. For example, the number of clicks of the share button on a web service, which is a user characteristic metric, can validate the assumption that some personas tend to recommend the web service to others more then other personas.

E. Step 5: Revise Personas

In this step, the personas in the previous step are evaluated and revised to understand the change of users. In practical situations, reconstruction of personas in each iteration is time-consuming. To restrain the time and cost to reconstruct personas, ID3P quantitatively evaluates the personas to determine whether or not they should be revised. The evaluation and revision of personas involves the following steps:

1) Build a classifier from the users' data used to develop personas as a label. This persona is defined as the previous persona.
2) Predict a suitable previous persona for every user in this service iteration.
3) Discuss the classification results based on quantitative criteria.
4) Develop personas from users' data on a service iteration when the classification result is unsuitable. The developed persona is defined as the revised persona. When the personas have no issues, define the previous personas as the revised persona.

For example, when previous personas are developed from the click logs in the previous step, in a given iteration, every user can be categorized into one of the personas determined by the classifier, which is built based on previous persona (training input is the click log and labels are the previous personas). After the classification, clustering or classification criteria are calculated. If the results become worse, it means that labeling of the previous personas is not suited for the users this iteration. Therefore, new personas should be developed from latest user data.

On the other hand, when the results of the criteria meet a minimum threshold, the persona can be used in the next iteration. In this situation, the change in the user KPI of each persona can be helpful to understand the change of a persona's attitude towards web service. Employing these steps allows the change in the user's behaviors and attitudes to be detected.

F. Step 6: Verify the Assumptions and Evaluate Strategies

The assumptions derived in the previous step are verified by analyzing the revised personas. Additionally, a strategy is quantitatively evaluated based on the personas and GQM+S.

When the assumptions cannot be verified, assumptions should be held and reverified in the next iteration. For example, when the intention of web service recommendation is aligning on an assumption in the previous step but there is no significant difference, the assumption should be also verified in the next iteration.

The effectiveness of a strategy is discussed based on the relationship between the change in the user characteristic metrics and the metrics for a business goal. In ID3P, the metrics in GQM+S can measure the achievement of every business goal. The effect of strategy is evaluated by relationship between user behavior and metrics for business goal. For example, when the number of daily active users and a persona's login time are correlated, it can be hypothesized that strategies improving the login time are effective for user acquisition.

IV. CASE STUDY

A. Overview of the Case Study

ID3P is the first data-driven personas development method, which includes quantitative evaluation and revision of personas to understand user's change. To verify our proposal, we applied ID3P to Netallica which is a service that provides articles on the web for users. Netallica is a services of Yahoo!JAPAN. Yahoo!JAPAN is the Japan's branch of Yahoo and its main service is a web search portal specified for Japanese. The case study is designed to answer the following research questions and to discuss about ID3P:

TABLE I
CONTENT OF QUESTIONNAIRE SURVEY (D1)

No.	Contents	Possible values
Q1	Interest in each article category	1 (favorite) to 5 (not a favorite)
Q2	Frequency of reading articles in each category	1 (usually) to 4 (never)
Q8	Intention to use Netallica continuously	1 (intended to) to 5 (never intended to)
Q9	Intention to recommend Netallica to others in percentage	100 to 0 in 10% increments

TABLE II
DETAILS OF THE LOG DATA OF USERS ON A SERVICE (D2)

Item	Contents	Possible values
User id	Number used to identify a user	Integer
Article category	Categories with articles that users read in October	List of categories (string)
Article	Articles users read in October	List of article ids with dates (string)
Count of shares	Number of shares by users on Twitter and on Facebook	Count on Twitter and one on Facebook (two integers)

RQ1 Can business strategies be derived from personas' characteristics developed through ID3P ?
RQ2 Can the assumptions derived from personas be verified quantitatively?
RQ3 Does revising personas aid in understanding about users ?

In this case study, we used two types of datasets: D1) a questionnaire survey implemented by a research company and D2) the log data of users on a service. The questionnaire was completed by 723 users of Netallica, including 217 users in their 20s, randomly selected by a research company. Table I shows the details of the questionnaire. Users' log data is the log data of 386,748 users in their 20s who visited to Netallica in Oct 2016 (Table II).

B. Initiate

First, we constructed a simple GQM+S model of Netallica (Fig. 3). In this case study, the target organizations are the Netallica team and Yahoo!JAPAN as the top organization. The Netallica team's goal is to acquire more users in their 20s as this demographic tends to not use Yahoo!JAPAN to run web search portals. Therefore, we defined the Yahoo!JAPAN's goal as *"acquire users who have not visited Yahoo!JAPAN's web search portal"* and Netallica team's goal as *"acquire more users in their 20's"*.

