*e-Health – For Continuity of Care*
*C. Lovis et al. (Eds.)*

*doi:10.3233/978-1-61499-432-9-216*

# A Computational Infrastructure for Evaluating Care-coordination and Telehealth Services in Europe

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**Abstract.** This paper presents the computational framework that is employed for the analysis of health related key drivers and indicators within ACT, a project aiming to improve the deployment of Care Coordination and Telehealth services/ programmes across Europe, through an iterative evidence collection-evaluation-refinement process. An open-source solution is proposed, combining a series of established software technologies. The paper focuses on technical aspects of the framework and presents a worked example of a usage scenario.

**Keywords.** Data collection, survey, evaluation, telehealth, care coordination

## Introduction

Managing the disability, needs and expectations of patients with chronic diseases and their social and financial consequences is an important issue the European national health systems are facing. In Europe today, there are at least 10 million patients with heart failure [1,2], 20 million with COPD [3] and 60 million with diabetes [4]. The direct financial cost of managing these conditions is enormous (e.g. in EU the annual cost for diabetes is estimated at $100 billion [5]). Integrating clinical management with telehealth services could improve both the quality and the efficiency of care, leading to benefits for patients, health professionals and services while constraining costs.

Many studies have highlighted the value of Coordinated Care as well as Telehealth systems (CC&TH) on the aid of chronically ill patients [6]. However, existing CC&TH systems are limited to pilot or small range installations. In order to maximize the beneficial effects of CC&TH, structural and organizational reforms of the existing health care systems are required. The ACT programme (http://www.act-programme.eu) is the first EU-wide project to tackle such challenges, aiming to produce and distribute guidelines for successful exploitation of CC&TH over Europe. ACT focuses on chronic pathological conditions, such as heart failure, diabetes, chronic obstructive pulmonary disease, and comorbidities. The main objectives of ACT are: i) to understand the working mechanism of existing CC&TH services, by gathering data from 5 regions

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already deploy such services (Basque Country, Catalonia, Groningen, Lombardy and Scotland) and ii) to produce and share with European healthcare authorities a set of guidelines that facilitate the deployment of high-quality CC&TH services in EU.

A major requirement for this goal has been the organisation and harmonisation of health-related information. In this respect, gathered data are organized as *Key Drivers* (i.e. generic aspects of healthcare programmes determining their quality with respect to CC&TH) and *Key Indicators* (i.e., measurable healthcare outcomes used for assessing the drivers) [7]. In order to explore the relation between the key drivers and indicators, the programme has developed an analysis framework, called the *ACT Evaluation Engine*. Besides the analysis requirements, iteratively provided by the end-users, a basic pillar of the Evaluation Engine is the computational backbone that will allow centralised data collection, web-based analysis and visualisation in a secure, flexible and user-friendly manner. Web-based analytics constitute an active field of research and development in the ICT domain; however few applications have been deployed in the health information technology [8]. In this paper we present a prototype design and implementation of the Evaluation Engine's computational infrastructure that is based on open source technology, in order to support the required health information management and analysis under diverse criteria of regional distribution, health programmes, user needs and privileges, as well as indicators.

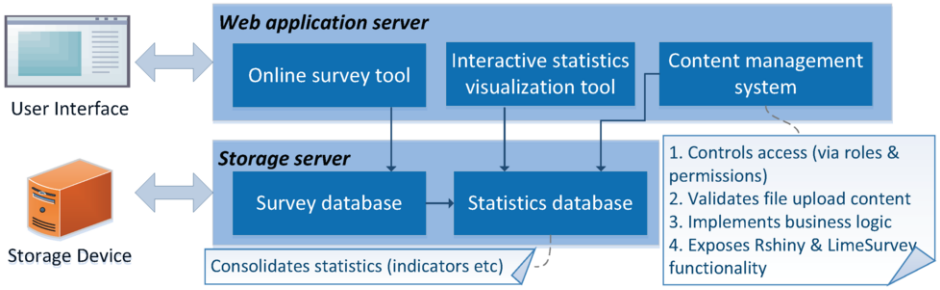


**Figure 1.** Overall system architecture

## 1. Methods

The main system functionality specifies that data are entered in the system using two distinct methods: *uploading structured excel files* and *filling out online surveys*. Both of these user interaction pathways are integrated in a unified web system, based on open source components. This system handles the data validation, consolidation, analysis and gives emphasis on visualising the results in an interactive fashion. Fig. 1 depicts the system architecture, identifying its basic modules, the *Storage server* and the *Web application server*, as well as their respective components. Since the Storage Server can be easily implemented by off-the-shelf data storage technologies, in this paper we focus on the components of the Web Application Server, which are of most interest.

