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## ON CDSS PLATFORM DIALOG'S COMPONENT CODE REFACTORING FOR USAGE WITH THE OPEN-SOURCE MIS OPENMRS

**Summary:** The significance of Medical Information Systems (MIS) for medical practice is emphasized. The wide use of Electronic Medical Records (EMR) software is displayed. Benefits of the open-source MIS usage are shown. Effectiveness of the Clinical Decision Support System (CDSS) application in the medical decision making process is emphasized. The open-source MIS OpenMRS developer tools and software APIs are reviewed. The results of code refactoring of the dialog subsystem of the CDSS platform which is made as a module for the open-source MIS OpenMRS are presented. The structure of the information model of the CDSS subsystem database was updated according to the MIS OpenMRS requirements and Liquibase framework guidelines. The Model - View - Controller (MVC) based approach to the CDSS dialog subsystem architecture was re-implemented with Java programming language using Spring and Hibernate frameworks. The MIS OpenMRS Encounter portlet form for the CDSS dialog subsystem integration is developed as an extension. The OpenMRS administrative forms for the CDSS platform are created. The data exchanging formats and methods for the interaction of the OpenMRS CDSS dialog subsystem module and the GAE Decision Tree service are implemented with the help of AJAX technology through the jQuery library.

**Keywords:** medical information systems, electronic medical records, decision support systems, decision tree, open-source software, MIS, EMR, OpenMRS, CDSS, Java, Spring, Hibernate, Google App Engine.

## REFRAKTORING KODU KOMPONENTU DIALOGOWGO OPROGRAMOWANIA DLA SZPITALI – DOPASOWANIA APLIKACJI DO POTRZEB UŻYTKOWNIKA

**Streszczenie:** W pracy podkreślono znaczenie medycznych systemów informatycznych (MSI) w praktyce leczniczej. Omówiono oprogramowanie do analizy elektronicznych zapisów medycznych (EZM). Przedstawiono zalety systemów MSI o otwartym kodzie. Ponadto, omówiono system wspierania decyzji klinicznych (SWPDK). Między innymi, rozpatrywany

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jest system o kodzie otwartym MSI OpenMRS oraz odpowiednie API. Przedstawiono wyniki refraktoringu kodu podsystemu dialogowego platformy SWPDK. System bazy danych systemu informatycznego SWPDK został dostosowany do wymagań SMI OpenMRS oraz poleceń szablonu Liquibase. Podejście typu Model-Widok—Sterownik (MWS) zostało wdrożone z użyciem języka programowania Java oraz szablonów Spring oraz Hibernate. Wprowadzono wiele szczegółowych rozwiązań informatycznych – jak na przykład: stworzono formy administracyjne do platformy SWPDK, natomiast formaty wymiany danych oraz metody interakcji pomiędzy: podsystemem dialogowym SWPDK OpenMRS a serwisem GAE Decision Tree są realizowane z pomocą technologii AJAX przez bibliotekę jQuery.

**Słowa kluczowe:** medyczne systemy informacyjne, elektroniczne zapisy medyczne, systemy wspierania podejmowania decyzji, drzewo decyzyjne, oprogramowanie o otwartym kodzie źródłowym, MSI, EZM, OpenMRS, SWPDK, Java, Spring, Hibernate, Google App Engine.

## Introduction

The importance of wide application of the Medical Information Systems (MIS) as a key element of informatization of healthcare, especially in Ukraine, is shown in [1, 2]. The development of information technologies makes it possible to improve the quality of medical care by providing medical personnel with hardware and software tools for the efficient processing of clinical information [2, 3]. A conceptual direction of modern information technologies adoption in hospitals pass through patient's Electronic Medical Record (EMR) formation and support [1, 2, 3].