C. Develop Personas

Second, we developed personas from D1 (Table I). Netallica categorizes articles into 11 categories (public entertainment, news, trends, love, beauty, food, travel, movies & music, animation, humor, and trivia news). In this case study, user characteristic metrics are the responses to Q1: interest in each category of article and Q2: frequency of reading articles in each category. Additionally, user KPIs are the answers to Q8: intention to use Netallica continuously and Q9: intention to recommend Netallica to others as percentage.

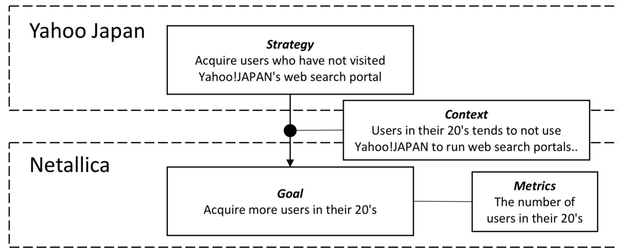

Fig. 3. GQM+S model of the Netallica case study

To derive the persona's characteristics, we applied hierarchical clustering based on cosine similarity to the Q1 answers. Through this analysis, we identified five clusters. Each cluster was defined as a persona (Table VI previous persona). In this table, goal of persona is preference on 11 categories and intentions to use and recommend Netallica are also mentioned.

D. Derive Assumptions for Planning Strategies

We assessed the Q9 distribution of the users for each persona. Some personas show higher intentions than others. Additionally, the questionnaire asked the intentions of using the SNS service; the responses of users in their 20s are higher than the other age's groups. The Mann-Whitney U test was used to determine if the difference is significant. Consequently, we derived a strategy,*"promote the sharing articles on SNS"*.

E. Revise Personas

We tried to detect the change of in the personas due to a difference in the data resources or major changes in service. First, we classified D2 into the previous personas using RandomForest classifier. In this case study, the training data was each user's answer to Q2 (Table I). To match the scale of D2, answers of 1 or 2 to Q2 were transformed into 1, while responses of 3 or 4 were converted into 0. Due to the missing of the *animation* category in D2, the answers about other 10 categories to Q2 were used as training data. After the classification, we evaluated the classification results quantitatively. In this case study, the Calinski-Harabasz score was adopted as the evaluation criterion. Let $W_k = \sum_{q=1}^{k} \sum_{x \in C_q} (x - c_q)(x - c_q)^T$ and $B_k = \sum_q n_q (c_q - c)(c_q - c)^T$. The Calinski-Harabasz score was calculated by $s(k) = \frac{Tr(B_k)}{Tr(W_k)} \cdot \frac{N-k}{k-1}$. In general, the larger Calinski-Harabasz score is, the better the clustering result. We calculated the Calinski-Harabasz score of D2 based on the previous personas and Table III (C1) shows the results. This calculated score is relatively small as the static part in formula: $\frac{N-k}{k-1}$ = 96687.

This analysis suggests that the previous personas are unsuited as representatives of the users of the service. Therefore, we developed new personas from D2 (revised persona). We applied

TABLE III
CALINSKI-HARABASZ SCORE

Case	Dataset type	Persona type	Number of personas	Dataset size	Score
C1	Service(D2)	Previous	5	386748	24431
C2	Service(D2)	Revised	5	386748	105659
C3	Survey(D1)	Previous	5	217	7.0866
C4	Survey(D1)	Revised	5	217	20.686
C5	Survey(D1) (before preprocessing)	Previous	5	217	12.580
C6	Survey(D1) (before preprocessing)	Revised	5	217	15.489

k-means based on the Jaccard distance to D2 and identified five clusters. To compare the revised personas with the previous personas, the Calinski-Harabasz score of D2 based on the revised personas was also calculated (Table III, C2). The revised personas produced better results than the previous personas.

Moreover, we calculated the Calinski-Harabasz score of D1 based on the previous and revised personas (Table III, C3, C4, C5 and C6). These calculated scores show that the revised personas are suitable even for users completing the questionnaire survey.

Table VII summarizes the revised personas. In this step, the goal of the personas (preference of categories) and login count as user intention to use Netallica were concluded.

F. *Verify Assumptions*

In this case study, we tried to verify that some personas are more willing to share articles on SNS than others. Our assumption in the previous step was that personas in their 20's have a relatively higher intention of making recommendations on SNS than other age groups. Unfortunately, the size restriction of the users' log data prevented us from comparing personas by age groups. Instead, we determined the statistical difference between personas in their 20's because the method to determine the difference is similar to the one used to verify the original assumption.

