Intelligent Decision Support Based on User Digital Life Model: Principles and Conceptual Framework

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***Abstract*—Digital technologies have become an integral part of all aspects of human life. Living digital style and interacting with various applications and Web sites, humans leave digital traces of their online activities. These traces organize human digital life. The paper introduces principles of intelligent decision support based on a model of user digital life. Such a model structures content of user digital life with relation to the problems the user have ever dealt with and the decisions made. The principles form the basis of a conceptual framework aiming at recommending decisions. Group patterns provide historical data to predict decisions. A group pattern represents a generalized model of digital life for a group of users with similar preferences and decision-making behaviours. An initial model of a decision maker ontology is presented that performs context-dependent classification of the users into decision maker types to provide context-aware recommendations.**

I. Introduction

The digital revolution that has been occurring since the middle of the last century is blurring the lines between the physical, digital, and biological spheres [1]. This revolution is impacting everything, from economy, science and education, to health, sustainability, governance, and lifestyles. Digital technologies have fundamentally change business models, institutions and society as a whole [2]. They became an integral part of all aspects of human life and given birth to digital lifestyle. Digital lifestyle is connected with a daily life in which humans use digital mediums and technologies for their business, daily concerns, entertainments, and other needs, i.e. it is tightly related to the overall need of "liveability" [3].

Living digital style and interacting with various applications and Web sites, humans leave digital traces of their activities. Digital life is designated to represent a daily human life in digital world by capturing online human activities [4], [5].

In decision support, the user digital lives are sources for recommending preventive and predictive decisions (e.g., [6]–[8]). This paper introduces principles of intelligent decision support based on user digital life model, which form the basis of a conceptual framework aiming at recommending decisions. A model of user digital life is proposed to systematize weekly structured and poorly curated content of digital lives. This model enables to represent the decision-making behavior of a user as a collection of digital traces related to the decision situation caused by a problem. Group patterns provide historical data to predict decisions. A group pattern represents a generalized model of digital life for a group of users with similar preferences and decision-making behaviours. A decision maker ontology supports the classification of users into decision maker types. This classification is context-dependent and allows ones to take as a basis for the prediction different groups of users with similar preferences and behaviours in different contexts.

The rest of the paper is structured as follows. Section II provides an overview of researches related to human digital life and summarizes digital life models found there. Section III and Section IV introduce requirements to and principles of intelligent decision support based on user digital life correspondingly. The conceptual framework is described in Section V. Some concluding remarks are given in the Conclusion.

II. Human Digital Life: Research Overview

The overview of the researches on human digital life is aiming at the identification of studies related to human digital life and the discovery of existing digital life models.

A significant effort in the human digital life domain is a research project MyLifeBits by Microsoft [9]. MyLifeBits (Fig. 1) is a system of archiving that produces a searchable digital archive of all the events of a person's life. Special software tracks all electronic interactions of the person, monitors the person's condition, and takes minute-by-minute photos of the person's context. The project implements the digital memory concept, i.e. the person can search the contents of the archive and share the found information with interested parties [10]. The MyLifeBits data model includes various entities such as photos and documents, and typed links between entities. For instance, a link from a contact to a photo may be of type "person in photo." In MyLifeBits, the traditional folder (directory) tree is replaced by collections that form a directed acyclic graph (DAG). Any object (including a collection) may

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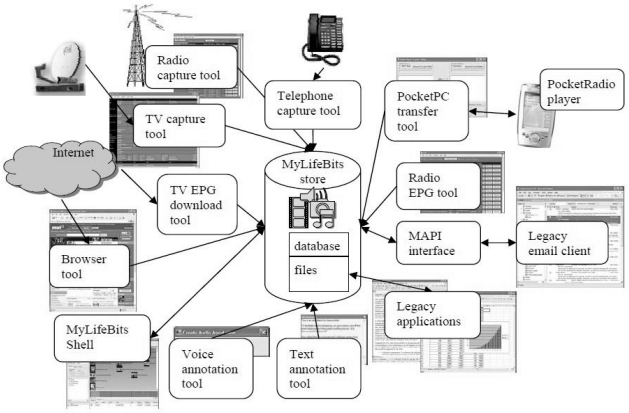

Fig. 1. The MyLifeBits system [11]

be filed in any number of parent collections (as long as cycles are not formed, violating the DAG constraint) [11].