### 1. On the Decision Support Systems application - as part of an open-source MIS usage

An overview of approaches of implementation into as well as brief list of the leading MIS developers is given in [2]. MIS global market has stable positive dynamics as it is shown in [4]. A few high-quality MIS has been created by Ukrainian software development companies too, for example, "Doctor Elex" (<http://www.doctor.eleks.com>), "EMSiMED" (<http://www.mcmed.ua>), etc. In fact, all they are commercial software with a high cost [1].

An open-source-based software solutions for healthcare has been actively developing for the last decade along with the commercial software applications [3, 5, 6]. Most widely used open-source MIS EMR are WorldVistA (<http://worldvista.org/>), OpenEMR (<http://www.open-emr.org/>) and OpenMRS (<http://openmrs.org/>) [3, 7]. Advantages of such MIS software are shown in [2, 3]. Prospects for open-source and free MIS software usage in developing countries, or countries with financial problems has been considered by F. Aminpour, F. Fritz, C. J. Reynolds and others [3, 5, 7]. The approaches to implementing open-source MIS, especially OpenEMR, OpenMRS and OpenDental, in Ukraine healthcare system has been studied as well as methods of integrating these MIS EMR with other MIS software has been developed by authors of this work during last few years [2, 8, 9].

Clinical Decision Support Systems (CDSS) regular usage in physician's practice is strongly recommended for improving of the quality of care. This thesis was confirmed in [10, 11, 12]. Advantages of CDSS usage in healthcare systems of the developing countries was shown in [13]. The importance of integration of different types of MIS,

and MIS EMR with CDSS especially, is provided in [14]. The CDSS theoretical approaches as well as software applications has been developed by TSMU Medical Informatics Department staff for last few years [15 - 19].

Approaches of the CDSS usage in obstetrics for early detection of pathologies of miscarriage of pregnancy are analyzed in [20, 21, 22]. A prototype of such CDSS has been developed by Semenets AV, Zhilyayev MM and Heryak SM in 2013 [23]. The effectiveness of proposed algorithm was confirmed by experimental exploitation of this CDSS prototype in the Ternopil state perinatal center "Mother and Child" during 2013-2015 that is proved in [24]. As result, the fully functional CDSS application for miscarriage pathology diagnostic has been developed by authors in form of an information module (plugin) for free- and open-source MIS OpenEMR [25, 26].

**Purpose of this work** is to represent authors' experience on code refactoring of the plugin, which implements dialog component of custom CDSS platform, for usage with free- and open-source MIS OpenMRS.

## 2. The CDSS platform dialog component's code refactoring implementation

The alternative method of the decision making process, based on the algorithm for induction of "decision trees", was proposed by VP Martsenyuk as result of preceding investigations described in [16-19]. Finally, given decision-making diagnostic algorithm was implemented with Java programming language as a web-service for the Google App Engine platform. A web-service training database has been deployed to Google Datastore service, which is a form of no-SQL data warehouse [25, 26]. This approach provide flexible way to integrate above GAE Decision Tree service with third-party MIS EMR by developing appropriate dialog components (modules, plugins) as well as administrative tools (Fig. 1). Therefore the feasibility of CDSS dialog component's plugin [25, 26] code refactoring for usage with free- and open-source MIS OpenMRS is obvious.

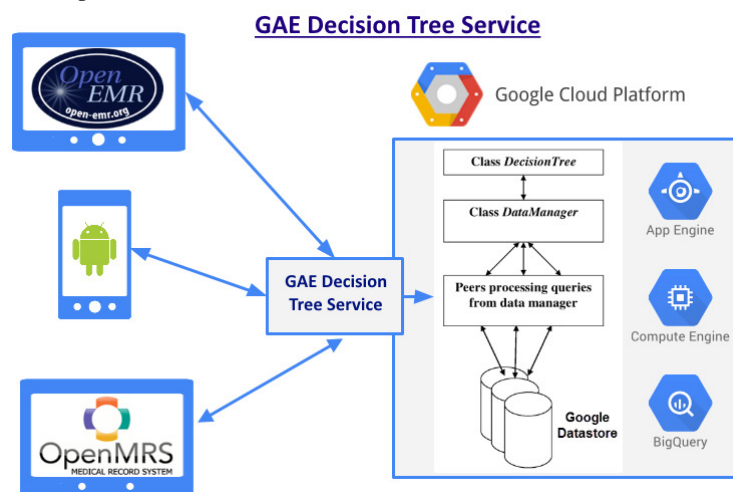


Figure. 1 Integration of the GAE Decision Tree CDSS web service with arbitrary EMR MIS

