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# Integration of chatbots with Knowledge Graphs in eGovernment: The case of *Getting a Passport*

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An important goal of electronic government initiatives worldwide is to provide citizens with personalized information about public services. Chatbots and knowledge graphs are emerging technologies that are potentially suitable for that purpose however, their use is not thoroughly researched. The aim of this paper is to investigate the integration of chatbots with knowledge graphs (KG) from both a technical and a public administration view. For this purpose, we develop a proof-of-concept chatbot-KG integration using *Getting a passport* public service. Specifically, we construct a new knowledge graph schema, device a technical architecture, and implement a prototype. In addition, the chatbot-KG integration is evaluated using TAM and SUS based questionnaires to obtain feedback on ease of use, usefulness and usability. We conclude that the chatbot-KG integration is technically feasible and provides potential benefits to citizens.

CCS CONCEPTS •Applied computing~Computers in other domains~Computing in government~E-government

**Additional Keywords and Phrases:** Chatbot, Passport, Python, Rasa, Grakn.ai, Knowledge Graphs, Core Public Service Vocabulary (CPSV)

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## 1 INTRODUCTION

An important aim of electronic government is to provide personalized information to citizens. Better information leads to better public services and consequently in the improvement of citizens' quality of life. To achieve this aim, efforts are focused on the use of rapidly evolving information and communication technology in the delivery of public services [1]. Thanks to the development of artificial intelligence, chatbots can assist in this effort due to their ability to understand natural language and create dialogues. Thus, their use in public services greatly

improves the distribution of information to citizens [2]. In addition, Knowledge Graphs (KG) is another potentially relevant technology also due to the advantages of employing linked data [3]. Their most important feature is applying rules, which results in extraction of knowledge quickly and easily. Although KG have not been widely used in public service provision, some research has been conducted with encouraging results [4].

In previous work, a chatbot was developed to provide personalized information on *Getting a passport* public service [5]. Public service data was stored in a relational database (MySQL) while the chatbot itself was developed using Rasa open source platform. In another previous work, a KG was constructed for the same public service using Grakn.ai open source platform [4].

The aim of this paper is to investigate the integration of chatbots with KG for providing personalized information on public services. For this purpose, we develop a proof-of-concept chatbot-KG integration using *Getting a passport* public service. Specifically, we construct a new KG schema, device a technical architecture, and implement a prototype. For developing the chatbot we used Rasa while for developing the knowledge graph we used Grakn.ai. In addition, we evaluate the prototype using TAM and SUS based questionnaires to obtain feedback on ease of use, usefulness and usability.

The rest of this paper is structured as follows. Section 2 outlines background work and Section 3 presents the methodology. Section 4 presents the developed proof of concept platform while Section 5 reports its evaluation results. Finally, section 6 provides the conclusions and the possible future work.

## 2 BACKGROUND WORK

In this section, we outline previous work related to the CPSV, chatbots and knowledge graphs. The first Core Public Service Vocabulary (CPSV) version was released in 2013 by the European Commission in the framework of ISA and ISA$^2$ programs. The goal was to provide a reusable and simplified core vocabulary (i.e., data model) that describes services provided by public administration [6]. In 2014 the CPSV-Application Profile (CPSV-AP) was launched constituting an important step for describing life and business events to facilitate the creation of service catalogs aimed at citizens and businesses [7].

Chatbots are artificial intelligence software applications that can perform dialogues with humans using natural language [8]. Facebook messenger, Google Home, and Amazon's Alexa are chatbot examples that assist users through dialogues to find personalized information, to book a hotel, etc. Also, chatbots can be used in a variety of applications, such as public services [2], health [9], education [10] and business [11]. Chatbots are divided into two main categories [12]: Task-Oriented chatbots, which have as main objective to help users complete a certain task and Non-Task-Oriented chatbots, which do not have a specific goal.

A large number of frameworks have been proposed to facilitate chatbot rapid development [5]. Rasa is such an open source software that supports the Greek language and provides a machine learning framework for generating automated discussions. Rasa can process messages both in writing and orally to complete a conversation. In addition, it supports the connection with various messaging platforms and APIs [13].

In previous work, "Passbot" was developed to provide personalized information to citizens seeking information related to getting a passport [5]. That chatbot was developed using Rasa ver. 1.x platform. The needed information was described according to the CPSV-AP model and a relational database (MySQL) was used to store the necessary data. To support the dialogues, CPSV-AP was extended with classes QuestionForDoc, AnswerForDoc and Feedback. Figure 1 illustrates part of the extended CPSV-AP model that can also support dialogues.