SemanticLIFE [12] is a project that stores all information an individual works with in a semantically enriched form. The SemanticLIFE system (Fig. 2) is designed to store, manage and retrieve an individual's digital information accumulated over years. The system enables the acquisition and storage of data and creates semantic annotations to email messages, browsed web pages, phone calls, images, contacts, and other resources. SemanticLIFE also provides an intuitive and effective search mechanism based upon the stored semantic knowledge. The model of digital life is represented as an ontology storage. The argument in favor of ontologies is that they support machine-readable representation of data and information, which facilitates solving complex problems associated with the aggregation of information from different sources, such as processing semantic queries, tracking the path of life, and processing events in the course of life. The project supports in parallel two ontology representation standards – RDF and Topic Maps.

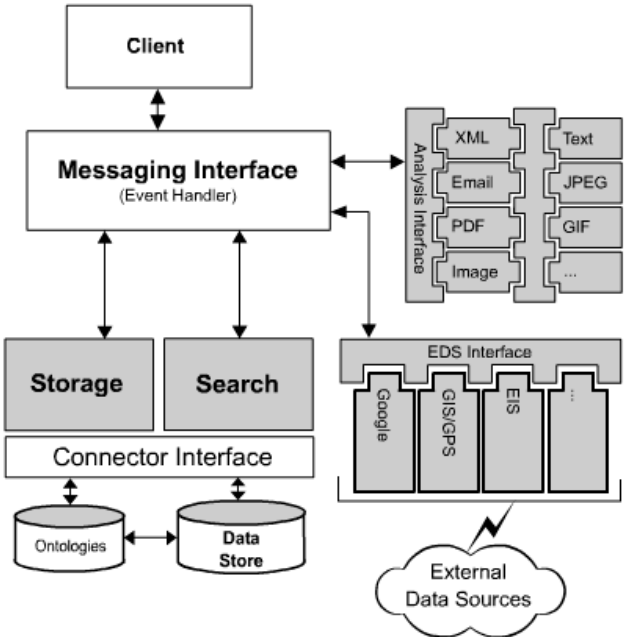

Fig. 2. Architecture for SemanticLIFE framework [12]

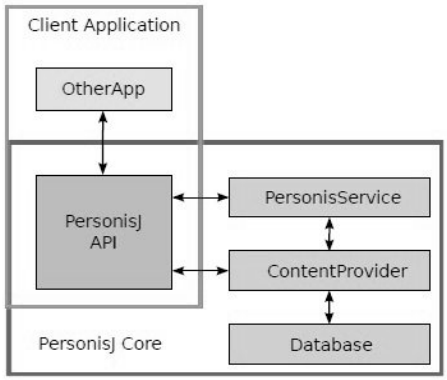

Fig. 4. PersonisJ Architecture [13]

PersonisJ [13] is a life-long user modelling framework (Fig. 4) that can support client-side personalisation on the Android phone platform. At the conceptual level, PersonisJ represents the user life model as a hierarchical structure of contexts, which can contain the components to be modelled. For example, it may have a context for the user's visits to museums and within this it may have components modelling the museums they prefer. Each component accretes evidence. This is essentially a value with metadata indicating how and when it was received. Applications authorized to the PersonisJ model can draw conclusions about the user (for example, about the user preferences). The hierarchy of contexts and components constitute an ontology.

