FP7-ICT-611140 CARRE

Project co-funded by the European Commission
under the Information and Communication Technologies
(ICT) 7th Framework Programme

D.5.1. Interactive Visual Interface

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August 2015

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CARRE is a Specific Targeted Research Project partially funded by the European Union, under FP7-ICT-2013-10, Theme 5.1. “Personalized health, active ageing & independent living”.

Document Control Page

Project

Contract No.:	611140
Acronym:	CARRE
Title:	Personalized Patient Empowerment and Shared Decision Support for Cardiorenal Disease and Comorbidities
Type:	STREP
Start:	1 November 2013
End:	31 October 2016
Programme:	FP7-ICT-2013.5.1
Website:	http://www.carre-project.eu/

Deliverable

Deliverable No.:	D.5.1
Deliverable Title:	Interactive Visual Interface
Responsible Partner:	BED
Authors:	Youbing Zhao, Enjie Liu, Farzad Parvinzamir, Hui Wei
Input from:	All partners
Peer Reviewers:	Darius Jegelevicius (KTU), Romualdas Kizlaitis (VULSK), Vaidotas Marozas (KTU)
Task:	T.5.1 Interactive Visual Interface
Task duration:	8 months: 1 January 2015 to 31 August 2015
Work Package:	WP5: Data management & visual analytics for empowerment
Work Package Leader:	BED – Enjie Liu
Due Date:	31 August 2015
Actual Delivery Date:	7 September 2015
Dissemination Level:	PU
Nature:	R & D
Files and format:	Deliverable report: 1 pdf file Software source code available from project web site, see Annex 2: https://www.carre-project.eu/innovation/interactive-visual-interface/
Version:	02
Status:	☐ Draft ☒ Consortium reviewed ☒ WP leader accepted ☒ Coordinator accepted ☐ EC accepted

Document Revision History

Version	Date	Modifications	Contributors
v01.1	10 July 2015	Template and content structure	Youbing Zhao
v01.2	21 August 2015	Updated template and content structure based on Technical Meeting 03	Youbing Zhao, Enjie Liu, Farzad Parvinzamir
v01.3	24 August 2015	Updated data sources by OU, KTU and PIAP	Allan Third, Dainius Stankevicius, Jan Piwinski
v01.4	28 August 2015	Updated introduction and use cases	Enjie Liu
v01.5	3 September 2015	General Update	Youbing Zhao, Enjie Liu
v01.6	3 September 2015	Revision of v01.5	Enjie Liu
v01.7	4 September 2015	Added draft of implementation.	Youbing Zhao, Zhikun Deng
v01.8	4 September 2015	For internal review	Darius Jegelevičius, Romualdas Kizlaitis
v01.9	4 September 2015	Added Implementation + updated after review (Darius and Vaidotas)	Hui Wei, Enjie Liu, Youbing Zhao
v01.10	5 September 2015	Revision	Youbing Zhao, Enjie Liu,
v01.11	6 September 2015	Updated after further internal review (Romualdas Kizlaitis)	Enjie Liu, Youbing Zhao
v02	7 September 2015	Edited for uniformity and conformance to QA	Eleni Kaldoudi

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Executive Summary

CARRE personalised patient empowerment and decision support services require presentation and analysis of a large volume of heterogeneous data and metadata as harvested from a variety of data sources including sensors, risk factors, PHR, decision support, etc. Without proper tools it is almost impossible to achieve this goal.

Work Package 5 “Data Management & Visual Analytics for Empowerment” aims to address this challenge. In Task 5.1 “Interactive Visual Interface”, an interactive visual analysis interface is designed and developed to empower both the patients and the medical experts to view, utilise, analyse and understand the data.

This document is a deliverable report of D5.1 “Interactive Visual Interface” of WP5 in CARRE project. In particular it covers tasks designated in Task 5.1. This deliverable report focuses on the design and initial implementation of visual analysis components in order to provide personalised views and analysis of sensor data, PHR data, risk factors and decision support data. The report is organised by data source, visual analytics interface and components, use cases and implementation.

About CARRE

CARRE is an EU FP7-ICT funded project with the goal to provide innovative means for the management of comorbidities (multiple co-occurring medical conditions), especially in the case of chronic cardiac and renal disease patients or persons with increased risk of such conditions.

Sources of medical and other knowledge will be semantically linked with sensor outputs to provide clinical information personalised to the individual patient, to be able to track the progression and interactions of comorbid conditions. Visual analytics will be employed so that patients and clinicians will be able to visualise, understand and interact with this linked knowledge and take advantage of personalised empowerment services supported by a dedicated decision support system.

The ultimate goal is to provide the means for patients with comorbidities to take an active role in care processes, including self-care and shared decision-making, and to support medical professionals in understanding and treating comorbidities via an integrative approach.

Terms and Definitions

The following are definitions of terms, abbreviations and acronyms used in this document.

Term	Definition
API	Application programming interface (API) is a set of functions and procedures that allow the creation of applications that access the features or data of an operating system, application, or other service
DSS	Decision Support System
EC	European Commission
EHC	European Health Card
eHealth	Electronic Health
EU	European Union
HTML	Hypertext Markup Language, the standard markup language used to create web pages.
HTTP	Hypertext Transfer Protocol, a data communication for the World Wide Web.
HTTPS	Hypertext Transfer Protocol Secure
OWL	Web Ontology Language
PHR	Personal Health Record
REST	Representational State Transfer, is a software architecture style for building scalable web services.
RDF	Resource Description Framework - a standard model for data interchange on the Web.
SPARQL	RDF query language, that is, a query language for databases, able to retrieve and manipulate data stored in RDF
SVG	Scalar Vector Graphics, is an XML-based vector image format for two-dimensional graphics with support for interactivity and animation
UC	Use case
UMLS	Unified Medical Language System
URL	Uniform Resource Locator
VA	Visual analytics
Vis	Visualisation
WWW	World Wide Web

1. Introduction

CARRE personalised patient empowerment and decision support services harvest data from a variety of data sources including sensors, risk factors, Personal Health Record (PHR), decision support, etc. Without proper tools it is almost impossible to present and analyse these large, heterogeneous, time-varying data.

Work Package 5 “Data Management & Visual Analytics for Empowerment” aims to address this challenge. In Task 5.1 “Interactive Visual Interface”, an interactive visual analysis approach has been designed and developed to empower both the patients and the medical experts to view, utilise, analyse and understand the data. Visual analytics is an integral approach which combines visualisation, human factors, and data analysis. This process incorporates automatic and visual analysis methods with a tight coupling through human interaction in order to view, analyse and understand the data.

As a science of analytical reasoning facilitated by interactive visual interfaces, the interface of visual analytics is critical in the applications development. Visual analytics interfaces allow the analysts to interact directly with the representation of the data or to modify visualisation parameters. In the visual analytics process knowledge can be gained from visualisation, automatic analysis, as well as interactions between visualisations, models, and the human analysts.

In WP5 the visual analytics techniques deliver different perspectives on specific data types to provide role-specific (personalized) and goal-oriented representations of the data. The interactive visual interface directly supports complex decision making tasks. Standard interaction techniques are implemented to facilitate data exploration and knowledge discovery.

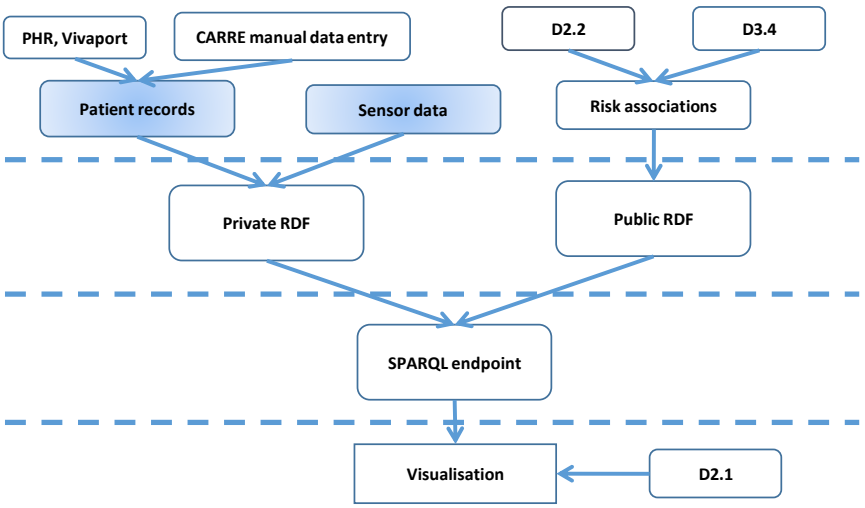


Figure 1. Relation of WP5 to other deliverables in CARRE.

This report of D5.1 interactive visual interface is a deliverable report of Task 5.1 “Interactive Visual Interface” whose aim is to provide a design of visual analytics interfaces and components for CARRE patients and medical experts to facilitate understanding and analysis of sensor data, risk factor data, PHR data and decision support data, etc.

In the previous deliverable D2.1, four high level visual analytics use cases have been identified, they are:

- UC_Vis_04 : The goal of this use case is to allow patients to understand their disease progression;
- UC_Vis_05 : The goal of this use case is to allow patients to understand their disease progression based on personal monitored data;
- UC_Vis_06 : The goal of this use case is to allow patients to understand their disease progression if they change their lifestyle;
- UC_Vis_07: The goal of this use case is to allow patients to understand their disease by comparing their personal state with current medical evidence.

In D2.1, five patient groups, two doctor groups, one nurse group, and one group of Administration & Policy Makers have been defined. In a recent development, more detailed virtual patients are defined: the medical partners have jointly generated 18 virtual patients with various cardiorenal syndrome related diseases based on real patient data.

A summary of relations of WP5 and other deliverables in CARRE is shown inFigure 1. Relation of WP5 to other deliverables in CARRE. Figure 1.

2. Visual Analytics Tasks in CARRE

We define the visual analytics tasks provided by the CARRE visual interface as follows:

- Visualising data from self-monitoring of own health-status including sensors, daily activities, symptoms and PHR data.
- Visualising individual risks and allowing for analytical analysis of the impact of behaviour changes to the risks

More specifically, the visualisation interface provides the following functionalities:

1. Enhancing user experiences in behaviour monitoring, symptom reporting, observables monitoring (refer to risk associations reported in D2.2) and facilitating their lifestyle management by allowing for health status data visualisation (behaviours, symptoms). These will include:
   - Monitoring: visualisation of a wide range of data including their activities, movement, step accounts, diet and other health-related behaviours and events, observables monitoring, such as blood pressure and blood glucose. The monitoring will make most use of sensors and mobile apps
   - Personal Diary: visualisation of the health status of the individual and their behaviours, including their locations, movements, diet, sleep quality, environment, mood, blood pressure, glucose, alcohol, smoking, and other symptoms, etc. Visual analytics will be used to display individual/aggregated data items to allow easy interpretation of the data from the patients. With the search bar of the system, the users can easily send queries about their activities, movements, diet, etc.
   - PHR Data: visualisation of a variety of medical related measurements. Most of them are time series with different sampling intervals.
2. Visualising individual risks and allowing for analytical analysis of the impact of the behaviour to the risks
   - Visualisation of the risk assessment outcomes by linking the personal diary with the behaviour prescription to show the underlying risk factors, demonstrating to the patients the relations between the outcomes of the self-management/treatment.
   - A considerable number of participants are and will be using the CARRE system and they will contribute a significant amount of data to the platform. The virtual patients that defined by medical partners will be used as examples to show the functionality of the visual analytics interface and the potential contributions to the decision support for patients in self-managing the diseases. The educational intervention schemes will be adopted to help the users improve their compliance to suitable lifestyles.
3. Supporting personal behaviour intervention modules that allow for planning and remaindering for daily physical exercise, diet and medication where necessary.
   - Supporting Intervention: allowing for the visualisation of “Behaviour prescription” including a set of targets in terms of daily activities, calorie intake and energy consumption, etc.
   - Education intervention: through visualisation, help the users to interpret the educational materials to the patients in needs, for example, highlight the key messages and show the relationship between different materials to assist their reading.

The architecture of the visual analytics interface is shown in **Error! Reference source not found.**

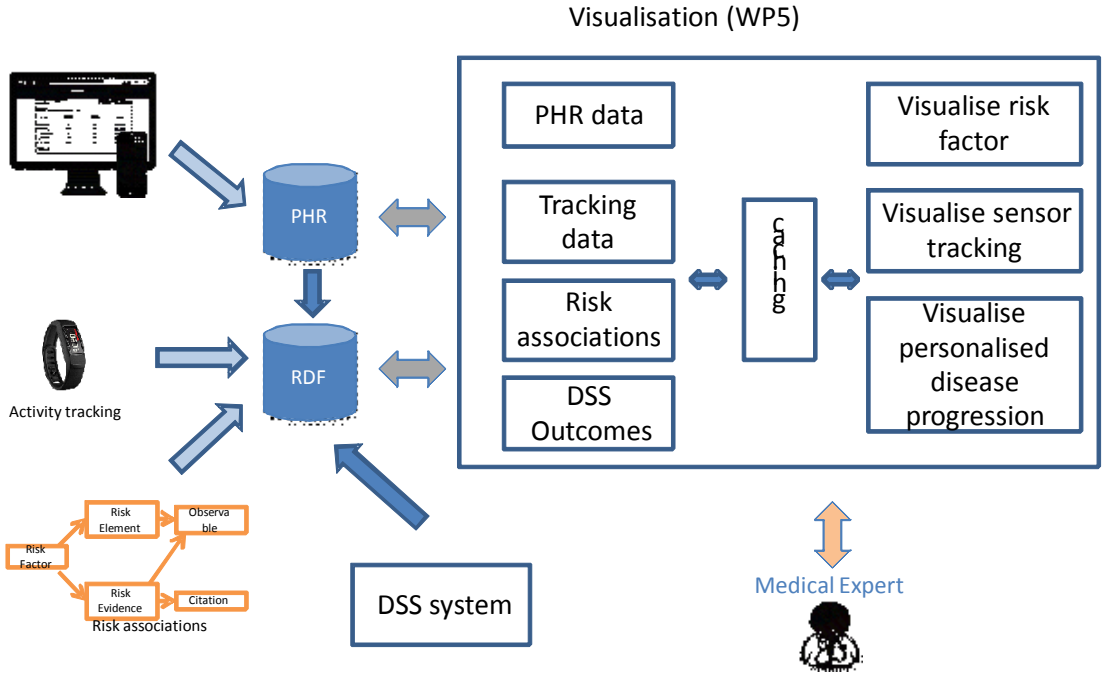


Figure 2. Visual analytics interface architecture

3. Visual Analysis Data Sources

3.1. Public data in the CARRE Semantic Repositories

In CARRE, the public data repository stores the medical knowledge of risk associations which have been reported in D2.2. The development of the public Resource Description Framework (RDF) repository is carried out by OU and the progress had been reported in D4.1 and D2.5.

3.1.1 Introduction

As outlined in D.2.5 and D.4.1, the main data store for CARRE consists of two repositories, hosted by the OU, which contain semantic representations of private and public data according to the CARRE ontology and RDF schema described in D.2.4. Access to data in these repositories is available via the APIs described in D.4.1 and D.4.2, and, in the case of private data, access is restricted to the data owner (patient) and CARRE-specific applications to which they have given permissions, e.g., decision support services, visual analysis interface.

3.1.2 Semantic Technologies

The data are stored using standard Semantic Web technologies such as RDF[1] and OWL[2], which enable analysis of data according to its meaning, as described in ontologies. D.2.4 presented the main ontologies for CARRE which specify the meaning of terms describing medical evidence and risk and their association with observable properties and personal sensor data. All data stored in the CARRE repositories is in accordance with these ontologies and the associated RDF schema, and, where relevant, different types of data are

[1] http://www.w3.org/standards/techs/rdf

[2] http://www.w3.org/standards/techs/owl

associated with relevant external ontologies and vocabularies. For example, by linking the CARRE representations of medical diagnoses with vocabularies such as the Unified Medical Language System (UMLS)[3], it is straightforward to link general medical knowledge from CARRE with any external system which uses any of the ontologies encompassed by UMLS (for example, the widely-used SNOMED-CT[4]). These external links are discussed in D.2.4 and D.4.2.