### *1.1. Web Application Server Components*

*Content management system (CMS)*. CMSs are considered as one of the most popular tools to build a web application. Using a CMS, the main functionality is already built in

and needs only to be configured to the specific application's needs. Specifically, this built in functionality includes a) keeping the content of the web site updated, which can be accomplished by users, not needing extra development, and b) defining roles, privileges and permissions is integrated in the CMS's normal data model. Additionally, its modular architecture allows easy integration of new functionalities, often developed by the CMS's community.

CMS provides the single point of final user interaction with the system. According to her defined permissions, the user can upload regional data, fill out the online surveys, and access data analysis and visualizations, through **one single interaction point**, using **one account**, having a **unified transparent interaction experience**. To implement this module, we adopted a widely used open source content management system, Drupal. We chose Drupal because it has a mature yet broad spectrum of modules and supported functionality, and an active development community. Furthermore, its modular structure allows extending the already provided functionality and the integration with other informational systems.

*Online survey tool.* The online survey tool is used to enable online surveys' creation, design and management. While there are many web platforms providing such services, we chose LimeSurvey (http://www.limesurvey.org/en/) as our online survey tool. One of its important features is that it can be integrated with Drupal by using an already built module which has a wide user basis and therefore can be considered thoroughly tested. Therefore, the access to the survey is controlled through the central access mechanism incorporated in Drupal, using the same user credentials (username and password) with Drupal. The use of LimeSurvey during the online survey filling is totally transparent to the end user. Moreover, it is a free software tool, and thus it can be setup as a stand-alone server in our physical server, having the total process control.

*Interactive statistics & visualization tool.* Visualizing results in interactive fashion is one of ACT primary goals. The interactive visualization tool is implemented using R Studio-Shiny server [http://www.rstudio.com/shiny]. R-Shiny is an open source software package designed to integrate the power of statistical processing language of R with interactive web applications. Shiny allows simple HTML pages to interactively execute R scripts and takes advantage of R's visualizing capabilities, in order to graphically present the analysis results on the webpage. Shiny applications can be further extended by using JavaScript and jQuery. The R-script execution and the use of the analysis and visualization mechanisms inside HTML pages are controlled via the User Interface (UI) rendering engine of the R-Shiny web server.

The HTML pages produced by R-Shiny have been integrated with the basic CMS by a custom in-house Drupal module. Therefore, access to the data analysis functionality can be controlled via the CMS control access mechanism, and the use of Shiny during the interactive visualization of analysis results is transparent to the end user, who navigates through a single unified web application.

### *1.2. Evaluation Engine Workflow*

The data workflow in our system is modeled using the successive steps of data entry, validation, storage, integration and interactive statistical analysis and visualization.

*Data Entry and Validation*. In the proposed platform, the data can be entered in the system via two endpoint procedures, the online survey and uploading files following predefined templates. Both services are accessible for the user using a single web

access point, the CMS web site. Data validation is very crucial in preventing errors, and thus is placed early in the data workflow. Validation pertains to both data entry points,. For the online surveys, javascript-based validation checks the format of each data field entry. For the file upload process, a special CMS module parses the file, as soon as it is uploaded, and applies a custom set of rules in order to validate the data contained, with respect to the template followed. In case of an error, the user is guided to immediately correct the error and reenter the correct data.

*Storage and Data Integration*. When the user fills an online survey, the data are saved in the survey database. As soon as the whole survey has been filled, the survey data are automatically transferred to the so called statistics database. When a user uploads regional data in a form of an excel file, data are validated and saved in the statistics database where they are consolidated with the survey data. The Data Integration step is triggered each time an online survey has been submitted. As a result, all useful data are consolidated in a unifying database, the Statistics database, further used as the single data source of statistical analysis and visualization process.