A project entitled "Rethinking Personal Data" is launched by the World Economic Forum in 2010. This project is devoted to personal data ecosystems and is not directly to human digital lives. Personal data are digital data created by and about people when digital interacting. They are thought of as the digital record of "everything a person makes and does online and in the world." From the viewpoint of modelling human digital lives, the project outcomes are interested in that there proposed a set of metadata to describe the personal data (Fig. 3) and an initial list of categories to structure information about persons. The set of metadata encompasses data of three kinds: observed data, volunteered data, and inferred data. The list of categories comprises eight categories. They are digital identity; relationships to other people and organisations; real-world and online context, activity, interests and behavior; communications data and logs; media produced, consumed and shared; financial data; health data; and institutional data. The proposed list of categories is considered as initial because the

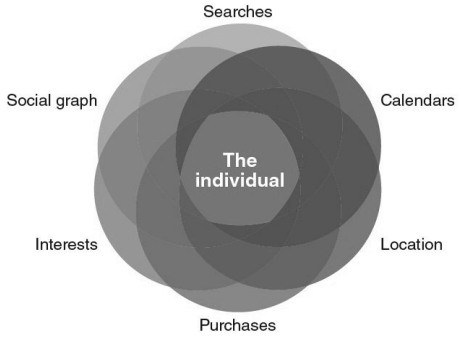

Fig. 3. Digital traces of personal data [14]

wide variety of forms that personal data assumes for storage and communication evolves constantly [14].

In the research aiming at providing recommendations to the users of smartphones for the applications that the users may need in certain contexts [15], user digital life is represented by his/her activities on the app usage. Each app usage is described in terms of the day of the week, time of the day, whether or not the day is a weekend, location, weather, category of app and the app name.

An integrated model of consumer decision-making in retail banking [16] represents the consumer digital life by four categories: search for alternatives, definition of consideration set, evaluation of consideration set, and purchase decision. Each category is described by a set of factors influencing on the consumer activities when he/she is accomplishing the task supposed by the name of a given category. Examples of the factors are the degree of satisfaction of the consumer by the bank for the category "search for alternatives, the consumer loyalty for the category "definition of consideration set" and others. More than 30 factors are defined for the four categories. A particular consumer is characterized by values of these factors.

Digital life is a source of data for public health statistics and policymaking [5]. Digital life here is data reflecting a direct action by a user. This often reflects the use of online platforms, including social media. Social media, social media, data produced by mobile phones—sometimes with GPS data, reports on online message boards, data collected by web scraping, data from environmental and health sensors, data produced by the Internet of Things, and many others are distinguished as sources of digital life data.

A framework for a self-determined life of citizens in an increasingly digitized world (Fig. 5) [17] relies upon the representation of citizen digital life in accordance with the Reference Architecture Model of IDS (International Data Space). IDS represents all objects including human as their digital (virtual) twins referred to as resources. A resource in the context of the International Data Spaces is uniquely identifiable. The resource representation is specified at three levels of formalization. They are conceptual, declarative, and operational code. Each level corresponds to a digital representation (Fig. 6). At the conceptual level a resource is modelled by six independent aspects: content, context, concept, communication, commodity. The declarative level is represented by ontology means. The programmatic representation provides best-effort mapping of the IDS Ontology onto native structures of a target programming language. Among the different representations, the declarative

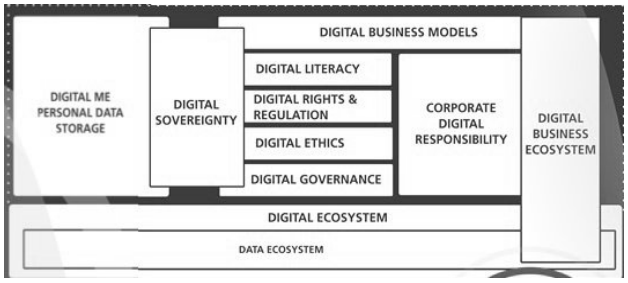

Fig. 5. Framework for sovereign digital life [17]

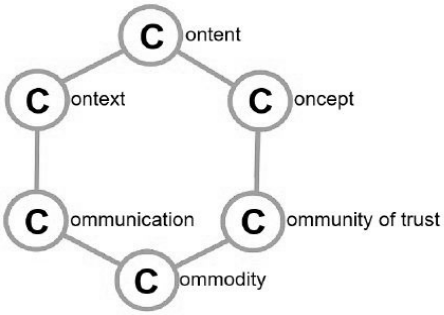

Fig. 6. Modeling aspects of Digital Resources in IDS [18]

representation (IDS Ontology) is the only normative specification [18].