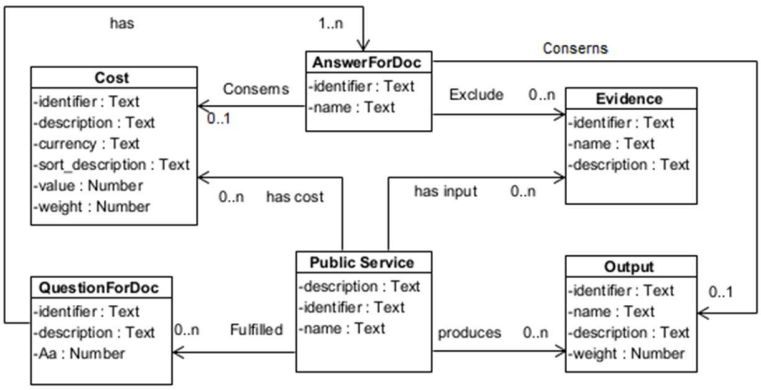


Figure 1. Extract of CPSV-AP ver. 2.2.1 (adapted from [5])

Knowledge graphs are visualized knowledge in the form of a graph. Nodes are the *Entities* and edges are the *Relations* between them. *Attributes* are the characteristics of the entities and *Rules* enable the derivation of new knowledge [4].

In a recent publication, a knowledge graph was developed specific on *Getting a passport* public service using Grakn.ai [4]. The knowledge graph was based on CPSV-AP model with one added entity, namely Citizen (Figure 2). Its goal was to inform users on all necessary documents for passport issuance, covering all possible cases. Entities, relations and rules were designed specifically for passport issuance thus cannot be reused in other public services.

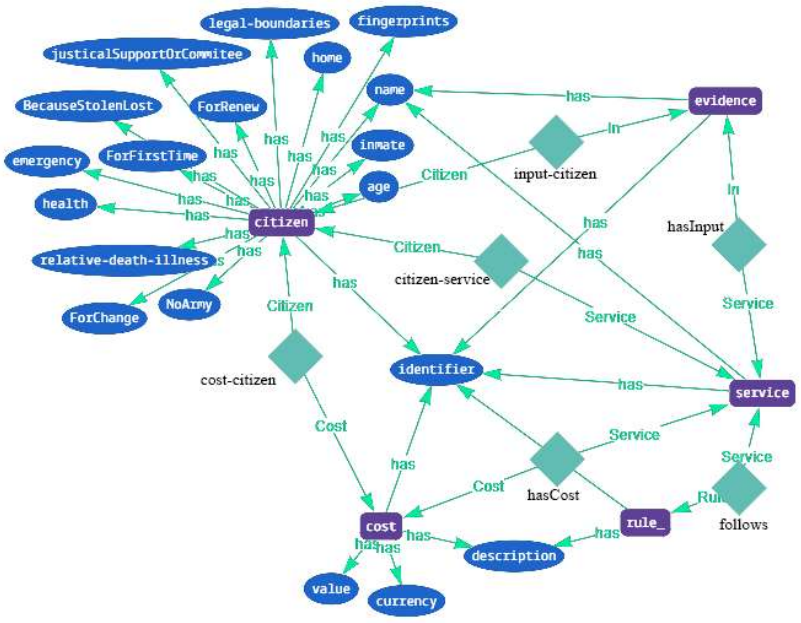


Figure 2. Previous knowledge graph schema (adapted from [4])

## 3 METHODOLOGY

In this paper we integrate previous work on chatbot development and knowledge graph (KG) development. Both works used *Getting a Passport* as an example. The methodology used to integrate these developments include the following steps.

**Step 1. Understanding existing systems and updating versions.** In this step, we studied the existing systems and updated all necessary files to be compatible with the current versions of Rasa and Grakn.ai platforms.

**Step 2. Design the overall architecture of the Chatbot.** In this step, we designed the overall architecture.

**Step 3. Design a new KG schema.** In this step, we designed a new KG schema to overcome limitations of previous work regarding flexibility and reusability.

**Step 4. Develop proof-of-concept.** In this step, we developed a proof-of-concept of the integration of chatbots with knowledge graphs.

**Step 6. Evaluate proof-of-concept.** In this step, we evaluated the developed chatbot. The evaluation was performed using two questionnaires that were designed for that purpose; one based on the Technology Acceptance Model (TAM) and another one based on the System Usability Scale (SUS).