3.1.3 Data Repositories

The CARRE repositories are divided by privacy concerns. The private repository stores data relating to individual patients, in a secure and access-limited fashion, with each patient's data in a separate and restricted RDF graph. All data from personal sensors, personal health records and any decision support services recommendations for an individual are stored and queried from that individual's private graph.

The public repository stores general medical knowledge relating to risk associations, evidence and observables, and is available for public querying without authentication, as it contains no personally identifying data for any patient and serves as a general-purpose resource for medical knowledge in a semantic format.

3.1.4 Accessing CARRE data

The RESTful API to access CARRE data is described in detail in D.4.1 and D.4.2, including the privacy-by-design features for private data. An authenticated and approved application can retrieve an access token per user from the API, which is used to authenticate all calls which access that user's private graph. API calls relating to public data may be performed without any token.

SPARQL[5] is the standard query language for RDF data. The API allows arbitrary SPARQL queries to be submitted via an authenticated call, and also contains several helper methods which wrap specific common queries in an optimised way (for example, retrieving a daily summary of sensor readings for a user).

3.1.5 Applicability to the rest of this document

The majority of the data, including that discussed in the following sections, to be displayed and analysed by the visual analytics interface can be retrieved from the repositories by using the CARRE RESTful API, with or without authentication tokens, depending on its privacy status.

3.2. Risk Factor Data Representation

In CARRE risk factor data are a large semantic graph structure data consisting of interlinked entities, such as risk elements and risk evidence, that are either related to ground knowledge in cardio-renal disease and comorbidities (symptoms, diseases, risk factors, treatments, medical evidence source data, educational content, etc.) or personalised to each patient (patient demographics, medical history, sensor data, lifestyle data, etc.). Figure 3 shows the risk factor conceptual model as described in more detail in D.2.2.

[3] https://uts.nlm.nih.gov/home.html

[4] http://www.ihtsdo.org/snomed-ct

[5] http://w3.org/TR/sparql11-query/

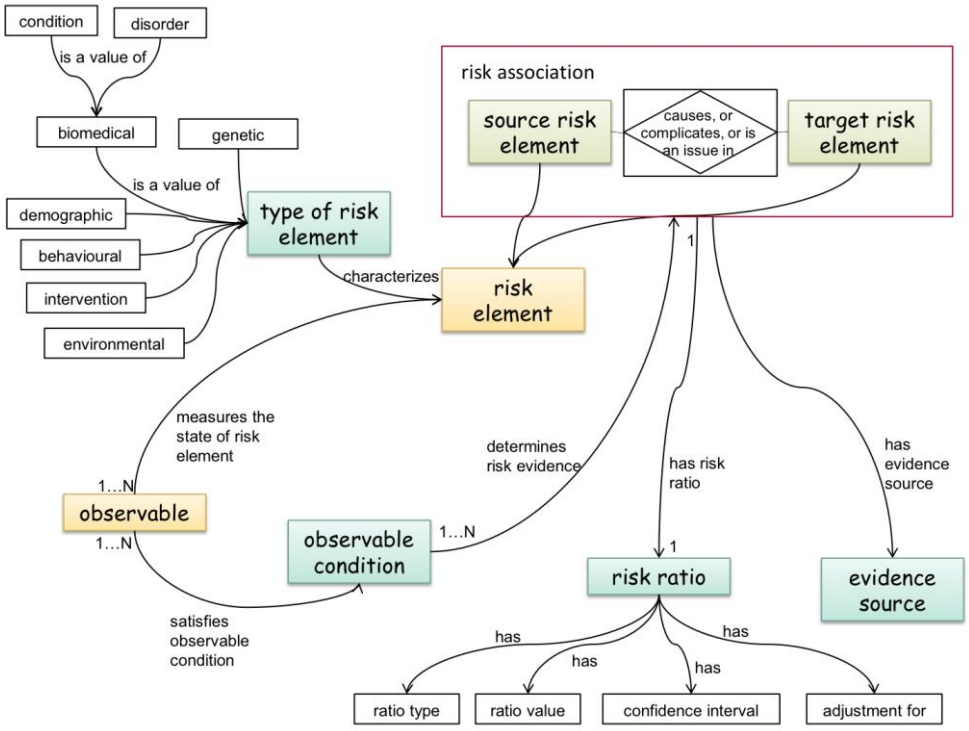


Figure 3. Risk factor data structure

3.3. Private data in the CARRE Semantic Repositories

In CARRE, the private data repository stores the patient related data, which mainly come from the PHR and the sensor data monitoring. The data comprises personal diary data which includes the biomarker records (with the necessary data of observables as indicated in the risk associations) and life style tracking data. The development of the public Resource Description Framework (RDF) repository is carried out by OU and the progress had been reported in D4.1 and D2.5.

For demonstration purposes, there are currently 18 virtual patients defined by medical experts in DUTH (Annex 1) based on data selected from real patients. Three virtual patients are selected from them as detailed use cases to be used in designing the visual analysis study to perform lifestyle management and risk assessment. In the following subsections we will list the basic information of three virtual patients that are used in this deliverable.

3.3.1 Virtual Patient #2

For the purposes of development and testing, a number of virtual patient data have been developed by medical experts in DUTH (Annex 1). Virtual Patient #2 is a 70 year old obese female diabetic with hypertension, dyslipidaemia, CKD stage 3 and left ventricular hypertrophy. The basic information of the patient is listed in Table 1. The related observables of virtual patient #2 are listed in Table 2.

Table 1. Demographics and biometrics data of virtual patient #2

Demographics and biometrics	
Sex	Female
Age	70
Height	160

Weight	94
waist circumference	125
Waist to height ratio	0.78
Waist to hip ratio	
Body Fat percentage	37
Family history of Ischemic heart disease:	No
Self history of Ischemic heart disease:	No

Table 2 Observables of virtual patient #2

Observables	
Acute kidney disease diagnosis	no
Acute myocardial infarction diagnosis	no
AHI (Apnoea– hypopnoea index)	no
Atrial fibrillation diagnosis	no
β-blockers administration	no
Blood Glucose: 2h glucose after oral glucose tolerance test	198
Blood Glucose: fasting	224
Blood pressure	160/90
Chronic kidney disease diagnosis	yes
Chronic obstructive pulmonary disease diagnosis	no
Contrast agents: coronary angiography administration	no
Diuretics administration	yes
eGFR	35
Fasting Plasma Glucose Levels	224
HbA1c	7.8
Haemoglobin (Hb)	10.9
HDL-C (High-density lipoprotein cholesterol)	62
Heart failure diagnosis	no
Hypertension Diagnosis	yes
Ischemic heart disease self history	no
Ischemic stroke diagnosis	no
LDL-C (Low-density lipoprotein cholesterol)	120
Left ventricular hypertrophy diagnosis	yes
Non-HDL-C	
Obstructive sleep apnea diagnosis	no
Physical activity	no

Renin-angiotensin system dual blockade administration	no
Serum creatinine level	2.0
Serum potassium	8.8
Smoking intensity	no
Smoking status	no
Statin administration	yes
Total cholesterol	215
Triglycerides (TG)	200
Uric acid serum concentration	7.0

3.3.2 Virtual Patient #5

Virtual Patient #5 is a 34 year old male with Type 1 diabetes, obese, smoker with history of sleep apnoea. The basic information of the patient is listed in Table 3.

Table 3 Demographics and biometrics of virtual patient #5

Demographics and biometrics	
Sex	Male
Age	34
height	175
weight	125
waist circumference	120
Waist to height ratio	0.93
Waist to hip ratio	
Body Fat percentage	32
Family history of Ischemic heart disease	no
Self history of Ischemic heart disease:	no

The related observables of the virtual patient #5 are listed in Table 4.

Table 4 Observables of virtual patient #5

Observables	
Acute kidney disease diagnosis	no
Acute myocardial infarction diagnosis	no
AHI (Apnoea– hypopnoea index)	
Atrial fibrillation diagnosis	no
β-blockers administration	no
Blood Glucose: 2h glucose after oral glucose tolerance test	203

Blood Glucose: fasting	150
Blood pressure	125/70
Chronic kidney disease diagnosis	no
Chronic obstructive pulmonary disease diagnosis	no
Contrast agents: coronary angiography administration	no
Diuretics administration	no
eGFR	81
Fasting Plasma Glucose Levels	150
HbA1c	7.2
Haemoglobin (Hb)	12.5
HDL-C (High-density lipoprotein cholesterol)	52
Heart failure diagnosis	no
Hypertension Diagnosis	no
Ischemic heart disease self history	no
Ischemic stroke diagnosis	no
LDL-C (Low-density lipoprotein cholesterol)	95
Left ventricular hypertrophy diagnosis	no
Non-HDL-C	
Obstructive sleep apnea diagnosis	yes
Physical activity	no
Renin-angiotensin system dual blockade administration	no
Serum creatinine level	1.0
Serum potassium	8,7
Smoking intensity	3 packs per day
Smoking status	yes
Statin administration	no
Total cholesterol	123
Triglycerides (TG)	87
Uric acid serum concentration	6.5

3.3.3 Virtual Patient #9

Virtual Patient 9 is a fake 74 year old male with CHD, congestive heart failure, CKD and type II diabetes. The basic information of virtual patient #9 is listed in Table 5.

Table 5 Demographics and biometrics of virtual patient #9

Demographics and biometrics	
sex	male

age	74
height	169
weight	76
waist circumference	117
Waist to height ratio	0.69
Waist to hip ratio	
Body Fat percentage	22
Family history of Ischemic heart disease:	yes
Self history of Ischemic heart disease:	yes

The related observables of virtual patient 9 are listed in Table 6.

Table 6 Observables of virtual patient #9

Observables	
Acute kidney disease diagnosis	no
Acute myocardial infarction diagnosis	no
AHI (Apnoea– hypopnoea index)	no
Atrial fibrillation diagnosis	yes
β-blockers administration	yes
Blood Glucose: 2h glucose after oral glucose tolerance test	220
Blood Glucose: fasting	135
Blood pressure	110/75
Chronic kidney disease diagnosis	yes
Chronic obstructive pulmonary disease diagnosis	no
Contrast agents: coronary angiography administration	no
Diuretics administration	yes
eGFR	29
Fasting Plasma Glucose Levels	130
HbA1c	7.7
Haemoglobin (Hb)	11.2
HDL-C (High-density lipoprotein cholesterol)	32
Heart failure diagnosis	yes
Hypertension Diagnosis	no
Ischemic heart disease self history	yes
Ischemic stroke diagnosis	no
LDL-C (Low-density lipoprotein cholesterol)	118
Left ventricular hypertrophy diagnosis	no

Non-HDL-C	
Obstructive sleep apnea diagnosis	no
Physical activity	no
Renin-angiotensin system dual blockade administration	yes
Serum creatinine level	2.4
Serum potassium	4.1
Smoking intensity	
Smoking status	No
Statin administration	Yes
Total cholesterol	190
Triglycerides (TG)	200
Uric acid serum concentration	8.0

3.4. Sensor monitoring data

Some of the above observable data will be collected using sensors regularly. For examples, for virtual patient #2, the glucose data will be collected by patients with diabetes at home several times a day. The data will be stored in the private repository. A large dataset of glucose that is collected over a time period along with other biomarkers and life style tracking data provide valuable information in analysing disease progression, for both patients and medical professionals.

3.4.1 Background

In recent years there has been a boom in the health sensor market. Sensors evolved from traditional devices such as the step meter to internet-enabled devices such as Fitbit[6] , Withings[7] , iHealth[8] , etc. They measure steps, walking distance, calories, sleep quality, heart rate, weight, etc., based on different device models. Some devices measure more health-oriented data, such as blood pressure, glucose, etc. The collected data can be uploaded to the servers and shared via APIs to other internet applications. Meanwhile, with the evolution of smart phones, fitness mobile apps have also become important data sources of health and lifestyle data. Mobile phones with proper sensors installed are capable of not only measuring the step number but also recording the user locations, thus keeping track of both the fitness data and daily lifestyle data of the user.

Moves[9] is a very popular app for life tracking. *Moves* automatically records the user's step number and locations and calculates calories burned and movement distance of movement accordingly. It automatically recognises the activity type, such as walking, running, cycling, transport, etc. An automatic daily storyline with time and location are recorded and shown on the map in the Moves app. The user can either view the distance, duration, steps, and calories data in the Moves app or export the data from the Moves server. Therefore, Moves app could be recommended as an alternative to hardware physical activity sensors in Table 8.

[6] http://www.fitbit.com

[7] http://www.withings.com

[8] http://www.ihealthlabs.com/

[9] http://moves-app.com

3.4.2 Sensors

Tables below (Table 7 – Table 11) represent sets of sensors which we tested and selected during Task 3.2, and described in Deliverable report D3.2. These tables also display which CARRE observables are related to the measurements obtained from the sensors.

Table 7. Recommended sensors for weight and body composition monitoring					
No.	**Measurements**	**Fitbit Aria**	**Withings WS-50**	**Medisana BS 440**	**Related CARRE observable**
1	Body weight, kg	✓	✓	✓	BMI (Body Mass Index)
2	Body fat, %	✓		✓	Body Fat percentage
3	Body water, %			✓	None
4	Muscle mass, %			✓	None
5	Bone mass, kg			✓	None
6	BMI			✓	BMI (Body Mass Index)
7	Basal Metabolic Rate (BMR)			✓	None
8	Standing heart rate		✓		None
9	Room CO2 level		✓		None

Table 8. Recommended sensors for physical activity monitoring				
No.	**Measurements**	**Fitbit One**	**Withings Pulse O2**	**Related CARRE observable**
1	Steps	✓	✓	Physical activity
2	Distance travelled	✓	✓	Physical activity
3	Calories burned	✓	✓	Physical activity
4	Stairs climbed	✓		Physical activity
5	Distance climbed		✓	Physical activity
6	Sleep quality	✓	✓	AHI (Apnoea – hypopnoea index)
7	Heart rate		✓	None
8	SpO2		✓	AHI (Apnoea – hypopnoea index)

Table 9. Recommended sensors for blood pressure monitoring				
No.	**Measurements**	**Medisana BU 575**	**iHealth BP5**	**Related CARRE observable**
1	Systole, mmHg	✓	✓	Blood pressure
2	Diastole, mmHg	✓	✓	Blood pressure
3	Pulse, bpm	✓	✓	None

Table 10. Recommended sensors for blood glucose monitoring				
No.	**Measurements**	**iHealth BG5**	**Medisana Meditouch 2**	**Related CARRE observable**
1	Blood glucose, mmol/L	✓	✓	Blood glucose: fasting, Blood Glucose: 2h glucose after oral glucose tolerance test

Table 11. Recommended sensor for atrial fibrillation monitoring			
Nb.	**Measurements**	**eMotion Faros 180**	**Related CARRE observable**
1	Start time of AF episode	✓	Atrial fibrillation diagnosis
2	AF episode duration	✓	Atrial fibrillation diagnosis
3	AF frequency	✓	Atrial fibrillation diagnosis
4	AF burden	✓	Atrial fibrillation diagnosis
5	AF density	✓	Atrial fibrillation diagnosis

All sensor data are imported into CARRE private RDF repository can be accessed via the sensor APIs provided thereby.

3.5. Decision Support Service (DSS) Data in CARRE

The DSS services are defined in WP6, WP5 is responsible to provide visualisation service for DSS.