Table I summarizes the models of human digital life found in the overviewed research works with relations to the domains of their usage.

TABLE I. MODELS OF HUMAN DIGITAL LIFE

Research	Model	Domain
MyLifeBits [9]–[11]	DAG: nodes are classes of objects, edges are typed links	Digital memory
SemanticLIFE [12]	Ontology	Management of individual's digital information
PersonisJ [13]	Ontology of contexts	Personalised services
Rethinking Personal Data [14]	Metadata	Personal data ecosystems
Recommendation of mobile apps [15]	Context-aware data	Recommender system
Consumer decision-making in retail banking [16]	Category-factor model	Decision making
Public health statistics and policymaking [5]	Data	Health policy planning
Self-determination of citizens in a digital ecosystem [17]	International Data Space (IDS)	Personal data ecosystems

As can be seen from Table I, most of the models for representation of human digital life use classification structures. Such structures can be implemented using an ontological model or mapped to such a model.

III. SPECIFICATION OF REQUIREMENTS TO INTELLIGENT DECISION SUPPORT BASED ON USER DIGITAL LIFE

The specification of requirements to intelligent decision support using information about user digital life comprises three groups of requirements: general requirements, requirements to user profiles and models of user digital life, and requirements to a domain ontology. The list of the requirements is presented below.

General requirements:

- availability of models of user digital lives and user profiles created in different domains;
- availability of a domain ontology;

- existence of relationships between the models of user digital lives, the user profiles, and the ontology to take into account changing information about the users in the ontology;
- context-aware decision recommendation;
- support of user data privacy.

Requirements to user profiles and models of user digital life:

- user profiles among other things represent user preferences revealed in domains;
- model of user digital life is represented in an ontology-compliant way;
- model of user digital life includes structural components to represent the problems the user has ever dealt with and decisions that the user made;
- representation of the problems in the model of user digital life provides information about domains that these problems come from;
- user profiles and model of user digital life provide user data in accordance with the Privacy Policy.

Requirements to a domain ontology:

- domain ontology represents types of decision makers and provides axioms enabling to categorize users into these types;
- domain ontology is updatable and takes into account new information about the users.

IV. Principles of Intelligent Decision Support Based on User Digital Life Model

The principles of intelligent decision support based on user digital life are stated as follows:

P1. The purpose of intelligent decision support is to recommend a decision to the user.

P2. Users with similar preferences and decision making behaviors are grouped.

P3. A group pattern describes collected information about preferences and decision-making behaviors of users belonging to this group.

P4. The recommended decision is predicted based on group patterns.

P5. The sources of user preferences are user profiles existing in various domains. A user can have several profiles.

P6. The source of information about the decision-making behavior of a user is the user's digital life.

P7. User's digital life is represented by a model that specifies the problems that the user has ever dealt with and the decisions made with references to the domains these problems came from.

P8. Models of user digital lives and profiles are compliant with a domain ontology.

P9. Ontology reasoner performs the classification of users in a decision situation into a user group.

P10. The belonging a user to a group depends on the user context. In different contexts, the same user can be classified in different user groups.

Table II summarizes the principles above regarding the information structure of a decision support environment to enable its expected functionality.

TABLE II. PRINCIPLES OF INTELLIGENT DECISION SUPPORT BASED ON USER DIGITAL LIFE MODEL

Information level		
Concept	**Description**	**Principle**
Information resources	User profiles, Models of user digital lives, Domain ontology	P5, P6, P9
Sources of historical data for predictive decisions	Group patterns	P3
Context information	User profile, Models of user digital lives, Problem, Domain	P5, P7
Functional level		
Process	**Description**	**Principle**
Information sharing support	Ontology compliant resource representations	P8
Creation of groups of users with similar preferences and decision making behaviors	User clustering	P2
User categorization into user groups	Ontology inference	P9
Context awareness	Monitoring digital traces, user type inference	P7, P9, P10
Decision prediction	Matching the user type against group patterns	P4
Recommendation of predicted decisions	Outcome of decision support	P1

The principles above form the basis of the conceptual framework for intelligent decision support based on user digital life.