## 4 PROOF-OF-CONCEPT

This section presents the main results of our work.

### 4.1 Systems analysis and Version update

Pre-existing work on chatbot and knowledge graph regarding *Getting a Passport* service was thoroughly studied [4][5]. During this research, Rasa software released a new version, namely 2.x replacing version 1.x. Consequently, we updated all pre-existing chatbot code to take advantage of the new features available in version 2.x, including the ability to connect to knowledge graphs through APIs. These changes took place in Rasa configuration files config.yml, domain.yml and actions.py as well as, to Passbot digital assistant forms. Furthermore, the configuration of the training data changed from Markdown to YAML.

### 4.2 System Architecture

The system architecture is depicted in Figure 3 and consists of three layers. The upper layer consists of a website where users communicate with the chatbot. The middle layer includes the chatbot application, which was developed using Rasa ver. 2.x open source software. The lower layer includes a knowledge graph (KG) from which the chatbot extracts the data that is presents to users. The KG was developed using Grakn.ai platform. Finally, the communication between levels is achieved through protocols, namely HTTP protocol between the upper and middle layer and GRPC protocol between the middle and lower layers.

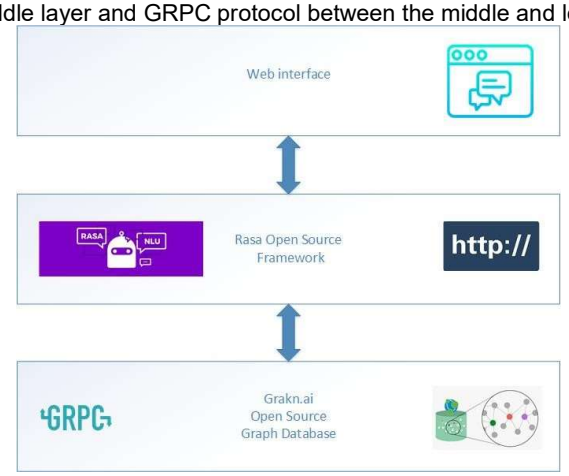


Figure 3. Chatbot Architecture

### 4.3 New Knowledge Graph schema

The new graph (Figure 4) describes the process of issuing supporting documents for a public service through a model of questions and answers. The graph is designed to support the provision of personalized information through a chatbot application. It allows public authorities to easily model complex processes such as issuing a passport that contains many sub-cases.

The KG entities emerged from the extended CPSV-AP model classes, with two adaptations. First, existing classes AnswerForDoc and QuestionForDoc were replaced with classes Answers and Questions respectively. Secondly, we added three more attributes to the entity Answers. Attributes cost_identifier and output_identifier that match an answer with a specific cost and input document each time and answers_value that describes the given answer by the user (e.g., passport renewal).

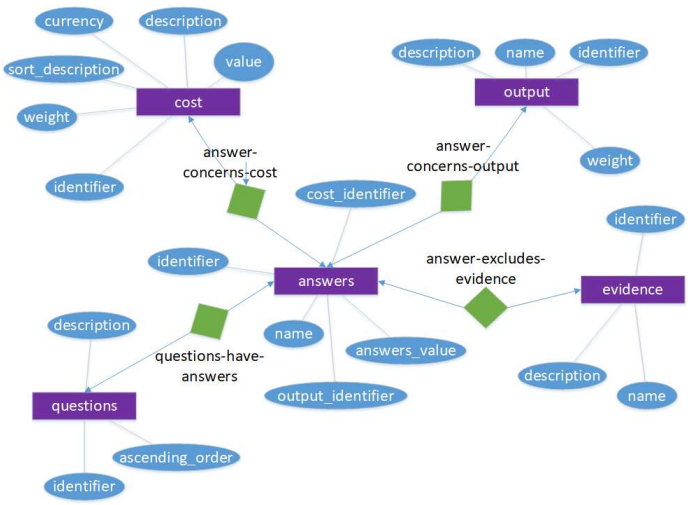


Figure 4. Chatbot KG schema

The use of a graph in contrast with the RDBMS implementation has several advantages. Firstly, it allows the expression of self-referential questions in a simpler way. For example, for a self-referential question-by-question correlation in RDBMS either an autocorrelation table must be created resulting in more JOINs or a correlation attribute must be added to the table where we can have no more than 1-1 correlations. Secondly, the new schema is easily scalable with new entities and relationships unlike the strictly defined schema used by RDBMS. Thirdly, it allows queries to be created without any restrictions, e.g., we do not need to create autocorrelation tables or additional features to ask similar questions. Fourth, the KG schema is more easily understandable because it is easy to visualize unlike an RDBMS schema. Finally, it allows the use of simple questions that approach natural language.