3.5.1 DSS Introduction

Decision support systems (DSS) can assist patients and medical experts by providing them advices, recommendations and diagnosis in cardiorenal domain, where the optimal solutions for a given sort of data about the possible consequences are determined similar as human experts in the field.

A modern intelligent decision support system not only provides access to data and models but also is a significant development in the field of analytical data processing, data warehousing and artificial intelligence-aided methods of knowledge discovery in databases (Data Mining).

In CARRE system decision support service will determine the optimal solution, by mining RDF repositories data to predict future trends and patterns as well as information data analytics and formal reasoning from ontologies, which are the main techniques supported by RDF Linked Data and ontologies.

This method searches particular patient's observables and assigns risk factors and evidences as well as showing the probability occurrence of a given risk factor and the most suitable risk ratio value.

DSS runtime infrastructure will provide:

- Framework and service to both Patient Application and Medical Expert.
- Forecasting models and analytics based on the risk model fulfilled by data in Repositories.
- Run-time decision based on current status of incoming data.

DSS will support Patient Application and will be the main source of decision recommendations for CARRE. This includes the analysis of the generic and personalised risk model so as to allow the CARRE stakeholders

to identify and assess critical medical conditions. Its aim will be to produce meaningful information that will be passed to the end-user interface with the synergy of the visualisation component.

DSS involves the development of decision support services for the Medical Expert. By means of this component a Medical Expert- with his expertise in given areas and knowledge from scientific literature, by utilising information of the patient's disease condition and calculated risks models of disease progression, will propose lifestyle recommendations to a particular patient and provide guidance to the treatment plan.

It should be addressed that such large amount of information requires hierarchical data presentation to allow easy access to all data as well as intuitive operation is required. This will create the requirements for the development of logical interface.

Analyses of requirements and interaction design will be completed on the basis of direct consultations carried out among patients and medical experts in cardiac and renal diseases domain during the integration, customization and update towards patient's and expert's perspectives.

In addition to the classical view of the decision making process, there is an understanding of this process as knowledge-based. This approach assumes that a decision is made based on fragments of knowledge describing the essence of information which is necessary to take decision. In this context, decision-making is a process of creating a new, previously non-existent piece of knowledge. New knowledge is created by converting and combining pieces of existing knowledge available in both Repositories.

3.5.2 Data Format

In CARRE system the data for DSS will be provided via common interfaces and common data exchange method, which will ease the further integration. The DSS will communicate with OU CARRE RDF Repositories over SPARQL to retrieve the RDF files from both Repositories. For DSS service the CARRE semantic repository will be a RDF store accessible as a RESTful Web Service.

It is planned that DSS output will be stored in private repository in RDF format. It is the most natural way, since RDF Repository is the central data storage of the CARRE system. This enables query of the data for visualisation purposes in an intuitive and user-friendly way.

3.5.3 Data Access

The prototype of DSS framework will be available on following website: http://galinos.med.duth.gr/, as shown in Figure 4. The website is currently under extensive development and new versions of service will be upgraded continuously.

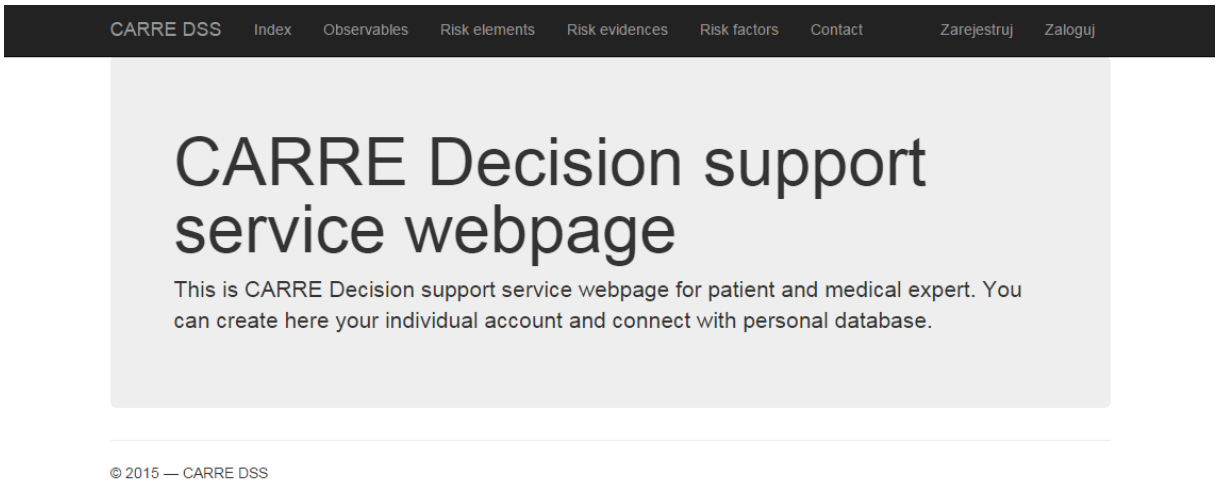


Figure 4. CARRE decison support service web interface

3.6. PHR data

3.6.1 Introduction

A personal health record, or PHR[10], is a health record where health data and information related to the care of a patient is maintained by the patient [PHR]. This stands in contrast to the more widely used electronic medical record, which is operated by institutions (such as hospitals) and contains data entered by clinicians or billing data to support insurance claims. The intention of a PHR is to provide a complete and accurate summary of an individual's medical history which is accessible online. The health data on a PHR might include patient-reported outcome data, lab results, and data from devices such as wireless electronic weighing scales or collected passively from a smartphone.

In CARRE, PHR is an important source of patient medical data and it will be retrieved from PHR system and stored in the private repository.

To test the interactive user interface the web-based PHR system Vivaport[11] is used as the PHR portal. VULSK is responsible for building and running of the system.

Vivaport personal health portal was created by the cooperation of 19 partner organisations from 8 European countries. VivaPort is a multilingual personal health summary information portal containing one's most vital personal information (Patient Summary). The aim of this PHR system is for medical professionals to reach patients' personal health record when needed or in case of emergency.

Vivaport provides web APIs for accessing the PHR data that is stored in the system.

3.6.2 PHR Data format

Patient data is retrieved from PHRs, Vivaport in particular, by CARRE PHR data aggregator using PHR's APIs. Then data is mapped and converted to format used in OU CARRE RDF and inserted into Private RDF via common interfaces and common data exchange method used by RDF repository (SPARQL syntax and methods).

CARRE manual data entry system is another option to enter patient records. It is also used for anonymous data collection.

[10] https://en.wikipedia.org/wiki/Personal_health_record

[11] https://vivaport.eu/

4. Visual Analytics System Interface and Components

In CARRE architecture design, the whole CARRE system is composed of different web-based functional modules that communicate with each other. The visual analytics module is a web-based sub-system that provides supporting functions for data exchange, visualisation and analysis. The system is available online at http://carre.ccgv.org.uk:8080/Carre.

In this section, the visual analytics web interface and the visual analytics components will be introduced.

4.1. Visual Analytics System Interface

The visual analytics system includes web hosting, access control and a web-based framework for hosting visual analysis components. Figure 5 shows the login page of CARRE visual analytics web system. The user authentication will use OU's authentication mechanism to achieve single-point access control. The web-based framework is composed of a dashboard and multiple visual analytics component containers.

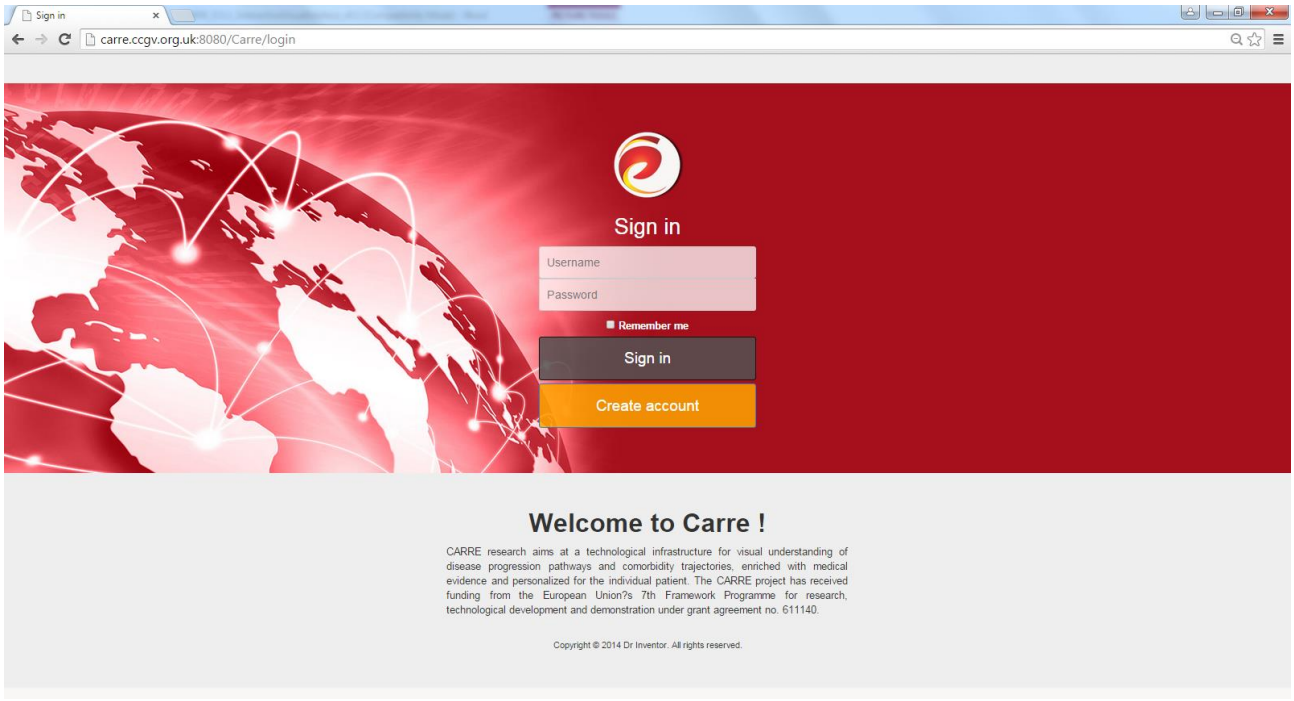


Figure 5. The login page of CARRE visual analysis system interface

4.1.1 Dashboard

There are multiple visual analytics components that can be accessed by the user from the web-based CARRE visual analytics interface. However, as there is a variety of data sources and data types, it is difficult for a user to grasp an overview with important features from the scattered health status visualisation. To present the user a quick overview of their health status, CARRE visual analytics web interface provides a dashboard as a front page. The dashboard provides a summary of the user's latest health status and may present important notifications. It may include several visualisation components to present data in a relatively recent period. Figure 6 shows the example dashboard with data tiles, map and a timeline. The user can interact with the map and the timeline to obtain more detailed information.

Figure 6. CARRE Visual analytics interface dashboard

4.1.2 Visual Analytics Component Container

Visual analytics components are designed for visualisation and analysis of particular tasks. Rarely a single visual analysis component can meet all the requirements of a task. More commonly multiple visual analytics components need to be coordinated in synergy for a task. This implies that the related visual analytics components need to be organised in a container. The visual analytics component container is provided as a single page container for those visual analytics components. It supports automatic and manual layout setting of components.

Commonly there are multiple tasks desired by the CARRE end users, such as risk factor, disease progression, etc. It further requires multiple visual analytics component containers which are organised as tabs in the CARRE visual interface. These tabs provide multiple visualisation containers in one place and are capable of performing coordinated tasks in terms of user interaction.

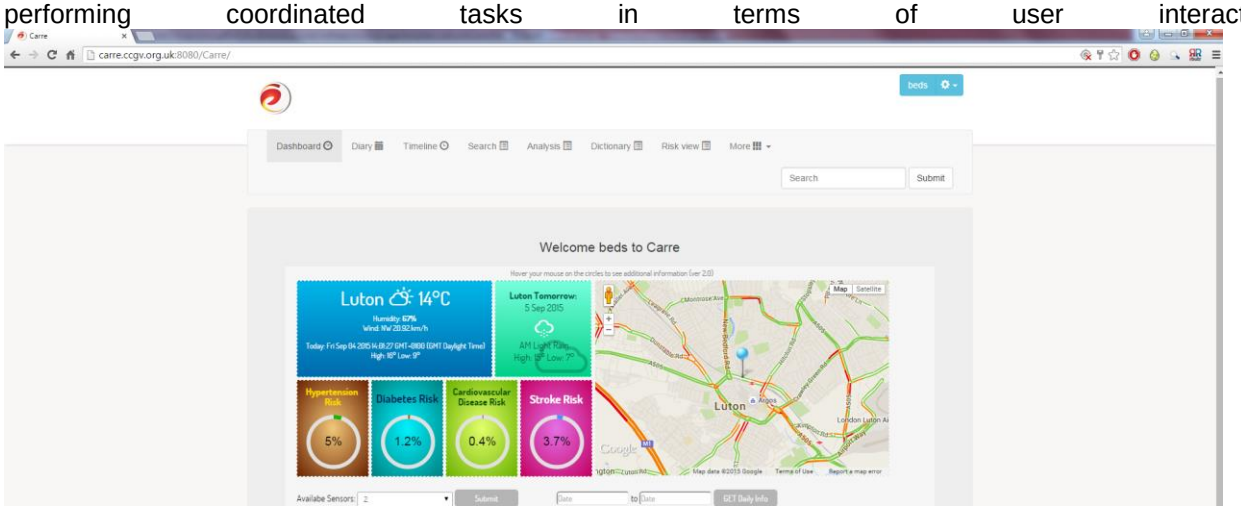


Figure 7 shows the current tab organisation in current CARRE visual interface implementation.

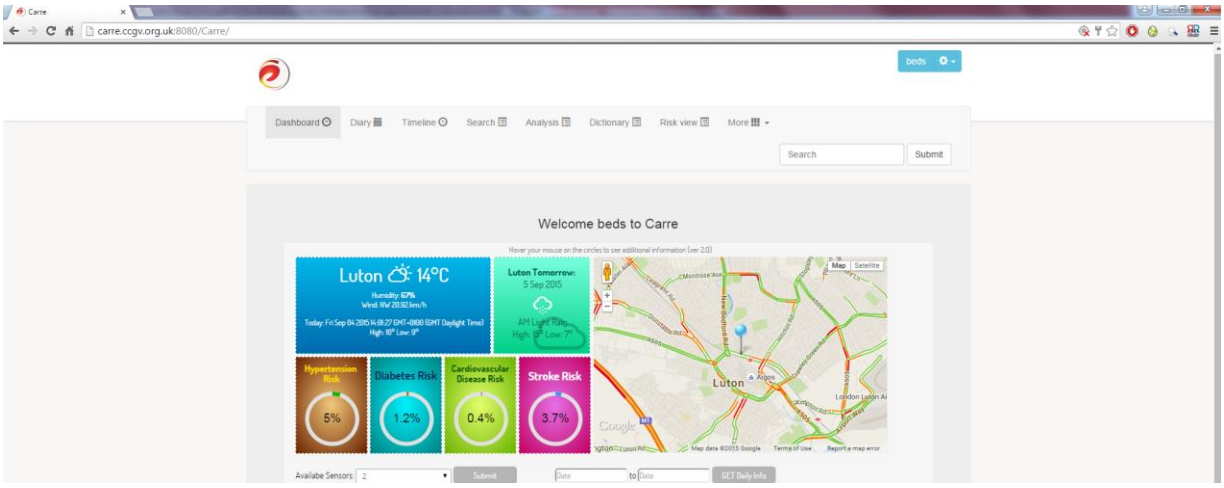


Figure 7. Tab-based component container organiser

4.2. Visual Analytics Components

In this section, details of individual components for visual analytics in CAREE are described. These components form the basis of CAREE visual analytics. To fulfil a particular visual analytics task, multiple visual analytics components are selected and organised into a container. The interactions between components and users as well as the interactions between components are carefully designed to achieve coordinated work.