V. Conceptual Framework for Intelligent Decision Support Based on User Digital Life Model

The conceptual framework for intelligent decision support based on user digital life model (Fig. 7) is intended to recommend decisions that the users would made in the current situation. The main components of this framework are a user profile, a model of user digital life, and a decision maker ontology.

A user profile represents information that describe the characteristics of this user. The user characteristics can be of two kinds: context-independent and context-dependent. Some examples of the context-independent characteristics are the user's birth name, his/her age, the education, etc. The users themselves can enter the context-independent characteristics when creating their profile, a system or site can acquire such characteristics by proposing the user to fill in a questionnaire during the registration process, domains can reuse these characteristics if the users made them available, as well these characteristics can be revealed from digital traces [19].

Special techniques and procedures are applied to capture the context-dependent user characteristics. For instance, procedures processing sensor data identify typical context-dependent characteristics as the user's location and time. In addition to typical user characteristics, domains reveal user specific characteristics that are of interest to these particular

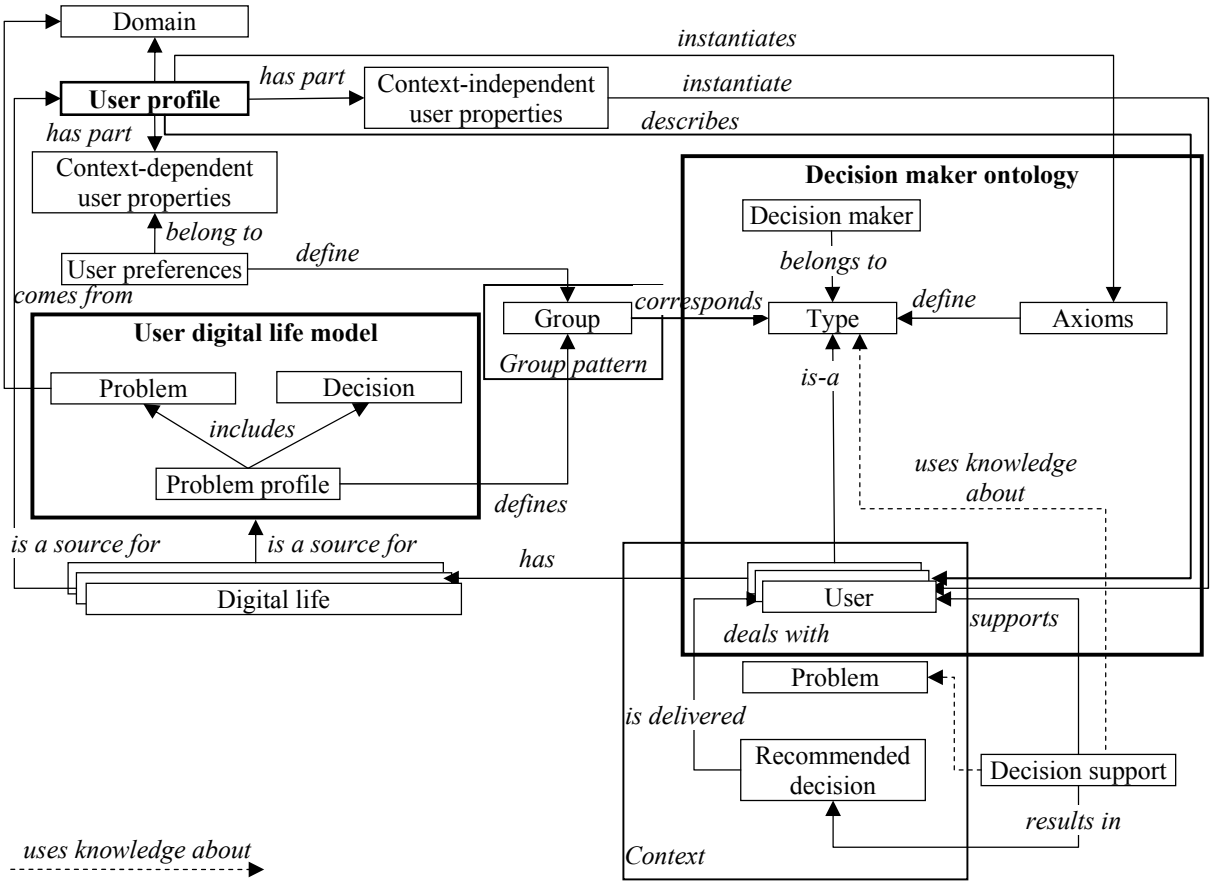

Fig. 7. Conceptual framework for intelligent decision support based on user digital life model

domains. For example, in the Internet banking, such characteristics are the integrity / unreliability of the customer-borrower, the customer segment (a group of customers with the same needs and behavioral responses to the product), how the customer is "advanced", and others. One of the ways to capture these characteristics is to analyze the user digital life.

Besides of all the above, an important piece of the user profiles are user preferences. These preferences can be both context-dependent and context-independent. A number of methods and techniques focus on the revealing user preferences [20].

User digital life is represented by a set digital traces that are traces of the user interactions with digital platforms. Among many other things, the digital life contain traces of user activity on making decisions in problem situations. A problem profile is one of the results of an analysis of the user digital life. Such a profile is a complex formalized description of the user interactions with a digital platform when making a decision on the problem this user deals with. The present framework considers the problem profile, the kinds of problems that the user has ever dealt with, and the decisions made as the structural components of the model of the user digital life. At that, the problems are described with relations to the domains where these problems occur.

The user preferences and the models of user digital lives are sources to reveal groups of users with similar preferences and decision making behaviors. A group pattern represents a generalized model of the digital life of the group.