### 2.1. The OpenMRS add-ons (modules) development capabilities

OpenMRS is a free- and open source software platform dedicated to develop and integrate MIS EMR solutions (<https://github.com/openmrs/>). This MIS is focused on EMR automation of primary health care institutions like ambulances and small clinics. Several academics and non-governmental organizations, including the Institute Regenstrief (<http://regenstrief.org/>) and In Health Partners (<http://pih.org/>), are responsible to support and maintain OpenMRS core code. There are dozens of implementation [27] are registered, mainly in Africa and Asia (<https://atlas.openmrs.org/>).

The OpenMRS core is written in Java programming language using Spring and Hibernate frameworks. An MySQL RDBMS is used as data storage. There are tree main way to perform OpenMRS customization and adoption process:

1. The visual interactive editor for managing templates of patient registration forms and their components - Concepts, Form Metadata and Form Schema – Form Administrator (<https://wiki.openmrs.org/display/docs/Administering+Forms>).
2. The tool for integration of forms, developed by InfoPath (<http://www.infopathdev.com/>) – InfoPath Administrator (<https://wiki.openmrs.org/display/docs/InfoPath+Notes>).
3. Set of programming interfaces (API) for creating custom modules using Java programming language (<https://wiki.openmrs.org/display/docs/API> and <https://wiki.openmrs.org/display/docs/Modules>).

Tools 1 and 2 are easy-to-use and do not require knowledge of programming languages. However, they do not have features which are required to implementation of given CDSS. Therefore, OpenMRS Modules API has been selected to develop a module that implements features of the dialog component of CDSS platform. Corresponded module architecture is shown on Fig. 2.

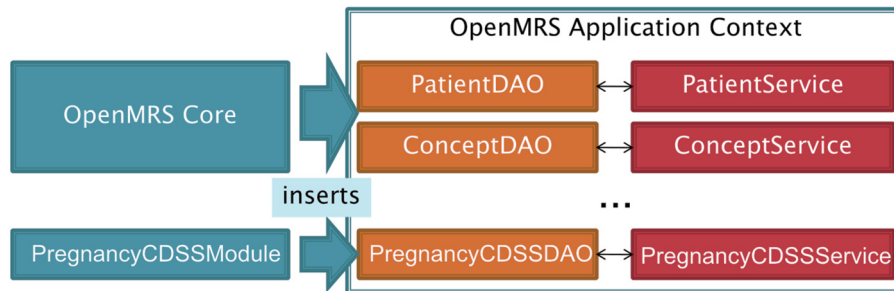


Figure 2. Software architecture of Pregnancy CDSS module for OpenMRS that implements the dialog component of the CDSS platform

### 2.2. Adaption of the information model of dialog component of the CDSS module

The external representations of the information model (IM) of CDSS dialog component, as well as the necessary data structures, are described in [25, 26]. The internal representation of information model has been adapted according to OpenMRS database requirements for the custom modules (<https://wiki.openmrs.org/display/docs/Data+Model>):

- a mechanism of IM key concepts identification by the universal identifier (UUID) values assignment has been introduced (<https://wiki.openmrs.org/display/docs/UUIDs>);
- some tables key field data types has been adopted according to OpenMRS coding guidelines (<https://wiki.openmrs.org/display/docs/Conventions>);
- module's database tables installation procedure according Liquibase technology (<http://www.liquibase.org>) description has been developed and set of special XML files has been formed.