4.2.1 Chart

A chart, also called a graph, is a graphical representation of data, in which the data is represented by symbols. A chart can represent tabular numeric data, functions or certain qualitative structure and provides different information[12]. Charts are often used to ease understanding of numerical/category data and the relationships between parts of the data. They facilitate representation and understanding of the raw data. Charts have been widely used in a variety of application domains. Spreadsheets also use charts to visualise their tabular data. Frequently used charts include line chart, dot chart, bar chart, pie chart, etc. In CARRE, a large portion of data is the sensor data which contain a large quantity of numerical data that can be visualised by charts and chart variations. These charts can be used as visual analytics components to fulfil a task such as sensor data or PHR data visual analytics. Figure 8 presents the line charts and bubble charts used in CARRE visual analysis.

[12] https://en.wikipedia.org/wiki/Chart

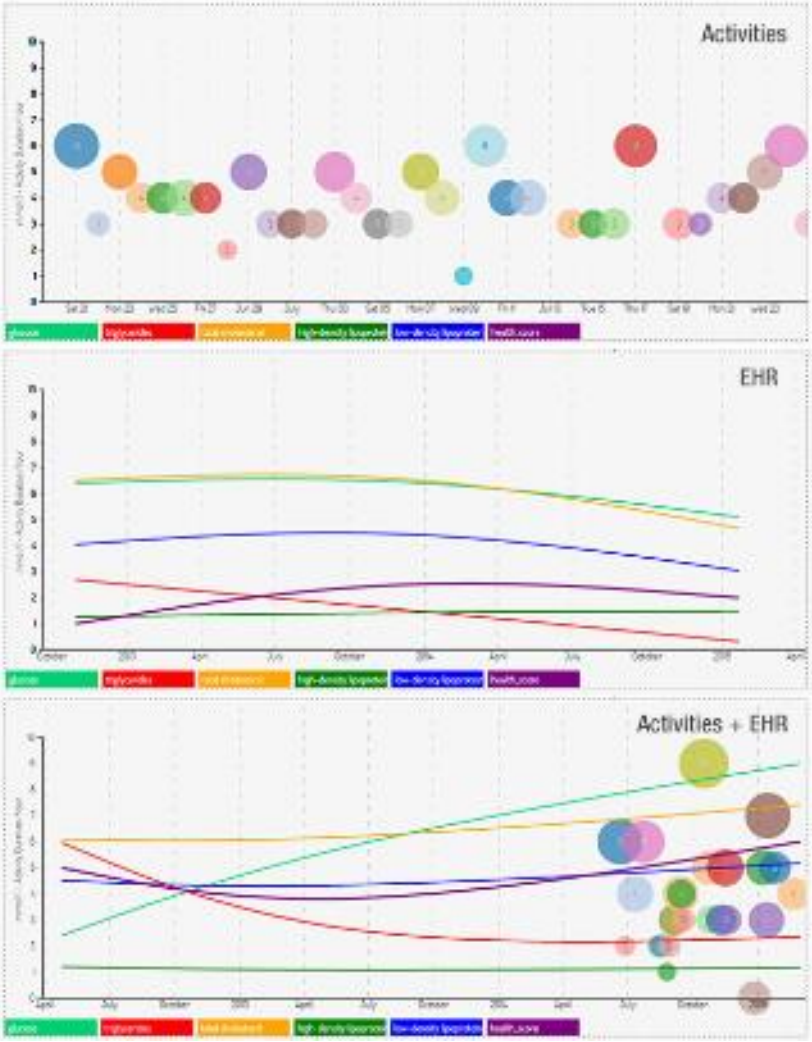


Figure 8. Example charts used in CARRE visual analytics

4.2.2 Node-link Diagram

Node-link diagrams are usually used to visualise a tree or network graph data structure. In node-link visualisations of a network, entities are represented by nodes, the links or edges among those nodes represent relationships among entities. A node-link diagrams is the intuitive and natural way to represent relations between objects.

The basic graph layout is straightforward. Given a set of nodes with a set of relations (edges), it only needs to calculate the positions of the nodes and draw each edge as a curve. However, with the increasing of the number of nodes and edges, it become more and more difficult to make graphical layouts understandable and useful to ender users.

Dynamic layout techniques can be used for node-link diagram to reduce difficulties in visualisation, such as force-directed layout[13] and Multi-Dimensional Scaling (MDS)[14] .

Figure 9 is an example of risk factor visualisation in CARRE which uses additional channels such as colour, line width to visualise data attributes.

[13] Peter Eades. A heuristic for graph drawing. Congressus Numerantium, 42:149–160, 1984

[14] JB Kruskal, M Wish, Multidimensional Scaling, Sage University Paper series on Quantitative Application in the Social Sciences, 07-011,Sage Publications, 1978

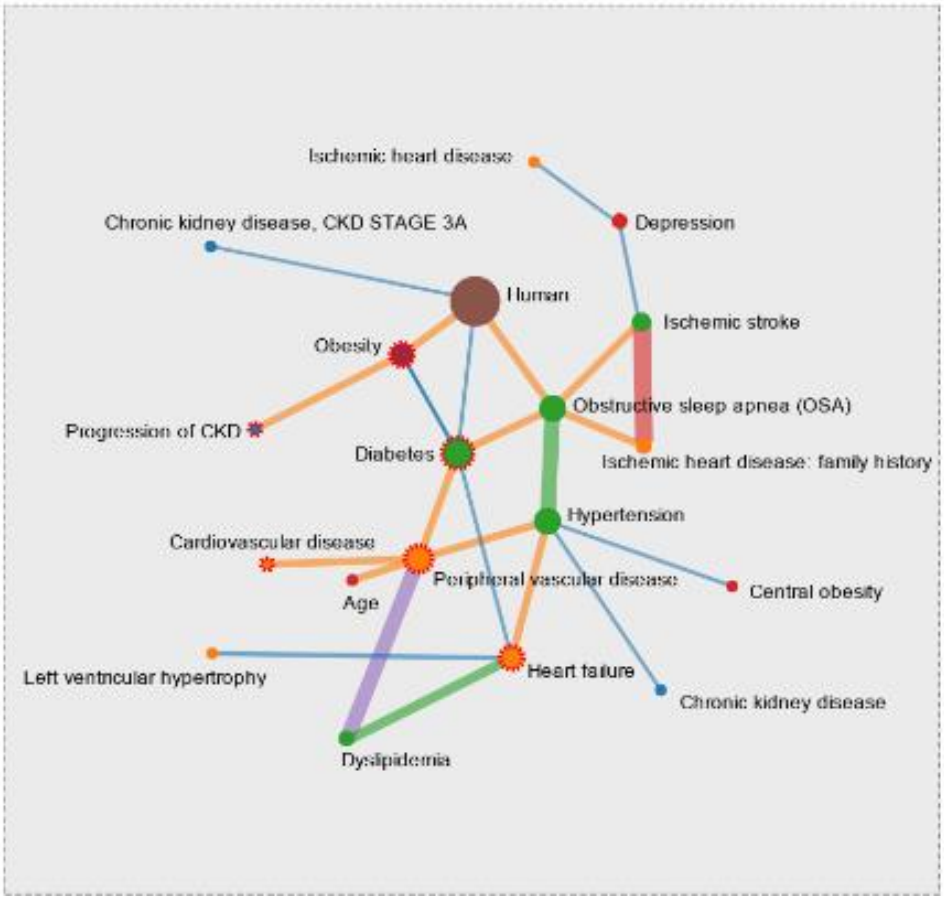


Figure 9. Node-link diagram example used in CARRE visual analytics to visualise risk factors

4.2.3 Matrix

Although node-link diagrams are capable of presenting the overall structure of the connections, density has a strong impact on readability in node-link diagrams. Alternatively a network can be presented by an adjacency matrix, where rows and columns refer to nodes in node-link diagrams and cells refers to relationships. Compared to node-link diagram, when there is are large number of connections in a network, the advantage of matrix is that it can present all the relationships in the visualisation while node-link diagrams will inevitably result in excessive edge crossings and hairballs. However, the effectiveness of a matrix diagram is heavily dependent on the order of rows and columns: if related nodes are placed close to each other, it is easier to identify clusters and bridges.

Figure 10 is an example view in CARRE visual analytics to visualise causal relationships of risk elements. The filled cell means that there is a causal relationship from the column risk element to the row risk element. The colour represents the disease category and the darkness of the colour represents the number of occurrence of the relationship among all risk factors.

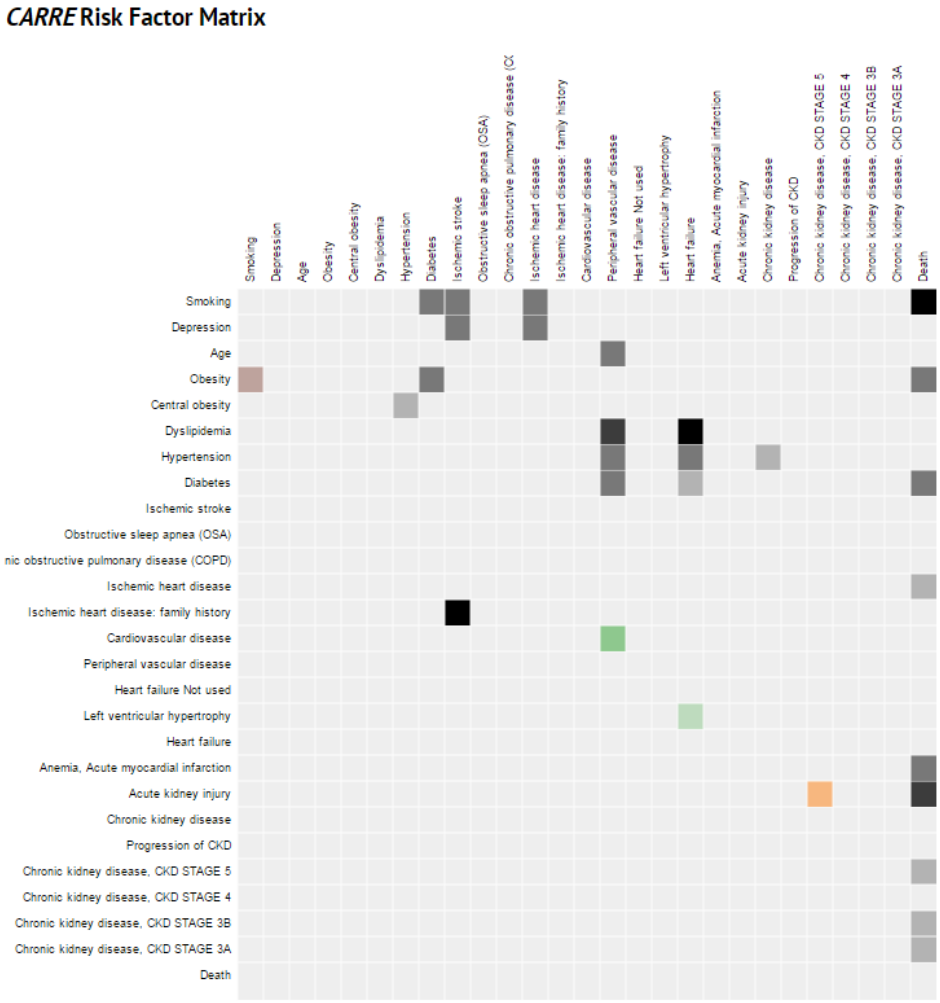


Figure 10. An example matrix view of sample risk factors

4.2.4 Timeline

Time-dependant data are ubiquitous in many application domains as, for example, in business, medicine, history, planning, or project management. In CARRE, most of data, such as PHR, sensor data are time dependant. Providing appropriate methods to facilitate the visualisation and analysis of time-varying data is a key issue in CARRE.

A timeline is a traditional method to visualise time-dependant data and events in a linear layout and is more suitable for visualising continuous variables which cover a relatively long period, such as health indicators and medical measurements. Activity events which are time dependent can also be shown in a timeline if a longer time scale is desired to view daily activity events and activities. In the current implementation, the timeline supports interactive visualisation of sensor data. There are five different visualisation styles including activity stack, 24-hour activity, activity cloud, activity bubbles and movement-place. Activity stack shows activities directly on the timeline in a form similar to stack bar charts. A 24-hour activity organises the activities on a daily basis for easier comparison of daily activity changes. The activity cloud uses concentric disks of different radius to represent the activities; activity bubbles use bubbles of different colour and radius. Movement-place shows the movement and place in the user's Moves data.

In addition to interactive time range selection and zooming, the timeline supports interactive filtering and automatic clustering of events when the number of events is too large for web-based applications. Figure 11 shows an example of daily activity events visualised in a timeline.

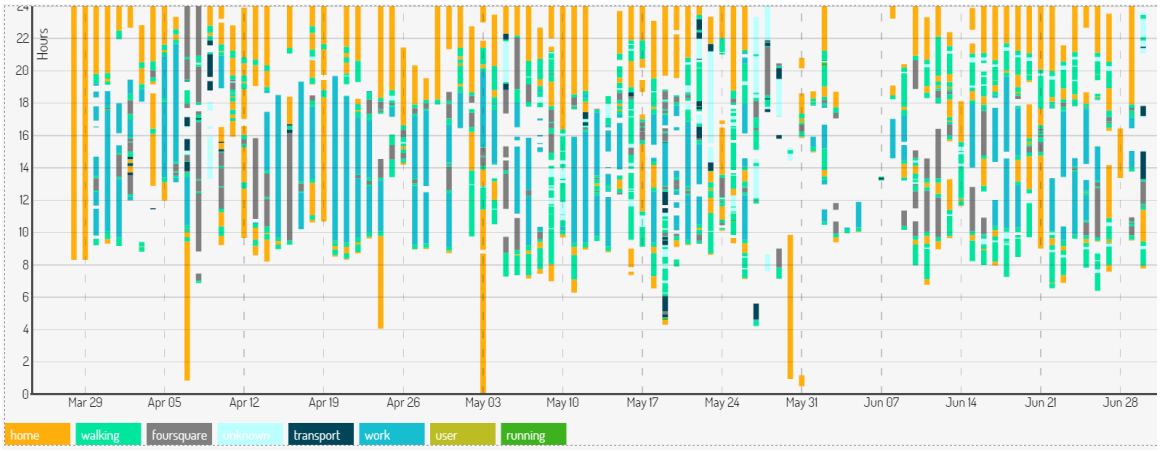


Figure 11. A timeline view of sensor data in a 24-hour style

4.2.5 Clockview

The standard technique for visualising time-varying data is linear layout. This technique works well to show the variations of the data variables with the time. However with linear layouts, it is difficult visualise and discover the intrinsic periodicity of time-varying data. In terms of periodicity the radial layout is more suitable to uncover the periodic patterns in the data.

For sensor data in CARRE and daily activities in particular, timeline provides visualisation over a relatively long period. Interactive timelines can provide zooming to smaller scales. However, the timeline may not be the best way for the user to understand and compare daily events. A fine-grained view of activities within one day is better visualised in a radial layout. A natural, real-life way of radial daily time representation is the clock. CARRE visual analytics uses a clock-like radial layout called clockview to visualise daily events. Movements and places from sensors such like *Moves* are visualised in the radial layout. Activity types are marked by icons and colours. When the user hovers the mouse over the icons more detailed information will be displayed, as shown in Figure 12.