The decision maker ontology specifies knowledge based on that the users can be categorized into the user groups. In this ontology, the class "type" represents the kinds of groups revealed from the models of the user digital lives. From the viewpoint of decision support, a user is a kind of decision maker. Axioms define conditions for the classification of the users into the decision maker types and the information from the user profiles produces assertions for this. Here the convention that axioms are statements that describe the domain being modelled, and assertions are axioms describing individuals is used [21].

The decision support according to the proposed conceptual framework is as follows. When a user faces a problem requiring a decision, the information from the profile of this user is introduced to the axioms of the ontology. The ontology reasoner defines the type of this user as a decision maker through the classification. The user preferences are predicted based on the information from a group pattern that corresponds to the inferred user type. For the prediction methods of collaborative filtering, which enable to make predictions about

preferences of a user based on the collected information about preferences of user groups, are used. The knowledge about the user type, the problem requiring a decision, and the user preferences are used to recommend a decision that the members of the group to that this user belongs would make in a similar context.

The problem requiring a decision occurs in some context. Context-depended user characteristics make the user type context-depended. This means that the same user can belong to different user groups and be of different decision maker types in different contexts. When the user is in a decision situation, context enables the context-aware inference of user type and the context-aware identification of user group.

VI. Conclusion

In this paper, we proposed the principles for intelligent decision support based on user digital life. These principles postulate the purpose of decision support, define kinds and originations of information and knowledge sources to achieve this purpose, and provide suggestions about requiring processes.

The principles form the basis of the conceptual framework for intelligent decision support based on user digital life model. The main components of the framework are user profiles, models of user digital lives, and a decision maker ontology. The user profiles provide information characterising the users including their preferences. The models of user digital lives are sources of information about the problems caused decision situations and the decisions that the users made in these situations. The decision maker ontology represents knowledge for the classification of users into decision maker types. The user profiles and models of user digital lives are used to organize group of users with similar preferences and behaviors. The ontology serves to determine to which group the user in decision situation belongs relating to the user context. The proposed framework enables to recommend to the user a decision that is predicted based on the knowledge about preferences and decision-making behaviours of the users from the group to which this user belongs.

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