*Statistical analysis and visualization.* In this ending step, the statistical analysis is performed. The user, according to her access permissions, can select multiple variables from different regions, saved in the Statistics database, and process them in a custom way. R shiny interface enables interactive selection of data, application of analysis methods, and export of results.

## 2. Results

In order to evaluate the whole architecture we developed a prototype according to a scenario where a user fills the survey and access the interactive analysing results view.

Supposing a region representative logs into the system using her username and password, she will see the menu option to “Fill Survey”. Clicking on the specific option and following the specific instructions (selecting language etc.) she will be led to the survey filling form, shown in Fig. 2.a.

When the user completes the online survey, the data are stored in the *statistics database.* Then she could access the interactive results analysing page through the menu option “Data Analysis” (Fig. 2.b), according to the user’s permissions. The user could define the analysis indicators and the respective parameters to adjust the analysis procedure. The data that are available for the analysis depends on the permissions each user has on the ACT programme.

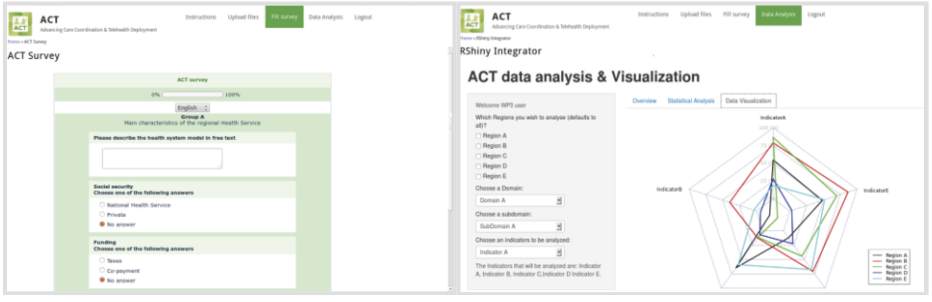


**Figure 2. a)** Executing an online survey, b) Interactive analyzing results page

## 3. Discussion

This paper presents the computational backbone of the ACT evaluation engine, supporting the data management and analysis methodology of ACT. Based on user input and requirements from different regions and domains, the functionality will be iteratively enriched, to support analysis at multiple dimensions.

Among the main functionalities to be included in the next period are the refinements of the data upload validation engine and the statistical processing of the consolidated data. These improvements will follow the data needs of the ACT project as they have not yet been finalized. Moreover, we plan to add many visualization capabilities focusing on user interaction. For example, we intend to add the capability of using predefined analysis scenarios and saving custom scenarios defined by user.

This computational infrastructure will be used and evaluated as part of the ACT's Evaluation Engine, and is expected to adequately serve as a tool for the generation of useful new knowledge on the organization of ehealth services. Furthermore, based on the generalization ability of the Evaluation Engine design methodology, the proposed infrastructure is planned to be extended and evaluated in other health-related domains, where web analytics are required, e.g. in the field of health technology assessment.

## Acknowledgments

The work leading to these results is funded by the European Community's Health Programme under grant agreement 0121209. The ACT programme is fully aligned with the European Innovation Partnership in Active and Healthy Ageing objectives to deploy integrated care for chronically ill patients. We acknowledge the contribution of the following researchers participating in ACT: S. Newman, R. Davidson (City University London); J. Roca (IDIBAPS); J. Escarrabill, M. Moharra (AIAQS); J. Cleland (Imperial College); D. Barrett, J. Hatfield (University of Hull); N. Hart, R. Harding (Guy & St Thomas NHS); M.D. Iturralde, J. M. Amengual, E. de Manuel Keenoy (Kronikgune); E. Buskens, D. Bultje, M. Lahr (UMCG); L. Bevilacqua, M. Romano, M. Nalin (Telbios); J. Rasmussen, A. Pavlickova (NHS 24/SCTT); C. Pagliari (University of Edinburgh); S. Störk, C. Wahl (University of Würzburg).

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