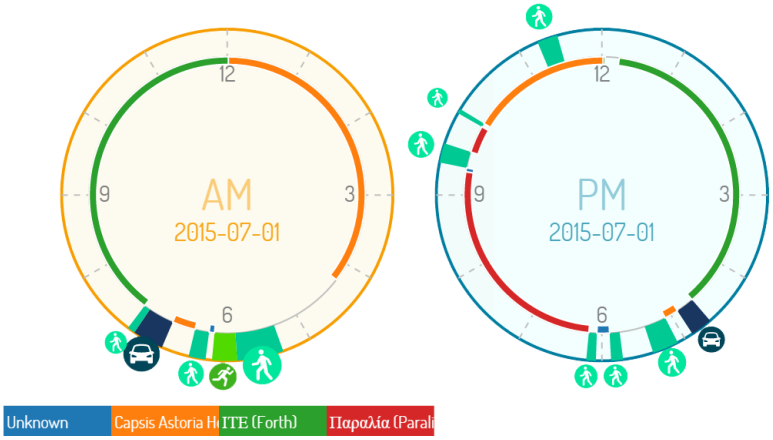


Figure 12. Clockview visualisation of daily activities

5. Mapping the high level use cases to the virtual patients

In this section, four use cases based on the virtual patients for visual analysis are designed and described. We will explain the visualisation functions by mapping them onto the four high-level conceptual use cases defined

in D2.1.The purpose of use cases is to select representative scenarios in CARRE visual analytics and demonstrate how visual analysis can help patients and medical experts to achieve their goals.

As described in section 2.3 we take three virtual patients from the eighteen virtual patient samples, i.e. Patient #2, Patient #5 and Patient #9 to explain the visualisation interfaces and functions that will be provided by CARRE visual analytics to support general patients and medical experts.

5.1. UC_Vis_04

The goal of use case UC_Vis_04 is to demonstrate how patients can use visual analytics to visualise and understand their disease progression interactively.

According to the risk associations summarised in D2.2, the risk associations shown in Figure 13 are the main factors that affect Patient #2. In the actual the visual analytics interface, patients should be able to view those risk associations in an interactive way and explorative way.

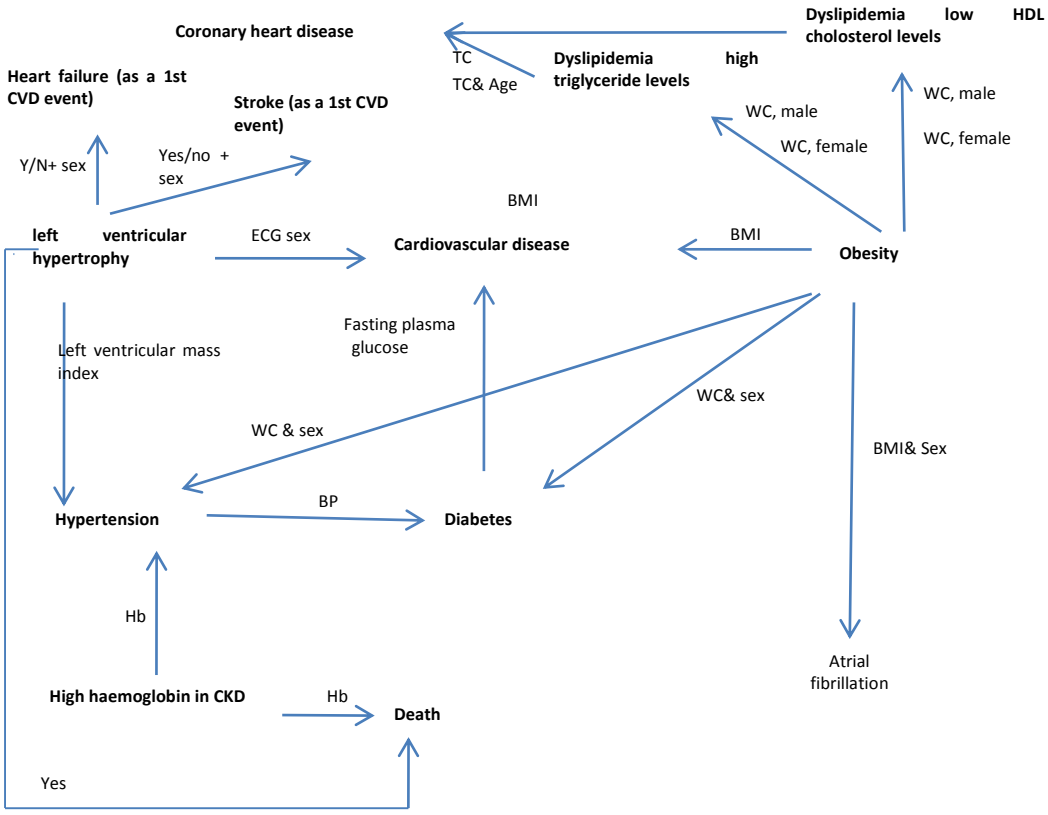


Figure 13. Risk associations of UC_Vis_04 as summarised in D2.2

Figure 14 is only an illustration of the risk associations related to patient #2. In the final demonstration, we will provide interactive interface using multiple dimensions of visualisation approaches, for example, the distance between risk association and the thickness of the link between the risk associations represent the level of associations. The interactive functions help patients, doctors and nurses to explore the possible disease progression.

5.2. UC_Vis_05

The goal of this use case UC_Vis_05 is to demonstrate how patients can use visual analytics to understand disease progression based on personal monitored sensor data.

UC_Vis_05 can be used as a complementation or support information for the disease progressions: what had been done which causes results shown in UC_Vis_04. In this aspect, the sensors that we used in CARRE project, which help monitor biomarkers (shown in Table x), such as blood pressures and glucose, provide detailed information about this patient. In addition, some activity tracking monitors, such as Fitbit, also may provide some additional life style information about this patient. In many cases, certain levels of activities are recommended by doctors as part of the disease self-management.

As shown in Figure 8 and Figure 14, the multiple timeline visualisation may provide information on the change of health indicators, such as the biomarker values, with changes of the life style. In addition, more information such as the life style and the disease progressions may be revealed for this patient by medical experts.

5.3. UC_Vis_06

The goal of use case UC_Vis_06 is to demonstrate how patients and medical experts can view and understand the changes in disease prospects interactively if they make changes to the current observables.

The changes may be related to life style, in particular, multiple factors of life style changes, including, activities, food intake, and medicine intake can all be monitored using sensors. These kinds of data are often too large and can often only make impact in a long run, such as the consequence of food intake. The functions provided by the visual interface allow users to aggregate the large dataset of the observations in many ways.

5.4. UC_Vis_07

The goal of use case UC_Vis_07 is to demonstrate how patients and doctors can understand the disease status by comparison of their personal state with current medical evidence.

This use case could be an addition to UC_Vis_06 to show the possible disease progression by change of the biomarkers based on the prediction of risk associations. This is only used for patients to explore some what-if scenarios, such as if they can reduce the value of biomarkers, they may largely reduce the possibility pf developing the comorbidity based on the current medical evidences. We anticipate using this feature with the educational materials to help patients in self-managing the diseases.

6. Data Visual Analysis

6.1. Risk Factor Visualisation

Risk factors themselves are network data, consequently they can be visualised as node-link diagrams as shown in Figure 9 or matrix as in Figure 10. As there are a large number of risk factors in the CARRE system, it is not reasonable, practical and necessary to visualise all the risk factors in the system. Filtering and dynamic loading is used to load and display only those risk factors that are related to the patient or selected by the user.

6.2. Sensor Data Visualisation

Sensor data is one very important data source in CARRE system. The fitness and the medical sensors generally provide numerical time series data while lifestyle sensors and apps also provide activity data and location data. In CARRE, the numerical sensor data, such as walking steps, blood pressure, glucose, are used

as evidence for risk analysis and decision support. For numerical time series, charts and timelines are used for visual analysis. User interactions are added for time range selection and sensor variable filtering.

Both risk factor visualisation and sensor data visualisation are used in disease progression visual analysis which is introduced in section 6.4.

6.3. PHR Data Visualisation

Similar to sensor data, most of PHR data are numerical time series. The difference is that the data sampling frequencies varies heavily from variables to variables according to variable types. Generally speaking the sampling rate of most of PHR variables are not as high as sensor data. Charts and timelines can both be used for visualisation and analysis of PHR data.

6.4. Disease Progression Visual Analysis

The purpose of disease progression visual analytics is to visualise related risk factors according to the patient's health and lifestyle status and to visualise the changes that may happen if the user changes the lifestyle or medical indicators.

Disease progression visual analytics is an integrated visual analysis of charts, timeline and graph. It is composed of a clear view of risk factors, user personal health records and activities (joint and separate view).

Different colour scheme, glyphs, and shapes are employed to compose an integrated visual analysis.

Figure 14 shows the implementation of disease progression visual analysis. The left column is line chart and bubble chart visualisations of sensor data and PHR data. The central part is an interactive node-link diagram visualisation of related risk elements and evidence and the right panels are for data selection and medical indicator adjusting.

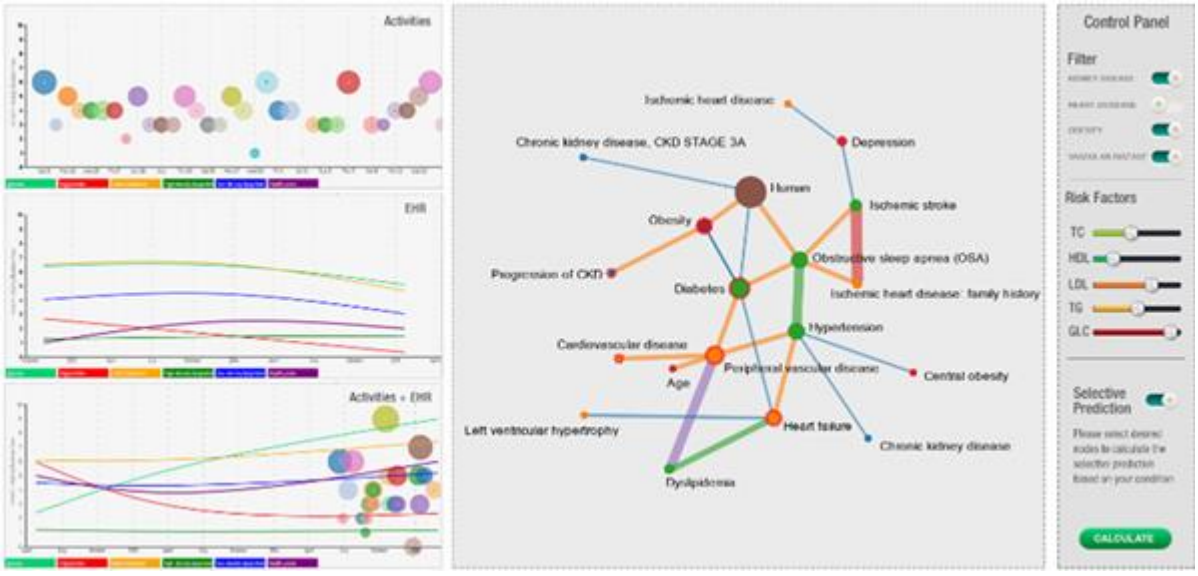


Figure 14. Disease Progression Visual Analysis

6.5. Decision Support Service Visual Analysis

Decision support service provides the patients and medical experts with tools to make decisions based on sensor data, PHR data and risk factor models. The visual analytics interface will be similar to disease

progression visual analysis. The difference is that due to the nature of decision support service, the calculation can hardly to be completed in real time, which means less user interactivity can be achieved.

7. Implementation

7.1. The Web Interface for Visual Analysis

The web-based visual analysis framework is developed in Java, Javascript and HTML and deployed on a Linux environment. The backend is based on Java programming language and Spring Framework[15] technology stack. Java runs on all major platforms include Windows, Linux and Mac OS, which makes module based on Java is generally more portable between different OSs, also JVM's proven high performance is crucial for our potential large user base. Spring Framework is the de-facto standard in enterprise Java programming, the developer team's high experience in Spring Framework makes it our pick on implement the project.

The frontend web-based UI is mainly based on Twitter Bootstrap, HTML, jQuery[16], Query plugins and AngularJS[17] . jQuery is used to facilitate javascript programming. The interactive visual analysis components are implemented in javascript and d3.js[18] which is a javascript based scalar vector graphics (SVG) library. Each component is placed in a DIV element in the component container and the container is managed automatically as tabs in the main user interface.

The sensor data, risk factor data and decision support data are all fetched from the OU CARRE server. The sensor data can be directly accessed via jQuery APIs while risk factor data and decision support data need to be accessed by SPARQL queries.

The frontend is a relatively separate Grunt project which uses Bower to manage the frontend JavaScript dependencies. The frontend source code is unit tested and built on a continuous integration manner. Twitter Bootstrap 3 is used to support both mobile and desktop browser, mobile first responsive design is applied for the web UI. AngularJS and jQuery JavaScript libraries are used to help shape the frontend logic, and interact with the REST service provided by backend. The combination of cutting-edge frontend technology stack does give us an enjoyable developing experience and a great dynamic user-friendly UI.

The project is hosted on Ubuntu 14.04.2 LTS VPS and is available at http://carre.ccgv.org.uk:8080/Carre, Apache is used to server static content while Tomcat 7 is reverse proxies to server the dynamic contents. A HAProxy server is configured to work as load balancer and Radis server is tested to be the cache server for scale to larger user groups.

7.2. The Code Matrix

This visual analytics web system uses several open source software, including D3.js for chart drawing, angularJS for the main framework of the web site, jQuery for front end javascript programming. We build up our own front end algorithms in javascript with the help of these libraries. The current implementation utilises Apache Maven for software project management and comprehension.

Code quality analysis has been conducted on the Javascript file at the stage. We use two tools jsComplexity[19] and jsmeter[20] for code metrics.

We check our codes from these aspects:

[15] http://www.springsource.org

[16] http://jQuery.com

[17] http://www.angularjs.org

[18] http://d3js.org/

[19] http://jscomplexity.org/

[20] http://research.microsoft.com/en-us/projects/jsmeter/

- LINES OF CODE (LOC)

  This can be either physical (a count of the actual lines in the file) or logical (a count of the imperative statements). The physical count is widely considered to be a less useful metric because it is easily subverted by collecting multiple statements on a single line of code. However it should be noted that the logical count can be similarly flawed, since the tersest expression of a solution is not necessarily the optimal one.

- CYCLOMATIC COMPLEXITY

  Defined by Thomas J. McCabe in 1976, this is a count of the number of cycles in the program flow control graph. Effectively the number of distinct paths through a block of code. Lower is better.

- CYCLOMATIC COMPLEXITY DENSITY

  Proposed as a modification to cyclomatic complexity by Geoffrey K. Gill and Chris F. Kemerer in 1991, this metric simply re-expresses it as a percentage of the logical lines of code. Lower is better.

- MAINTAINABILITY INDEX

  Designed in 1991 by Paul Oman and Jack Hagemeister at the University of Idaho, this metric is calculated at the whole program or module level from averages of the other 3 metrics, using the following formula:

  171 -

  (3.42 * ln(mean effort)) -

  (0.23 * ln(mean cyclomatic complexity)) -

  (16.2 * ln(mean logical LOC))

  Values are on a logarithmic scale ranging from negative infinity up to 171, with greater numbers indicating a higher level of maintainability. In their original paper, Oman and Hagemeister identified 65 as the threshold value below which a program should be considered difficult to maintain.

We describe our code matrix from below functions:

7.2.1 Dashboard

Moment.js

jsComplexity

RESULTS

Note: Floating point values have been rounded to the nearest integer.