The new schema has fewer relations and features compared to the older graph (e.g., lines of code: Previous schema 440 versus 92 in new schema). It covers many different types of documents with little or no conversions. Its development was based on the object-oriented way of design (e.g., use of abstract attributes). For those reasons, the new schema is easily extensible to other public services. Finally, security is also important. In the new schema no data is entered by uncertified users thus improving security significantly.

### 4.4 Connecting chatbot with the KG

For connecting the chatbot platform (in our case Rasa 2.x platform) with external APIs, we used Rasa Action Server SDK (Python) which allows running custom actions. With a custom action we can run any code including API calls, database queries etc. When the dialogue engine predicts an execution of a custom action, it calls the action server with the appropriate information. Then, the action server responds with a list of events and responses. In order to read and write to a Grakn knowledge graph we used the Grakn client interface through a rasa custom action. Grakn client handles the database operations. The main components are “client”, “session” and “transaction”. We connected to the Grakn database by using the client. A session is responsible for connecting our application to a particular database and finally, a transaction is responsible for performing write and read operations over the concept types and instances within the connected database.

### 4.5 Data migration from MySQL to Grakn.ai

The data migration from MySQL to Grakn.ai was a crucial step for chatbot's functionality. The data exported and stored from the relational database in CPSV format from each table separately. Finally, the data passed through a query template in Graql and imported in Grakn.ai using Grakn client API.

## 5 EVALUATION OF THE CHATBOT

For evaluating the newly developed chatbot, we designed two questionnaires. First, an eighteen questions Technology Acceptance Model (TAM) [14] based questionnaire to examine the chatbot's ease of use and usefulness. Secondly, a ten questions System Usability Scale (SUS) [15] based questionnaire to measure the chatbot's usability. Both questionnaires were answered by students in the Information Systems and E-Government courses at the University of Macedonia. Students completed both questionnaires after using the chatbot according to pre-defined usage scenarios. In total, sixty five students completed the first questionnaire and sixty two the second questionnaire.

The results from the first questionnaire were encouraging. 77% of the students agreed that by using the chatbot they could easily find the needed information; 13,8% were neutral; and only 9,2% disagreed. Also, 89,3% of the students agreed that using the chatbot was easy and did not require much mental effort; 3,1% were neutral; and only 7,6% disagreed. Finally, 86,1% of the students agreed that using the chatbot allowed them to obtain the needed information for passport issuance in less time than before; 6,2% were neutral; and 7,7% disagreed. The results from the second questionnaire were also encouraging. The final result indicated a SUS score of 76,8, which classifies the chatbot as acceptable. Thus, we do not expect users to encounter any significant usability problems during the use of the chatbot. We should note however that all users were postgraduate students which suggests a certain bias in our evaluation.

## 6 CONCLUSIONS AND FUTURE WORK

Chatbots can be an important tool that improves communication between citizens and public authorities providing public services. Chatbots offer easy and quick access to information and can replace searching websites and reading difficult-to-understand texts. Also, physical presence of citizens is no longer necessary in different public authorities.

In this research, we illustrated that using a high-level KG can simplify the design of the database schema, which follows standards, such as CPSV-AP for describing public services. For example, unlike relational databases, we do not need to know all the attributes of entities from the schema. The integration of the data could be done in parts without the constraints imposed by a relational database, such as pre-designing and properly modeling the tables from the beginning. This means that the integrated chatbot and KG schema, after some small configurations, can be used in different public services for providing different information.

Additionally, Grakn.ai supports object-oriented programming thus, allowing the creation of queries approaching natural language while Rasa supports Python, many popular messaging APIs and the Greek language.

Regarding future work, we plan to experiment with oral speech as it could greatly improve user experience, especially through devices such as mobile phones. The connection of the chatbot with external APIs that are popular with users (e.g., Facebook Messenger) would be also useful. We also plan more thorough evaluation that also include comparing the chatbot with existing information websites (e.g., passport.gov.gr). Finally, we

plan to develop an alternative chatbot design that answer general questions about different public services, instead of asking questions only about Passport Issuance.

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*To be filled in after the review.*

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