Data structures for the recorded patient's data representation has been developed as the following Java-classes according to general (MVC, Model - View - Controller) approach adoption with the Spring framework usage (Fig. 3):

- SymptCategoryModel.java - represent symptom's categories;
- SymptomModel.java - represent symptom's description;
- SymptomOptionModel.java – represent possible symptom's values;
- DiseasesSymptOptModel.java – represent information about probability of a certain diagnosis depending on the given symptom's value;
- PatientExamModel.java – represent general Patient questionnaire data model;
- PatientSymptomByExamModel.java – represent each patient's questionnaire submission.

The Java Hibernate framework should be used within OpenMRS to implement database management operations according coding guidelines (<https://wiki.openmrs.org/display/docs/For+Module+Developers>). Therefore, necessary service classes has been developed as shown on the Fig. 3.

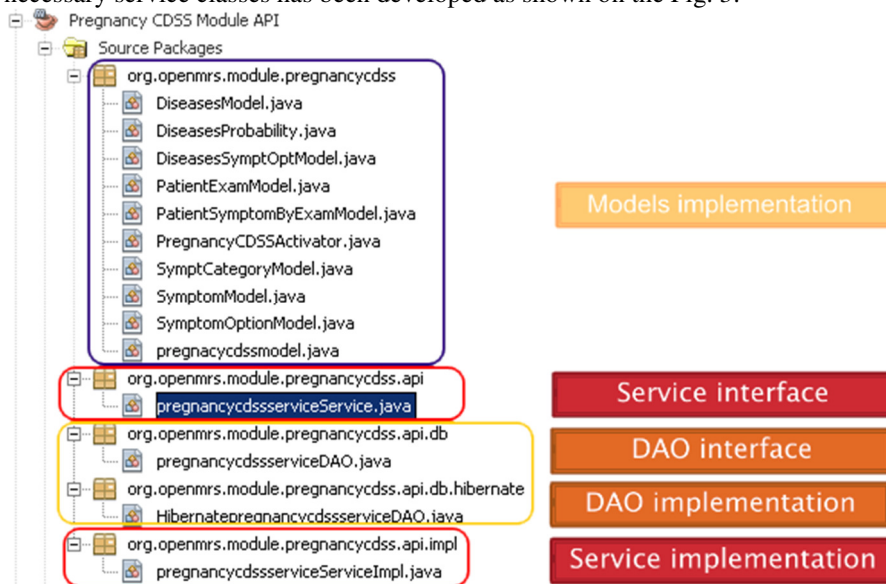


Figure 3. Structure of Java classes of Models and Services for patient data management in the Pregnancy CDSS module for OpenMRS MIS

### 2.3. CDSS dialog component User Interface development

Most of modern web- technologies could be used for UI development of OpenMRS custom modules, including HTML 5, CSS 3, AJAX (jQuery usage is recommended). According to above, set of flexible forms and reports has been developed to effectively implement necessary Pregnancy CDSS module User Interface views according to IM external representations as it was shown in [25] and MVC paradigm (Fig. 7). Those views are included especially:

- patientExamForm.jsp – the patient's survey main form (Fig. 4);
- encounterPatientExamData.jsp – the portlet which represent pregnancy miscarriage pathology diagnostic data, provided by Pregnancy CDSS module, inside OpenMRS patient encounter form (Fig. 5);
- patientExamForm2Print.jsp – the survey report with patient's answers and diagnostic conclusion;
- series of forms under OpenMRS Administration section for the CDSS platform dialog component content management, settings adjustment and configuration customization (Fig. 6).