- Logical LOC: 1816
- Mean parameter count: 262
- Cyclomatic complexity: 516
- Cyclomatic complexity density: 28%
- Maintainability index: 110

radialProgress.js

jsComplexity

RESULTS

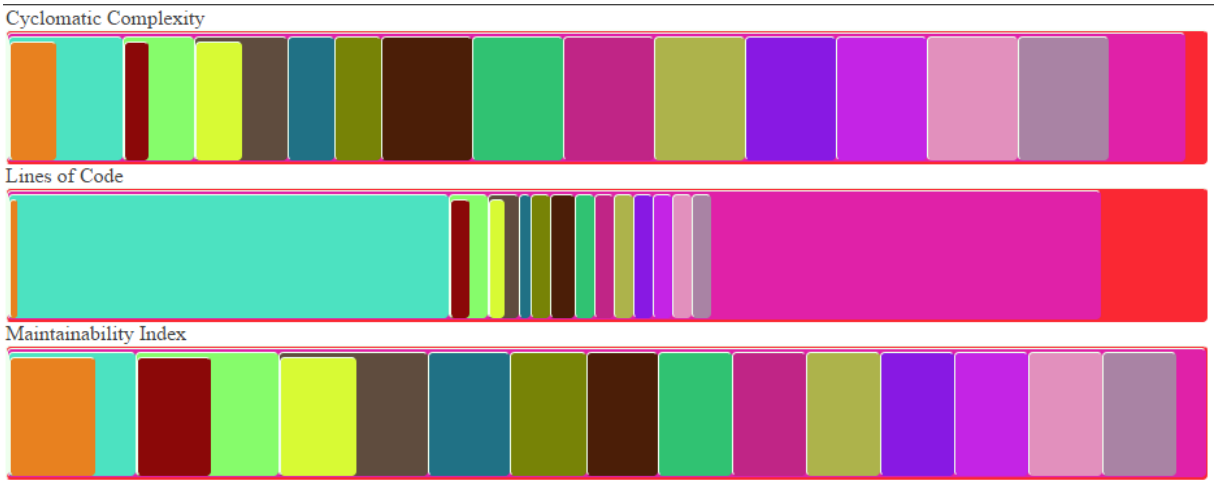
Note: Floating point values have been rounded to the nearest integer.

- Logical LOC: 133
- Mean parameter count: 19
- Cyclomatic complexity: 11

- Cyclomatic complexity density: 8%
- Maintainability index: 115

Jsmeter

Line	Function	Statements	Lines	Comment Lines	Comment%	Branches	Depth	Cyclomatic Complexity	Halstead Volume	Halstead Potential	Program Level	MI
1	[[code]]	197	274	10	3.65%	0	0	1	0	0	0	
26	radialProgress	195	249	10	4.02%	1	1	4	1100	8.00	0.00727	66.647
62	radialProgress.(Anonymous1)	63	103	6	5.83%	1	1	3	3050	8.00	0.00262	73.729
132	radialProgress.(Anonymous1).(Anonymous1)	2	1	0	0%	0	0	2	61.3	8.00	0.131	156.46
177	radialProgress.labelTween	8	8	2	25%	0	0	2	48.1	8.00	0.166	125.59
181	radialProgress.labelTween.(Anonymous1)	2	4	2	50%	0	0	1	89.2	8.00	0.0897	134.93
189	radialProgress.arcTween	7	6	0	0%	0	0	2	28.7	8.00	0.279	130.03
192	radialProgress.arcTween.(Anonymous1)	2	3	0	0%	0	0	2	46.6	8.00	0.172	139.60
201	radialProgress.(Anonymous2)	1	2	0	0%	0	0	2	26.6	8.00	0.301	148.09
218	radialProgress.component.render	2	4	0	0%	0	0	2	18.0	4.75	0.264	138.20
224	radialProgress.component.value	8	5	0	0%	1	1	4	75.1	8.00	0.107	129.24
232	radialProgress.component.margin	7	4	0	0%	1	1	4	45.7	8.00	0.175	134.55
238	radialProgress.component.diameter	7	4	0	0%	1	1	4	45.7	8.00	0.175	134.55
244	radialProgress.component.minValue	7	4	0	0%	1	1	4	45.7	8.00	0.175	134.55
250	radialProgress.component.maxValue	7	4	0	0%	1	1	4	45.7	8.00	0.175	134.55
256	radialProgress.component.label	7	4	0	0%	1	1	4	45.7	8.00	0.175	134.55
262	radialProgress.component._duration	7	4	0	0%	1	1	4	45.7	8.00	0.175	134.55
268	radialProgress.component.onClick	7	4	0	0%	1	1	4	45.7	8.00	0.175	134.55

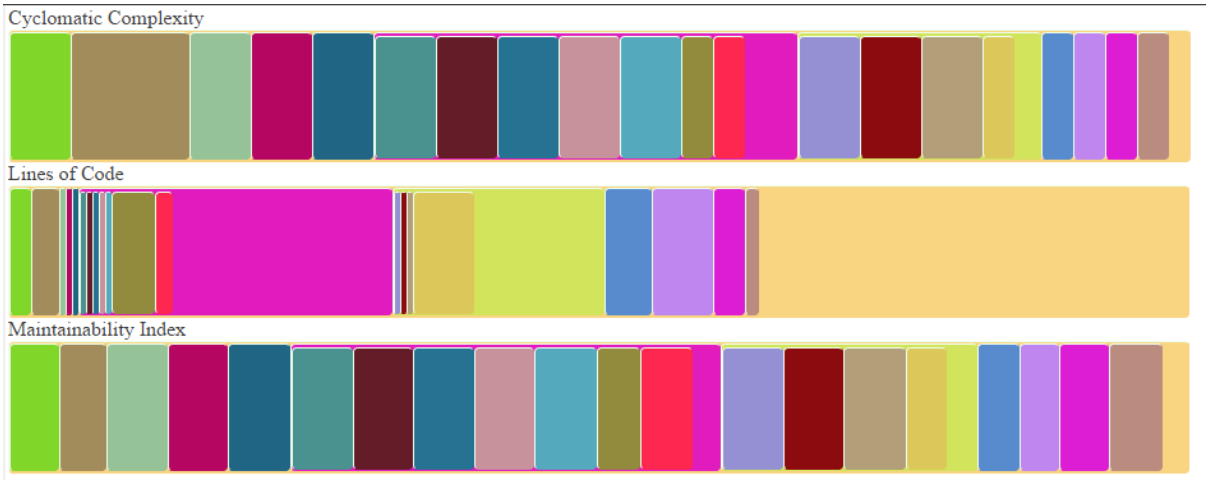


7.2.2 Diary

Cal.js

Jsmeter

Line	Function	Statements	Lines	Comment Lines	Comment%	Branches	Depth	Cyclomatic Complexity	Halstead Volume	Halstead Potential	Program Level	MI
1	[[code]]	217	310	37	11.94%	0	0	1	1600	4.75	0.00297	89.236
31	numberOfDays	5	5	0	0%	0	0	2	64.0	11.6	0.181	130.24
54	getMonthFromString	6	7	0	0%	1	1	4	108	8.00	0.0741	122.54
79	(Anonymous1)	2	1	0	0%	0	0	2	12.0	8.00	0.667	162.04
87	(Anonymous2)	2	1	0	0%	0	0	2	27.7	8.00	0.289	159.18
89	(Anonymous3)	2	1	0	0%	0	0	2	5.17	8.00	1.55	164.92
96	drawDays	57	81	12	14.81%	0	0	2	1220	11.6	0.00951	86.925
114	drawDays. (Anonymous1)	2	1	0	0%	0	0	2	12.0	8.00	0.667	162.04
118	drawDays. (Anonymous2)	2	1	0	0%	0	0	2	27.7	8.00	0.289	159.18
127	drawDays. (Anonymous3)	2	1	0	0%	0	0	2	12.0	8.00	0.667	162.04
148	drawDays. (Anonymous4)	2	1	0	0%	0	0	2	27.7	8.00	0.289	159.18
150	drawDays. (Anonymous5)	2	1	0	0%	0	0	2	5.17	8.00	1.55	164.92
160	drawDays. (Anonymous6)	9	11	0	0%	0	0	1	336	8.00	0.0238	112.03
173	drawDays. (Anonymous7)	0	4	1	25%	0	0	1	26.6	8.00	0.301	138.08
185	drawMonths	46	55	5	9.09%	0	0	1	587	8.00	0.0136	88.999
200	drawMonths. (Anonymous1)	2	1	0	0%	0	0	2	12.0	11.6	0.967	162.04
218	drawMonths. (Anonymous2)	2	1	0	0%	0	0	2	27.7	8.00	0.289	159.18
220	drawMonths. (Anonymous3)	2	1	0	0%	0	0	2	5.17	8.00	1.55	164.92
224	drawMonths. (Anonymous4)	18	16	0	0%	0	0	1	533	8.00	0.0150	104.38
257	drawTimeAxis	12	12	0	0%	0	0	1	295	11.6	0.0393	111.07
278	(Anonymous4)	17	16	0	0%	0	0	1	572	8.00	0.0140	104.14
297	mouseOn	2	8	5	62.5%	0	0	1	39.4	11.6	0.294	129.47
308	MouseOut	2	3	1	33.33%	0	0	1	39.4	4.75	0.121	141.40



7.2.3 Riskview.js

jsComplexity

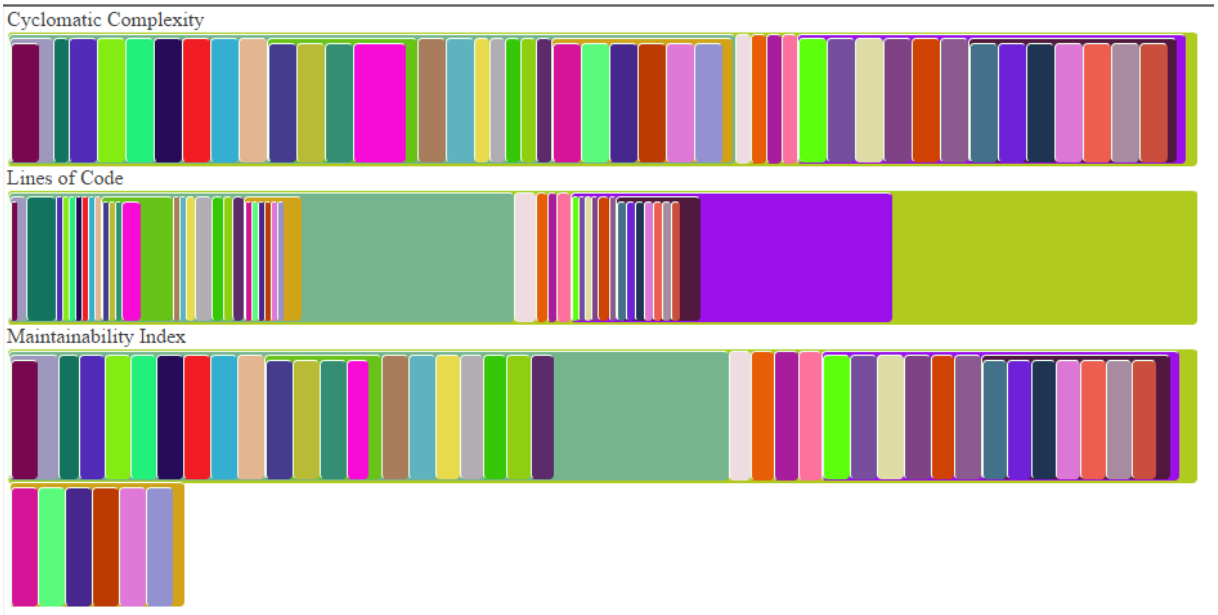
RESULTS

Note: Floating point values have been rounded to the nearest integer.

- Logical LOC: 125
- Mean parameter count: 63
- Cyclomatic complexity: 2
- Cyclomatic complexity density: 2%
- Maintainability index: 138

Jsmeter

Line	Function	Statements	Lines	Comment Lines	Comment%	Branches	Depth	Cyclomatic Complexity	Halstead Volume	Halstead Potential	Program Level	MI
1	[[code]]	265	402	90	22.39%	0	0	1	1150	4.75	0.00413	138.62
24	(Anonymous1)	149	162	13	8.02%	0	0	1	1390	8.00	0.00576	76.470
30	(Anonymous1).(Anonymous1)	8	4	0	0%	0	0	1	83.4	11.6	0.139	133.18
33	(Anonymous1).(Anonymous1).(Anonymous1)	4	1	0	0%	0	0	2	15.8	8.00	0.506	161.10
37	(Anonymous1).(Anonymous2)	2	10	5	50%	0	0	1	102	8.00	0.0784	122.60
51	(Anonymous1).orders.(Anonymous3)	3	1	0	0%	0	0	2	53.3	11.6	0.218	156.94
52	(Anonymous1).orders.(Anonymous4)	2	1	0	0%	0	0	2	43.0	11.6	0.270	157.68
54	(Anonymous1).orders.(Anonymous5)	2	1	0	0%	0	0	2	43.0	11.6	0.270	157.68
76	(Anonymous1).row.(Anonymous6)	2	1	0	0%	0	0	2	27.7	11.6	0.419	159.18
87	(Anonymous1).(Anonymous7)	2	1	0	0%	0	0	2	19.9	11.6	0.583	160.31
93	(Anonymous1).column.(Anonymous8)	2	1	0	0%	0	0	2	27.7	11.6	0.419	159.18
103	(Anonymous1).(Anonymous9)	2	1	0	0%	0	0	2	19.9	11.6	0.583	160.31
105	(Anonymous1).row	21	22	2	9.09%	0	0	1	285	8.00	0.0281	103.34
107	(Anonymous1).row.cell.(Anonymous1)	2	1	0	0%	0	0	2	12.0	8.00	0.667	162.04
110	(Anonymous1).row.cell.(Anonymous2)	2	1	0	0%	0	0	2	19.0	8.00	0.421	160.47
113	(Anonymous1).row.cell.(Anonymous3)	2	1	0	0%	0	0	2	19.0	8.00	0.421	160.47
114	(Anonymous1).row.cell.(Anonymous4)	4	6	0	0%	1	0	4	148	8.00	0.0541	123.96
130	(Anonymous1).(Anonymous10)	2	1	0	0%	0	0	2	19.9	11.6	0.583	160.31
131	(Anonymous1).(Anonymous11)	2	1	0	0%	0	0	2	19.9	11.6	0.583	160.31
135	(Anonymous1).mouseout	2	2	0	0%	0	0	1	27.7	4.75	0.171	148.18
141	(Anonymous1).tooltipOn	3	5	2	40%	0	0	1	70.9	11.6	0.164	132.10
150	(Anonymous1).tooltipMove	3	3	0	0%	0	0	1	106	11.6	0.109	137.02



8. Conclusion

Visual analytics is an integral approach combining visualisation, human factors, and data analysis. This process combines automatic and visual analysis methods with a tight coupling through human interaction in order to gain knowledge from data.

The target of Work Package 5 in CARRE project is to provide effective data management and visual analytics tools to empower patients and medical experts to access, view, understand and analyse patients' health status and possible disease progressions.

In this deliverable report of D5.1, the design and implementation of task 5.1 "Interactive Visual Interface" is presented. Three virtual patients are selected for visual analytics use case demonstration. Visualisation components such as charts, timeline are used for visual analysis of sensor data and PHR data. Node-link diagram and matrix are used for visual analysis of risk factor data and decision support data.

A web-based CARRE visual analytics web system is provided as the hosting system of the visual analysis components. A dashboard is designed for an overview of the user's health status and functional visual analytics components are organised in visual analysis containers for different visual analysis tasks.

The design and implementation meets the demands of visual analytics of sensor data, PHR data, risk analysis, disease progression analysis and decision support analysis for patients and medical experts. It also provides a solid foundation for more detailed implementation in D5.3: Advanced visual analytics module.

Annex 1
Virtual Patients Descriptions

Stefanos Roumeliotis (DUTH), Kostantinos Zagkas (DUTH)

Patient #1

65years old male with CKD stage 4, dyslipidemia, hypertension and heart failure, and atrial fibrillation.