First, we showed each persona's distribution of the share count on Facebook (Table IV) and we applied Kruskal-Wallis test to the persona's share count and determined if a significant difference exists. To specify which persona is a factor responsible for a significant difference, we applied Dunn's test, which is a multiple comparison method, to the share counts. Table V shows the p-value from Dunn's test. Persona RPa and RPd differ significantly from the others with regard to shares on Facebook and have a slightly higher means than RPb. Therefore, we hypothesize that RPa and RPd are slightly more inclined to share articles on Facebook than the other personas (Table VII Recommend intention).

To identify the difference between the previous and the revised personas, we also compared Table VI and Table VII qualitatively. Through comparison, persona PPc and RPb have the same goal (*News* category). Moreover, both of persona PPe

TABLE IV
THE DISTRIBUTION OF THE SHARE COUNTS ON FACEBOOK

Persona	Count	Mean	Std	75%	Max
RPa	51446	0.001147	0.038165	0.00	3.00
RPb	143841	0.001133	0.034461	0.00	2.00
RPc	65993	0.002228	0.056501	0.00	8.00
RPd	63023	0.001317	0.038803	0.00	3.00
RPe	62445	0.004004	0.071921	0.00	5.00

TABLE V
THE P-VALUE FROM DUNN'S TEST FOR EVERY PERSONA'S SHARE COUNT USING THE BENJAMINI-HOCHBERG ADJUSTMENT

Persona \ Persona	RPa	RPb	RPc	RPd
RPb	0.0000			
RPc	0.0000	0.3610		
RPd	0.0000	0.0000	0.0000	
RPe	0.0002	0.2779	0.2472	0.0000

and RPe read many types of articles, but RPe's recommend intention is not particularly high like PPe's. Fig. 4 (Yoshiko) depicts an example of PPe and RPe. In contrast, the previous personas doesn't include the same personas as RPa, RPc and RPd with regard to the goal of personas. Fig. 4 depicts some persona descriptions to show the difference between the previous personas and the revised ones. Additionally, many revised personas didn't intend to login Netallica as frequently as the previous ones.

Consequently, it is assumed that many personas didn't have the habit of using Netallica, but it is not considered well to plan strategies for improvement existing user's satisfaction because the previous persona's intention to use Netallica is so high. Therefore, in the next iteration, we should try not only to promote the sharing articles, which users prefer, but also to provide the attractive articles to promote existing users login.

TABLE VI
THE PREVIOUS NETALLICA PERSONA

Persona	Goal	Use intention	Recommend intention
PPa	High *beauty* and low *animation*	Not particularly	Relatively high
PPb	Almost high, particularly *beauty* and *trip*	Relatively high	Relatively high
PPc	High *news*	relatively low	low
PPd	Almost high but low *love* and *beauty*	Relatively high	Relatively low
PPe	All categories	High	High

TABLE VII
THE REVISED NETALLICA PERSONA

Persona	Goal	Use intention	Recommend intention
RPa	Relatively high *humor*	Low	Relatively high
RPb	High *news*	Relatively low	Not particularly
RPc	High *public entertainment*	Low	Not particularly
RPd	High *trivia news*	Low	Relatively high
RPe	High *trivia news* and *news* Additionally, relatively high other categories	Relatively high	Not particularly

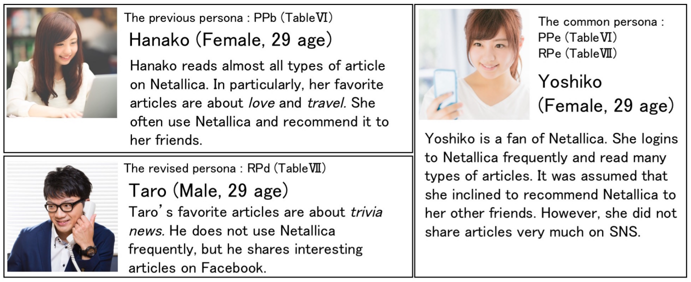

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Fig. 4. Example of three types of personas

G. Threats to Validity

1) Clustering algorithm: In ID3P, the clustering method impacts the verification of personas based on the clustering criteria. In the case study, we changed the clustering algorithm from hierarchical clustering in step 2 to k-means in step 5 due to the limitations in the computation resources. In particular, the Calinski-Harabasz score has a relatively large value when k-means is applied because the evaluation function of k-means is the same as W_k in the Calinski-Harabasz score formula. However, we believe that the reconstruction of previous personas based on k-means is unsuited for practical situations and Tables VI and VII and Fig. 4 show that revised personas, which reflect the users who did not complete the questionnaire survey, seems to be reasonable.