#### Pregnancy CDSS Module

Survey for the patient: Id=4 name=[Ser Serv] Is it first pregnancy: false Form created=2015-12-19 18:13:45.0

Final Disease (if known)???: Своєчасні роди

Save Form

**Анкетні дані вагітної**

**1.1. Вік жінки**

- 1. до 18 років
- 2. 19-25
- 3. 26-30
- 4. 31-35
- 5. 36-40
- 6. 40>

**1.2. Сезон року**

- 1. Зима
- 2. Весна
- 3. Літо
- 4. Осінь

**1.3. Адреса проживання**

- 1. Місто
- 2. Село

**1.4. Реєстрація шлюбу**

- 1. Зареєстрований
- 2. Незареєстров.

**1.5. Вид роботи**

- 1. Фізична
- 2. Розумова
- 3. Домогосп

**1.6. Шкідливості роботи**

- 1. Перегрівання
- 2. Переохолодження

**1.7. Спадковість**

- 1. Необтяжена
- 2. Обтяжена
- 3. Вади розвитку
- 4. Невиншування
- 5. Попередньо мисленнєві

**1.8. Шкідливі звички**

- 1. Кава
- 2. Чай

Figure 4. A patient's survey form View in the Pregnancy CDSS module for OpenMRS MIS

**Encounter Management**

Encounter Summary

Patient\* ser Serv

Location

Encounter Date\* 16/11/2015 19:19 (Format: y/m/aaaa hh:mm)

Visit 16/11/2015 Outpatient ser Serv

Encounter Type ADULTINITIAL

Form v

Created By Super User - 16-Nov-2015

Deleted

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**Pregnancy CDSS Module**

Pregnancy Exam Form data for the current patient is there

Create New Survey Form

Search:

Exam ID	Form Created	Patient ID	Last Updated	First Pregnancy	Final Disease	Expected Disease	DecisionTree Disease	GAEDecisionTree submit	Edit survey form	Delete survey form
8	2015-12-19 18:13:45.0	Serv	2015-12-19 18:13:45.0	No	Своєчасні роди	Своєчасні роди		Submit data to GAE Decision Tree Service	Edit Form	Delete Form
9	2015-12-19 20:14:05.0	Serv	2015-02-19 11:09:34.0	No	Передчасні роди	Передчасні роди		Submit data to GAE Decision Tree Service	Edit Form	Delete Form
12	2015-12-19 20:30:24.0	Serv	2015-12-19 20:30:24.0	No				Submit data to GAE Decision Tree Service	Edit Form	Delete Form
13	2015-12-19 21:02:49.0	Serv	2016-02-18 16:28:03.0	No		Своєчасні роди		Submit data to GAE Decision Tree Service	Edit Form	Delete Form

Showing 1 to 4 of 4 entries

Figure 5. Representation of pregnancy miscarriage pathology examination summary, provided by Pregnancy CDSS module, inside OpenMRS patient encounter form

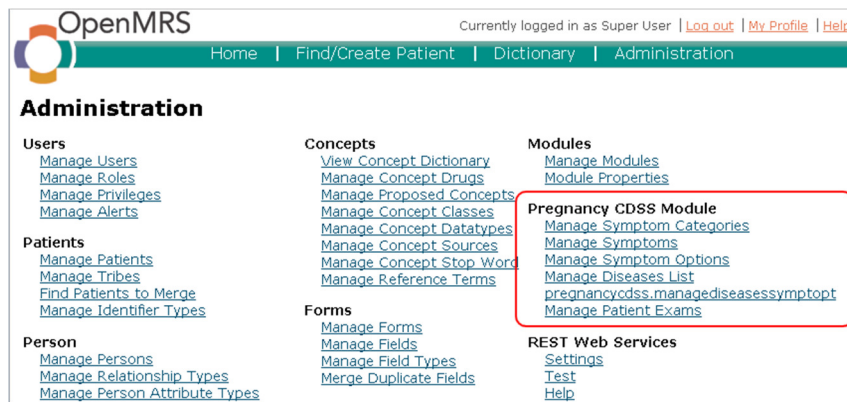


Figure 6. Pregnancy CDSS module customization forms under OpenMRS Administration section