Demographics and biometrics	
sex	male
age	65
height	174
weight	88
waist circumference	105
Waist to height ratio	0.6
Waist to hip ratio	
Body Fat percentage	22
Family history of Ischemic heart disease:	no
Self history of Ischemic heart disease:	no

Observables	
Acute kidney disease diagnosis	no
Acute myocardial infarction diagnosis	no
AHI (Apnoea– hypopnoea index)	no
Atrial fibrillation diagnosis	yes
β-blockers administration	yes
Blood Glucose: 2h glucose after oral glucose tolerance test	92
Blood Glucose: fasting	83
Blood pressure	167/92
Chronic kidney disease diagnosis	yes
Chronic obstructive pulmonary disease diagnosis	no
Contrast agents: coronary angiography administration	no
Diuretics administration	yes
eGFR	27
Fasting Plasma Glucose Levels	83
HbA1c	6.0
Haemoglobin (Hb)	11.0
HDL-C (High-density lipoprotein cholesterol)	69
Heart failure diagnosis	yes

Hypertension Diagnosis	yes
Ischemic heart disease self history	no
Ischemic stroke diagnosis	no
LDL-C (Low-density lipoprotein cholesterol)	130
Left ventricular hypertrophy diagnosis	no
Non-HDL-C	
Obstructive sleep apnea diagnosis	no
Physical activity	Rare-mild
Renin-angiotensin system dual blockade administration	no
Serum creatinine level	2.8
Serum potassium	8.5
Smoking intensity	no
Smoking status	no
Statin administration	yes
Total cholesterol	220
Triglycerides (TG)	180
Uric acid serum concentration	6.7

Patient #2

70 year old obese female diabetic (Type II) with hypertension, dyslipidemia, CKD stage 3B and left ventricular hypertrophy

Demographics and biometrics	
sex	female
age	70
height	160
weight	94
waist circumference	125
Waist to height ratio	0.78
Waist to hip ratio	
Body Fat percentage	37
Family history of Ischemic heart disease:	No
Self history of Ischemic heart disease:	no

Observables	
Acute kidney disease diagnosis	no
Acute myocardial infarction diagnosis	no
AHI (Apnoea– hypopnoea index)	no
Atrial fibrillation diagnosis	no
β-blockers administration	no
Blood Glucose: 2h glucose after oral glucose tolerance test	198
Blood Glucose: fasting	224
Blood pressure	160/90
Chronic kidney disease diagnosis	yes
Chronic obstructive pulmonary disease diagnosis	no
Contrast agents: coronary angiography administration	no
Diuretics administration	yes
eGFR	35
Fasting Plasma Glucose Levels (mg/dl)	200
HbA1c	7.8
Haemoglobin (Hb)	10.9
HDL-C (High-density lipoprotein cholesterol)	62
Heart failure diagnosis	no
Hypertension Diagnosis	yes
Ischemic heart disease self history	no
Ischemic stroke diagnosis	no

LDL-C (Low-density lipoprotein cholesterol)	120
Non-HDL-C	
Obstructive sleep apnea diagnosis	no
Physical activity	no
Renin-angiotensin system dual blockade administration	no
Serum creatinine level	2.0
Serum potassium	8.8
Smoking intensity	no
Smoking status	no
Statin administration	yes
Total cholesterol	215
Triglycerides (TG)	200
Uric acid serum concentration	7.0
Left ventricular hypertrophy diagnosis	yes

Patient #3

78 years old male end-stage renal disease under hemodialysis thrice weekly. Diabetic, with dyslipidemia and established heart failure

Demographics and biometrics	
sex	male
age	78
height	172
weight	80
waist circumference	100
Waist to height ratio	0.58
Waist to hip ratio	
Body Fat percentage	21
Family history of Ischemic heart disease:	yes
Self history of Ischemic heart disease:	no

Observables	
Acute kidney disease diagnosis	no
Acute myocardial infarction diagnosis	no
AHI (Apnoea– hypopnoea index)	no
Atrial fibrillation diagnosis	no
β-blockers administration	yes
Blood Glucose: 2h glucose after oral glucose tolerance test	92
Blood Glucose: fasting	72
Blood pressure	120/70
Chronic kidney disease diagnosis	yes
Chronic obstructive pulmonary disease diagnosis	no
Contrast agents: coronary angiography administration	no
Diuretics administration	no
eGFR	7
Fasting Plasma Glucose Levels	72
HbA1c	6.1
Haemoglobin (Hb)	9.2
HDL-C (High-density lipoprotein cholesterol)	52
Heart failure diagnosis	yes
Hypertension Diagnosis	no
Ischemic heart disease self history	no
Ischemic stroke diagnosis	no

LDL-C (Low-density lipoprotein cholesterol)	100
Left ventricular hypertrophy diagnosis	yes
Non-HDL-C	
Obstructive sleep apnea diagnosis	no
Physical activity	Yes mild(3/weekly 40 minutes walk)
Renin-angiotensin system dual blockade administration	no
Serum creatinine level	7.2
Serum potassium	7.8
Smoking intensity	no
Smoking status	no
Statin administration	yes
Total cholesterol	189
Triglycerides (TG)	130
Uric acid serum concentration	6.8

Patient #4

82 year old female with end stage renal disease under hemodialysis. Smoker, with history of MI, Stroke, Atrial fibrillation

Demographics and biometrics	
sex	female
age	82
height	162
weight	60
waist circumference	81
Waist to height ratio	0.5
Waist to hip ratio	
Body Fat percentage	26
Family history of Ischemic heart disease:	yes
Self history of Ischemic heart disease:	yes

Observables	
Acute kidney disease diagnosis	no
Acute myocardial infarction diagnosis	no
AHI (Apnoea– hypopnoea index)	no
Atrial fibrillation diagnosis	yes
β-blockers administration	yes
Blood Glucose: 2h glucose after oral glucose tolerance test	90
Blood Glucose: fasting	80
Blood pressure	120/75
Chronic kidney disease diagnosis	yes
Chronic obstructive pulmonary disease diagnosis	no
Contrast agents: coronary angiography administration	no
Diuretics administration	no
eGFR	9
Fasting Plasma Glucose Levels	80
HbA1c	6.2
Haemoglobin (Hb)	9.0
HDL-C (High-density lipoprotein cholesterol)	60
Heart failure diagnosis	yes
Hypertension Diagnosis	no
Ischemic heart disease self history	yes
Ischemic stroke diagnosis	yes

LDL-C (Low-density lipoprotein cholesterol)	95
Left ventricular hypertrophy diagnosis	yes
Non-HDL-C	
Obstructive sleep apnea diagnosis	no
Physical activity	Yes mild(occasional walks 4 times per week)
Renin-angiotensin system dual blockade administration	no
Serum creatinine level	7.0
Serum potassium	8.2
Smoking intensity	yes
Smoking status	2packs per day
Statin administration	no
Total cholesterol	146
Triglycerides (TG)	91
Uric acid serum concentration	5.9

Patient #5

34 year old male with Type 1 diabetes, obese, smoker with history of sleep apnoea

Demographics and biometrics	
sex	male
age	34
height	175
weight	125
waist circumference	120
Waist to height ratio	0.93
Waist to hip ratio	
Body Fat percentage	32
Family history of Ischemic heart disease	no
Self history of Ischemic heart disease:	no

Observables	
Acute kidney disease diagnosis	no
Acute myocardial infarction diagnosis	no
AHI (Apnoea– hypopnoea index)	
Atrial fibrillation diagnosis	no
β-blockers administration	no
Blood Glucose: 2h glucose after oral glucose tolerance test	203
Blood Glucose: fasting	150
Blood pressure	125/70
Chronic kidney disease diagnosis	no
Chronic obstructive pulmonary disease diagnosis	no
Contrast agents: coronary angiography administration	no
Diuretics administration	no
eGFR	81
Fasting Plasma Glucose Levels	150
HbA1c	7.2
Haemoglobin (Hb)	12.5
HDL-C (High-density lipoprotein cholesterol)	52
Heart failure diagnosis	no
Hypertension Diagnosis	no
Ischemic heart disease self history	no
Ischemic stroke diagnosis	no
LDL-C (Low-density lipoprotein cholesterol)	95

Left ventricular hypertrophy diagnosis	no
Non-HDL-C	
Obstructive sleep apnea diagnosis	yes
Physical activity	no
Renin-angiotensin system dual blockade administration	no
Serum creatinine level	1.0
Serum potassium	8,7
Smoking intensity	3packs per day
Smoking status	yes
Statin administration	no
Total cholesterol	123
Triglycerides (TG)	87
Uric acid serum concentration	6.5

Patient #6

52 year old male, overweight, smoker with history of hypertension

Demographics and biometrics	
sex	Male
age	52
height	170
weight	91
waist circumference	92
Waist to height ratio	0.54
Waist to hip ratio	
Body Fat percentage	22
Family history of Ischemic heart disease:	no
Self history of Ischemic heart disease:	no

Observables	
Acute kidney disease diagnosis	no
Acute myocardial infarction diagnosis	no
AHI (Apnoea– hypopnoea index)	no
Atrial fibrillation diagnosis	no
β-blockers administration	no
Blood Glucose: 2h glucose after oral glucose tolerance test	91
Blood Glucose: fasting	67
Blood pressure	154/95
Chronic kidney disease diagnosis	no
Chronic obstructive pulmonary disease diagnosis	no
Contrast agents: coronary angiography administration	no
Diuretics administration	no
eGFR	105
Fasting Plasma Glucose Levels	70
HbA1c	6.2
Haemoglobin (Hb)	13.5
HDL-C (High-density lipoprotein cholesterol)	65
Heart failure diagnosis	no
Hypertension Diagnosis	yes
Ischemic heart disease self history	no
Ischemic stroke diagnosis	no
LDL-C (Low-density lipoprotein cholesterol)	95

Left ventricular hypertrophy diagnosis	no
Non-HDL-C	no
Obstructive sleep apnea diagnosis	no
Physical activity	no
Renin-angiotensin system dual blockade administration	no
Serum creatinine level	0.9
Serum potassium	8.5
Smoking intensity	1,5 pack per day
Smoking status	yes
Statin administration	yes
Total cholesterol	198
Triglycerides (TG)	123
Uric acid serum concentration	6.8

Patient #7

45 year old male , with Type 1 diabetes and hypertension with family history of heart failure

Demographics and biometrics	
sex	male
age	45
height	162
weight	54
waist circumference	80
Waist to height ratio	0.5
Waist to hip ratio	
Body Fat percentage	28
Family history of Ischemic heart disease:	yes
Self history of Ischemic heart disease:	no

Observables	
Acute kidney disease diagnosis	no
Acute myocardial infarction diagnosis	no
AHI (Apnoea– hypopnoea index)	no
Atrial fibrillation diagnosis	no
β-blockers administration	no
Blood Glucose: 2h glucose after oral glucose tolerance test	190
Blood Glucose: fasting	160
Blood pressure	160/78
Chronic kidney disease diagnosis	no
Chronic obstructive pulmonary disease diagnosis	no
Contrast agents: coronary angiography administration	no
Diuretics administration	yes
eGFR	98
Fasting Plasma Glucose Levels	160
HbA1c	7.6
Haemoglobin (Hb)	11.9
HDL-C (High-density lipoprotein cholesterol)	65
Heart failure diagnosis	no
Hypertension Diagnosis	yes
Ischemic heart disease self history	no
Ischemic stroke diagnosis	no
LDL-C (Low-density lipoprotein cholesterol)	87

Left ventricular hypertrophy diagnosis	no
Non-HDL-C	
Obstructive sleep apnea diagnosis	no
Physical activity	no
Renin-angiotensin system dual blockade administration	no
Serum creatinine level	1.0
Serum potassium	8.6
Smoking intensity	no
Smoking status	no
Statin administration	no
Total cholesterol	134
Triglycerides (TG)	97
Uric acid serum concentration	6.7

Patient #8

30 year old male smoker , obese with sleep apnea and without any other medical history

Demographics and biometrics	
sex	male
age	30
height	180
weight	132
waist circumference	140
Waist to height ratio	0.8
Waist to hip ratio	
Body Fat percentage	35
Family history of Ischemic heart disease:	no
Self history of Ischemic heart disease:	no

Observables	
Acute kidney disease diagnosis	no
Acute myocardial infarction diagnosis	no
AHI (Apnoea– hypopnoea index)	no
Atrial fibrillation diagnosis	no
β-blockers administration	no
Blood Glucose: 2h glucose after oral glucose tolerance test	100
Blood Glucose: fasting	76
Blood pressure	140/90
Chronic kidney disease diagnosis	no
Chronic obstructive pulmonary disease diagnosis	no
Contrast agents: coronary angiography administration	no
Diuretics administration	no
eGFR	120
Fasting Plasma Glucose Levels	78
HbA1c	6.3
Haemoglobin (Hb)	13.6
HDL-C (High-density lipoprotein cholesterol)	65
Heart failure diagnosis	no
Hypertension Diagnosis	no
Ischemic heart disease self history	no
Ischemic stroke diagnosis	no
LDL-C (Low-density lipoprotein cholesterol)	89

Left ventricular hypertrophy diagnosis	no
Non-HDL-C	no
Obstructive sleep apnea diagnosis	yes
Physical activity	no
Renin-angiotensin system dual blockade administration	no
Serum creatinine level	0.8
Serum potassium	8.9
Smoking intensity	yes
Smoking status	2,5 pack per year
Statin administration	no
Total cholesterol	125
Triglycerides (TG)	107
Uric acid serum concentration	7.1

Patient #9

74 year old male with CHD, congestive heart failure, CKD and type II diabetes

Demographics and biometrics	
sex	male
age	74
height	169
weight	76
waist circumference	117
Waist to height ratio	0.69
Waist to hip ratio	
Body Fat percentage	22
Family history of Ischemic heart disease:	yes
Self history of Ischemic heart disease:	yes

Observables	
Acute kidney disease diagnosis	no
Acute myocardial infarction diagnosis	no
AHI (Apnoea– hypopnoea index)	no
Atrial fibrillation diagnosis	yes
β-blockers administration	yes
Blood Glucose: 2h glucose after oral glucose tolerance test	220
Blood Glucose: fasting	135
Blood pressure	110/75
Chronic kidney disease diagnosis	yes
Chronic obstructive pulmonary disease diagnosis	no
Contrast agents: coronary angiography administration	no
Diuretics administration	yes
eGFR	29
Fasting Plasma Glucose Levels	130
HbA1c	7.7
Haemoglobin (Hb)	11.2
HDL-C (High-density lipoprotein cholesterol)	32
Heart failure diagnosis	yes
Hypertension Diagnosis	no
Ischemic heart disease self history	yes
Ischemic stroke diagnosis	no
LDL-C (Low-density lipoprotein cholesterol)	118

Left ventricular hypertrophy diagnosis	no
Non-HDL-C	
Obstructive sleep apnea diagnosis	no
Physical activity	no
Renin-angiotensin system dual blockade administration	yes
Serum creatinine level	2.4
Serum potassium	4.1
Smoking intensity	
Smoking status	no
Statin administration	yes
Total cholesterol	190
Triglycerides (TG)	200
Uric acid serum concentration	8.0

Patient #10

69 year old male with dyslipidaimia, dilated cardiomyopathy, heart failure NYHA stage III and type II diabetes

Demographics and biometrics	
sex	male
age	69
height	160
weight	71
waist circumference	100
Waist to height ratio	0.62
Waist to hip ratio	
Body Fat percentage	23
Family history of Ischemic heart disease:	no
Self history of Ischemic heart disease:	no

Observables	
Acute kidney disease diagnosis	no
Acute myocardial infarction diagnosis	no
AHI (Apnoea– hypopnoea index)	no
Atrial fibrillation diagnosis	yes
β-blockers administration	yes
Blood Glucose: 2h glucose after oral glucose tolerance test	242
Blood Glucose: fasting	140
Blood pressure	90/60
Chronic kidney disease diagnosis	no
Chronic obstructive pulmonary disease diagnosis	no
Contrast agents: coronary angiography administration	no
Diuretics administration	yes
eGFR	77.8
Fasting Plasma Glucose Levels	110
HbA1c	8.2
Haemoglobin (Hb)	10.2
HDL-C (High-density lipoprotein cholesterol)	33
Heart failure diagnosis	yes
Hypertension Diagnosis	no
Ischemic heart disease self history	no
Ischemic stroke diagnosis	no
LDL-C (Low-density lipoprotein cholesterol)	100

Left ventricular hypertrophy diagnosis	no
Non-HDL-C	
Obstructive sleep apnea diagnosis	no
Physical activity	no
Renin-angiotensin system dual blockade administration	yes
Serum creatinine level	0.9
Serum potassium	3,9
Smoking intensity	
Smoking status	no
Statin administration	yes
Total cholesterol	163
Triglycerides (TG)	100
Uric acid serum concentration	7.6

Patient #11

61 year old, female, obese with hypertension, left ventricular hypertrophy, diastolic dysfunction,sleep apnea syndrome.