Additionally, in ID3P, the clustering algorithm impacts the analysis process because the clustering results affect the metrics distribution of each persona. Because the results of the k-means algorithm depends on the initial values, the results in the evaluation step are not always the same even when using the same data set. The unstable result in step 6 is verified by applying ID3P iteratively. When the result in step 6 is suspicious, the result is used as one of the assumptions in the next iterations. The process allows suspicious assumptions to be verified more clearly because the impact of the change in the personas is small when change in the service environment is small in the short term.

2) Training metrics: It is possible that the results are affected by the handling of the training data. In this case study, the training input of the classifier in the persona revision step was Q2: Frequency of reading articles in each category in Table I. However, the metrics used in the persona development step was Q1: Interest in each article category in Table I. Although it can be assumed that there is correlation between Q1 and Q2, the impact on results might not be ignored.

Moreover, Tables I and II (col Possible values) shows the measurable degree of the difference for the users' action in D1 and D2. However, we believe that reconstruction of the previous personas is unsuited for practical situations, but the above issues can be solved in the next iteration by feedback about the format of the metrics.

V. Discussion

RQ1: Can business strategies be derived from personas' characteristics developed through ID3P ?

In the Netallica's case study, we derived a strategy to promote article sharing by users in their 20s based on assumptions that users in their 20's are more inclined to recommend Netallica on SNS than other age groups. Additionally, we showed the example of strategies in the next iteration through the qualitative comparison between the previous and the revised personas. Based on this result, we believe that showing the change of the personas is helpful for planning strategies.

RQ2: Can the assumptions derived from personas be verified quantitatively ?

We were unable to verify the assumptions exactly as derived. However, we were able to verify a similar assumption. We showed statistical significant difference in the persona metric (Table V). Therefore, the original assumption can be verified via this method.

RQ3: Does revising of personas aid in understanding about users and planning strategies ?

ID3P is the first data-driven personas development method, which quantitatively evaluate and revise the personas. ID3P evaluates the personas to distinguish the two types of changes: 1) the dramatically change of users' goal and 2) the temporal change of users' satisfaction or actions.

Through the case study, we showed that ID3P could detect the first change. Table VI and VII and Fig. 4 described that the revised personas differ from the previous personas with regard to a persona's favorite article, which is a certain personas' goal.

With regard to the second change, we showed the satisfaction changes of the common persona through the qualitative comparison between the previous and the revised personas. Moreover, when the users' goal don't change dramatically, ID3P shows the temporal change of persona's satisfaction or actions as the distribution of user characteristic metrics. We believe that showing the difference of satisfaction helps the managers to understand the change of users and to discuss about the effects of business strategies. Additionally, when you keep the previous personas, you can restrain the time and cost to reconstruct personas. Therefore, it is also helpful for rapidly developing the personas, which reflect on the current actual users.

To detect which change happened, it is necessary to evaluate the previous personas based on the current actual user. Consequently, ID3P, which includes quantitative evaluation and revision of personas, aids in understanding users and planning strategies.

VI. Related Works

To solve practical issues of personas, ID3P proposes iterative revision of personas to understand actual users' requirement and to help for planning business strategies. We believe that this is a practical applications of a persona over Agile iterations focusing on a data-driven approach. Previous works have proposed integrating personas into Agile [15] [16] [25] [26]. However, we believe these works were unable to solve practical issues of personas because they did not assumed a continuous practice of personas over all iterations. As shown in Tables VI and VII and Fig. 4, iterative revisions of personas are helpful for understanding actual users on a service.

With regard to the data-driven approach, ID3P includes a refinement of business strategies based on GQM+S and big data. Previous work reported the integration of big data into Agile [17], but it was not validated though a case study. In this study, we applied ID3P to a service with 386,748 users and developed personas. The findings suggest that ID3P is a practical utilization of big data in an Agile-like project.

Additionally, some previous works described the relationship between personas and the goal-oriented model [27] [28]. In particular, Uchida described a GQM+S practice, which is helpful for understanding users' requirements and planning effective strategies [28]. ID3P is an extension of Uchida's work in terms of data-driven personas development from big data. In addition, ID3P is an integration of big data utilization into GQM+S practice, which is Agile-like and based on a goal-oriented model.

VII. Conclusion and Future Work

Herein we propose ID3P based on the quantitative evaluation and the revision of personas. Our contributions are: 1) quantitative evaluations and revisions of personas to better understand users on a service, 2) quantitative analysis of personas to derive business strategies, and 3) quantitative evaluation of strategies based on personas. The case study of users of an actual web service demonstrates that ID3P assists in understanding users on a service as personas. The step to verify the assumptions confirm a user's action statistically and iteratively.

In the future we plan to verify the effectiveness of the quantitative evaluation of strategies based on temporal persona revisions. Moreover, we will examine the relationships between GQM+S and persona construction.

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