Main decision-making algorithm are based on results of research obtained in [19, 23, 25, 26]. This algorithm as well as common module's management activities has been implemented in form of Java servlets, according to general MVC approach (Fig. 7):

- EncounterPatientExamDataPortletController.java – portlet controller to manage module data representation within OpenMRS patient's encounter form;
- PatientExamFormController.java – patient's survey form controller;
- GAEDecisionTreeController.java – provides interaction of the Pregnancy CDSS module with GAEDecisionTree diagnostic web-service;
- PregnancyCDSSManageController.java - provides Pregnancy CDSS module administrative features and customization capabilities.

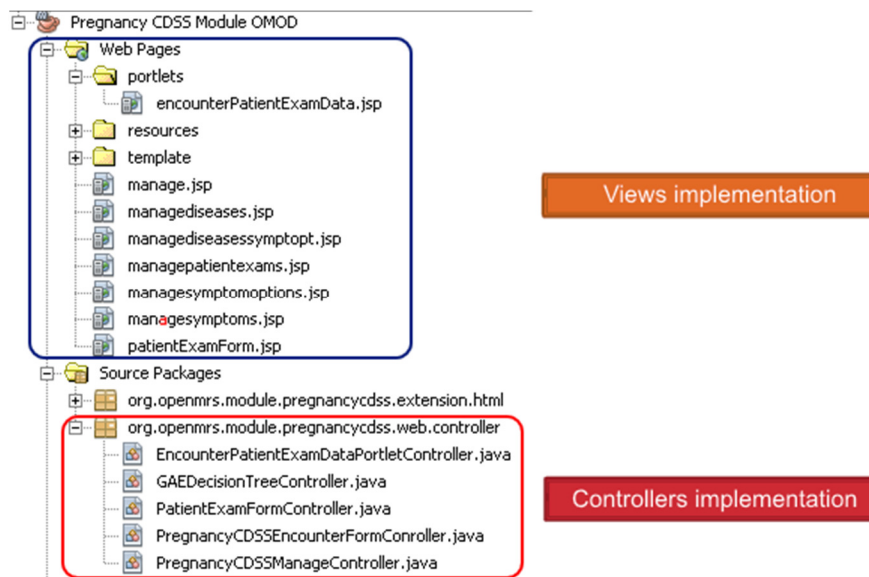


Figure 7. Structure of Java classes of views and controllers in the Pregnancy CDSS module for OpenMRS MIS

The presented CDSS platform dialog's component and provided GAE Decision Tree web-service interaction procedure has been developed according to recommendations how to cross-site data request being performed (<http://www.gwtproject.org/doc/latest/tutorial/Xsite.html#design>). The following methods of the `GAEDecisionTreeController.java` controller are responsible for:

- `getPatientDataJson2` – handles GET-type of HTTP request and returns data for the selected survey form as a JSON object;
- `getAllPatientDataJson` – handles GET-type of HTTP request and returns data for all survey forms, where final diagnosis is given, as a JSON object. It is used for the training dataset formation during GAE Decision Tree web-service education stage (<http://decisiontree-1013.appspot.com>);
- `setGAEDecision` – handles POST-type of HTTP request and store GAE Decision Tree diagnostic output in Pregnancy CDSS module database for appropriate patient's record.

Practically, Querying service GAE Decision Tree service has been queried directly from view (`portlet encounterPatientExamData.jsp`) with AJAX technology using jQuery library via the following code snippet (listing 1):

- `gaeDecisionTreeSubmitFunction` – retrieves a survey form data by asynchronous calling of the `getPatientDataJson2` method of the `GAEDecisionTreeController.java` servlet;
- `submitData2GAE` – submits a survey form data to the GAE Decision Tree service via asynchronous request;
- `setDecisionTreeResponseFunction` – receives a diagnostic conclusion provided by GAE Decision Tree service and redirect it to the `GAEDecisionTreeController.java` servlet by asynchronous calling of the `setGAEDecision` method.