Demographics and biometrics	
sex	female
age	61
height	170
weight	135
waist circumference	145
Waist to height ratio	0.85
Waist to hip ratio	
Body Fat percentage	32
Family history of Ischemic heart disease:	no
Self history of Ischemic heart disease:	no

Observables	
Acute kidney disease diagnosis	no
Acute myocardial infarction diagnosis	no
AHI (Apnoea– hypopnoea index)	no
Atrial fibrillation diagnosis	no
β-blockers administration	yes
Blood Glucose: 2h glucose after oral glucose tolerance test	110
Blood Glucose: fasting	92
Blood pressure	170/95
Chronic kidney disease diagnosis	no
Chronic obstructive pulmonary disease diagnosis	no
Contrast agents: coronary angiography administration	no
Diuretics administration	yes
eGFR	140
Fasting Plasma Glucose Levels	95
HbA1c	6.5
Haemoglobin (Hb)	13
HDL-C (High-density lipoprotein cholesterol)	45
Heart failure diagnosis	no
Hypertension Diagnosis	yes
Ischemic heart disease self history	no
Ischemic stroke diagnosis	yes

LDL-C (Low-density lipoprotein cholesterol)	115
Left ventricular hypertrophy diagnosis	yes
Non-HDL-C	
Obstructive sleep apnea diagnosis	yes
Physical activity	no
Renin-angiotensin system dual blockade administration	no
Serum creatinine level	0.9
Serum potassium	4
Smoking intensity	
Smoking status	no
Statin administration	yes
Total cholesterol	180
Triglycerides (TG)	100
Uric acid serum concentration	5.0

Patient #12

77 year old female, pulmonary hypertension, mitral and tricuspidal rigurgitation, heart failure, CKD, diabetes type II.

Demographics and biometrics	
sex	female
age	77
height	155
weight	80
waist circumference	100
Waist to height ratio	0,64
Waist to hip ratio	
Body Fat percentage	21
Family history of Ischemic heart disease:	no
Self history of Ischemic heart disease:	no

Observables	
Acute kidney disease diagnosis	no
Acute myocardial infarction diagnosis	no
AHI (Apnoea– hypopnoea index)	no
Atrial fibrillation diagnosis	yes
β-blockers administration	yes
Blood Glucose: 2h glucose after oral glucose tolerance test	195
Blood Glucose: fasting	129
Blood pressure	130/80
Chronic kidney disease diagnosis	yes
Chronic obstructive pulmonary disease diagnosis	no
Contrast agents: coronary angiography administration	no
Diuretics administration	yes
eGFR	42
Fasting Plasma Glucose Levels	130
HbA1c	8,8
Haemoglobin (Hb)	9.4
HDL-C (High-density lipoprotein cholesterol)	30
Heart failure diagnosis	yes
Hypertension Diagnosis	no
Ischemic heart disease self history	no
Ischemic stroke diagnosis	yes

LDL-C (Low-density lipoprotein cholesterol)	95
Left ventricular hypertrophy diagnosis	no
Non-HDL-C	
Obstructive sleep apnea diagnosis	no
Physical activity	no
Renin-angiotensin system dual blockade administration	yes
Serum creatinine level	1.4
Serum potassium	3,5
Smoking intensity	
Smoking status	no
Statin administration	no
Total cholesterol	150
Triglycerides (TG)	50
Uric acid serum concentration	7.9

Patient #13

49 year old male, overweight, smoker, coronary heart disease, percutaneous coronary intervention 1 year ago.

Demographics and biometrics	
sex	male
age	49
height	176
weight	88
waist circumference	125
Waist to height ratio	0,71
Waist to hip ratio	
Body Fat percentage	24
Family history of Ischemic heart disease:	yes
Self history of Ischemic heart disease:	no

Observables	
Acute kidney disease diagnosis	no
Acute myocardial infarction diagnosis	no
AHI (Apnoea– hypopnoea index)	no
Atrial fibrillation diagnosis	no
β-blockers administration	yes
Blood Glucose: 2h glucose after oral glucose tolerance test	120
Blood Glucose: fasting	98
Blood pressure	127/78
Chronic kidney disease diagnosis	no
Chronic obstructive pulmonary disease diagnosis	no
Contrast agents: coronary angiography administration	no
Diuretics administration	no
eGFR	139
Fasting Plasma Glucose Levels	100
HbA1c	6.5
Haemoglobin (Hb)	12.9
HDL-C (High-density lipoprotein cholesterol)	41
Heart failure diagnosis	no
Hypertension Diagnosis	no
Ischemic heart disease self history	no
Ischemic stroke diagnosis	no
LDL-C (Low-density lipoprotein cholesterol)	102

Left ventricular hypertrophy diagnosis	no
Non-HDL-C	
Obstructive sleep apnea diagnosis	no
Physical activity	rare-mild
Renin-angiotensin system dual blockade administration	no
Serum creatinine level	0.8
Serum potassium	4.2
Smoking intensity	1 pack/day
Smoking status	yes
Statin administration	yes
Total cholesterol	178
Triglycerides (TG)	175
Uric acid serum concentration	4.2

Patient #14

76 year old male, diabetic, ex-smoker, myocardial infarction, dyslipidaimia, hypertension,CKD

Demographics and biometrics	
sex	male
age	76
height	170
weight	86
waist circumference	115
Waist to height ratio	0.68
Waist to hip ratio	
Body Fat percentage	24
Family history of Ischemic heart disease:	yes
Self history of Ischemic heart disease:	yes

Observables	
Acute kidney disease diagnosis	no
Acute myocardial infarction diagnosis	no
AHI (Apnoea– hypopnoea index)	no
Atrial fibrillation diagnosis	yes
β-blockers administration	yes
Blood Glucose: 2h glucose after oral glucose tolerance test	238
Blood Glucose: fasting	150
Blood pressure	149/85
Chronic kidney disease diagnosis	yes
Chronic obstructive pulmonary disease diagnosis	no
Contrast agents: coronary angiography administration	no
Diuretics administration	yes
eGFR	47.8
Fasting Plasma Glucose Levels	145
HbA1c	7.4
Haemoglobin (Hb)	11.6
HDL-C (High-density lipoprotein cholesterol)	38
Heart failure diagnosis	yes
Hypertension Diagnosis	yes
Ischemic heart disease self history	yes
Ischemic stroke diagnosis	yes
LDL-C (Low-density lipoprotein cholesterol)	85

Left ventricular hypertrophy diagnosis	no
Non-HDL-C	
Obstructive sleep apnea diagnosis	no
Physical activity	rare
Renin-angiotensin system dual blockade administration	yes
Serum creatinine level	1.6
Serum potassium	4.9
Smoking intensity	
Smoking status	no
Statin administration	yes
Total cholesterol	167
Triglycerides (TG)	220
Uric acid serum concentration	9.2

Patient #15

70 year old male, smoker, overweight, coronary artery by-pass graft surgery 6 months ago, COPD.

Demographics and biometrics	
sex	male
age	70
height	168
weight	84
waist circumference	125
Waist to height ratio	0.74
Waist to hip ratio	
Body Fat percentage	25
Family history of Ischemic heart disease:	no
Self history of Ischemic heart disease:	yes

Observables	
Acute kidney disease diagnosis	no
Acute myocardial infarction diagnosis	no
AHI (Apnoea– hypopnoea index)	no
Atrial fibrillation diagnosis	no
β-blockers administration	yes
Blood Glucose: 2h glucose after oral glucose tolerance test	118
Blood Glucose: fasting	106
Blood pressure	126/82
Chronic kidney disease diagnosis	no
Chronic obstructive pulmonary disease diagnosis	yes
Contrast agents: coronary angiography administration	no
Diuretics administration	no
eGFR	81
Fasting Plasma Glucose Levels	100
HbA1c	6.8
Haemoglobin (Hb)	14.1
HDL-C (High-density lipoprotein cholesterol)	40
Heart failure diagnosis	no
Hypertension Diagnosis	no
Ischemic heart disease self history	no
Ischemic stroke diagnosis	no
LDL-C (Low-density lipoprotein cholesterol)	132

Left ventricular hypertrophy diagnosis	no
Non-HDL-C	
Obstructive sleep apnea diagnosis	no
Physical activity	rare
Renin-angiotensin system dual blockade administration	no
Serum creatinine level	1.0
Serum potassium	3.8
Smoking intensity	120 packs/year
Smoking status	yes
Statin administration	yes
Total cholesterol	210
Triglycerides (TG)	190
Uric acid serum concentration	6.8

Patient #16

37 year old female, diabetes type I, hypertension, left ventricular hypertrophy, history of transient ischemic attack.

Demographics and biometrics	
sex	female
age	37
height	165
weight	66
waist circumference	90
Waist to height ratio	0.54
Waist to hip ratio	
Body Fat percentage	28
Family history of Ischemic heart disease:	yes
Self history of Ischemic heart disease:	no

Observables	
Acute kidney disease diagnosis	no
Acute myocardial infarction diagnosis	no
AHI (Apnoea– hypopnoea index)	no
Atrial fibrillation diagnosis	no
β-blockers administration	yes
Blood Glucose: 2h glucose after oral glucose tolerance test	201
Blood Glucose: fasting	170
Blood pressure	161/85
Chronic kidney disease diagnosis	no
Chronic obstructive pulmonary disease diagnosis	no
Contrast agents: coronary angiography administration	no
Diuretics administration	no
eGFR	100
Fasting Plasma Glucose Levels	170
HbA1c	7.3
Haemoglobin (Hb)	12.5
HDL-C (High-density lipoprotein cholesterol)	50
Heart failure diagnosis	no
Hypertension Diagnosis	yes
Ischemic heart disease self history	no
Ischemic stroke diagnosis	yes

LDL-C (Low-density lipoprotein cholesterol)	106
Left ventricular hypertrophy diagnosis	yes
Non-HDL-C	
Obstructive sleep apnea diagnosis	no
Physical activity	mild (30 minutes of walking twice per week)
Renin-angiotensin system dual blockade administration	no
Serum creatinine level	0.8
Serum potassium	3.8
Smoking intensity	
Smoking status	no
Statin administration	no
Total cholesterol	182
Triglycerides (TG)	200
Uric acid serum concentration	4.3

Patient #17

37 year old male, asthma, obesity, sleep apnea, paternal family history of diabetes

Demographics and biometrics	
sex	male
age	37
height	175
weight	112.6
waist circumference	130
Waist to height ratio	0.74
Waist to hip ratio	
Body Fat percentage	30
Family history of Ischemic heart disease:	no
Self history of Ischemic heart disease:	no

Observables	
Acute kidney disease diagnosis	no
Acute myocardial infarction diagnosis	no
AHI (Apnoea– hypopnoea index)	no
Atrial fibrillation diagnosis	no
β-blockers administration	no
Blood Glucose: 2h glucose after oral glucose tolerance test	135
Blood Glucose: fasting	103
Blood pressure	not recorded
Chronic kidney disease diagnosis	no
Chronic obstructive pulmonary disease diagnosis	no
Contrast agents: coronary angiography administration	no
Diuretics administration	no
eGFR	146.4
Fasting Plasma Glucose Levels	103
HbA1c	6.8
Haemoglobin (Hb)	14.5
HDL-C (High-density lipoprotein cholesterol)	47
Heart failure diagnosis	no
Hypertension Diagnosis	no
Ischemic heart disease self history	no
Ischemic stroke diagnosis	no

LDL-C (Low-density lipoprotein cholesterol)	130
Left ventricular hypertrophy diagnosis	no
Non-HDL-C	
Obstructive sleep apnea diagnosis	no
Physical activity	rare
Renin-angiotensin system dual blockade administration	no
Serum creatinine level	1.1
Serum potassium	4.3
Smoking intensity	
Smoking status	no
Statin administration	no
Total cholesterol	233
Triglycerides (TG)	280
Uric acid serum concentration	5.7

Patient #18

53 year old male, dyslipidaimia.

Demographics and biometrics	
sex	male
age	53
height	177
weight	65.07
waist circumference	80
Waist to height ratio	0.45
Waist to hip ratio	
Body Fat percentage	17
Family history of Ischemic heart disease:	no
Self history of Ischemic heart disease:	no

Observables	
Acute kidney disease diagnosis	no
Acute myocardial infarction diagnosis	no
AHI (Apnoea– hypopnoea index)	no
Atrial fibrillation diagnosis	no
β-blockers administration	no
Blood Glucose: 2h glucose after oral glucose tolerance test	90
Blood Glucose: fasting	82
Blood pressure	105/60
Chronic kidney disease diagnosis	no
Chronic obstructive pulmonary disease diagnosis	no
Contrast agents: coronary angiography administration	no
Diuretics administration	no
eGFR	98
Fasting Plasma Glucose Levels	82
HbA1c	5.6
Haemoglobin (Hb)	13.9
HDL-C (High-density lipoprotein cholesterol)	70
Heart failure diagnosis	no
Hypertension Diagnosis	no
Ischemic heart disease self history	no
Ischemic stroke diagnosis	no
LDL-C (Low-density lipoprotein cholesterol)	81

Left ventricular hypertrophy diagnosis	no
Non-HDL-C	
Obstructive sleep apnea diagnosis	no
Physical activity	intensive(1 hour 5 days per week)
Renin-angiotensin system dual blockade administration	no
Serum creatinine level	0.8
Serum potassium	3.7
Smoking intensity	
Smoking status	no
Statin administration	no
Total cholesterol	165
Triglycerides (TG)	70
Uric acid serum concentration	3.2

Annex 2

Interactive Visual Interface Software

What is CARRE Interactive Visual Interface?

The main goal of the CARRE Interactive Visual Interface is to provide data visualization functions for users to explore the data stored in the CARRE repositories. Users (patients and medical professionals) can: 1) explore the risk associations stored in the public RDF repository to see the possible development of a diseases and comorbidities; 2) explore the patients' tracking data stored in CARRE private RDF repository. These data are mainly expected to be collected by using various sensors, the data include: biomarkers, lifestyles, and medicine intake. The visual analytic approaches provided by the interface that allows these data to be visualized in different style and level of details, which aims to reveal detailed conditions of the patient; 3) visualize patient's tracking data against the risk associations to understand the personalized disease progression.

Download

The source code of the interactive interface contains 2.06mb of java code, 4.5mb images, the rest are html code, js code and resources. The zipped source code size in total is 11MB.

The source code is maintained by a web-based Git revidion control system Bitbucket. The code can be visited via Bitbucket repository: https://bitbucket.org/weihuiBeds/doc_repos_ccgv. Then check out "carre" branch.

Users without bitbucket account are able to read but not edit the code.

The code is also public available under the following link:

- v1.0 (Released 01 Sept. 2015, Deliverable 5.1)
- Source (113 MB): CARRE_Interactive_Visual_Interface_v1.0.7z

Visit

The interactive visual interface can be accessed at:

The CARRE interactive visual interface is Open Source

CARRE interactive interface is Open Source and can be freely used in Open Source applications under the terms GNU General Public License (GPL).