A training dataset deployment to the GAE Decision Tree service has been implemented in the same way within the `managepatientexams.jsp` view in OpenMRS administrative panel of the Pregnancy CDSS module.

Listing 1. Implementing of asynchronous interaction of the OpenMRS Pregnancy CDSS module with the GAE Decision Tree web-service

```
<script type="text/javascript">
  function submitData2GAE(formData) {
    jQuery.ajax({
      type : 'GET',
      url   : 'http://decisiontree-1013.appspot.com/patientdata',
      data : formData,
      dataType : 'json',
      success : function(response) {
        var mystr = JSON.stringify(response);
        setGAEDecision (response);
      },
      error : function(e) {
        alert ('Error: ' + e);
      }
    });
  };
};
```



```

function
gaeDecisionTreeSubmitFunction(examId, encounterId, patientId) {
  jQuery.ajax({
    type : 'GET',
    url                                     :
    '${pageContext.request.contextPath}/module/pregnancycdss/gAE
DecisionTree/single.json',
    data : 'examId=' + examId + '&encounterId=' +
encounterId + '&patientId=' + patientId,
    dataType : 'json',
    success : function(response) {
      submitData2GAE(response);
    },
    error : function(e) {
      alert('Error: ' + e);
    }
  });
};

function setGAEDecision(GAEResponse){
  jQuery.ajax({
    type : 'POST',
    url                                     :
    '${pageContext.request.contextPath}/module/pregnancycdss/gAE
DecisionTree/setdisease.json',
    data : gAEResponse = ' + GAEResponse,
    dataType : 'json',
    success : function(response) {
      alert('Sucessfully saved!');
    },
    error : function(e) {
      alert('Error: ' + e);
    }
  });
};
</script>

```

The Pregnancy CDSS module installation process has been performed according general OpenMRS administration guide

(<https://wiki.openmrs.org/display/docs/Administering+Modules>):

1. Download the Pregnancy CDSS module compiled file (pregnancycdss-1.xx-SNAPSHOT.omod) from author's GitHub repository ([https://github.com/semteacher/pregnacy\\_cdss](https://github.com/semteacher/pregnacy_cdss)).
2. Log in to OpenMRS as administrator. Go to MIS module administration page (*Administration* → *Manage Modules*).
3. Press *Add or Upgrade Module* button. In "Add Module" dialog click *Choose File* in the *Add Module* section. Specify downloaded module file location and click *OK* than *Upload*.
4. After installation will complete – new "Pregnancy CDSS Module" section will appears in OpenMRS patient Encounter form (Fig. 4).

## Conclusion

Effectiveness of the Clinical Decision Support System (CDSS) application in the medical decision making process has been signed. An opportunities provided by CDDS in diagnostics of miscarriage pathologies with aim to prevent of preterm birth has been shown as a result of trial evaluation of the CDSS prototype in Ternopil regional perinatal center "Mother and Child".

An approach to the decision making process which is based on the decision tree algorithm has been recommended. The implementation of the given above approach as separate web-service based on the Google App Engine (GAE) capabilities has been provided.

The results of code refactoring of the dialog subsystem of the CDSS platform which is made as module for the open-source MIS OpenMRS has been presented. The Model-View-Controller (MVC) based approach to the CDSS dialog subsystem architecture has been implemented with Java programming language using Spring and Hibernate frameworks. The OpenMRS Encounter portlet form for the CDSS dialog subsystem integration has been developed as a module. The data exchanging formats and methods to establish interaction between OpenMRS newly-developed Pregnancy CDSS module and GAE Decision Tree service are developed with AJAX technology via jQuery library.

The prospects for the further research is to extend web-service core decision tree algorithm capabilities to support different types of diagnostic problems. Such achievements will allow to more comprehensive end more effective utilize of patient's health data which are collected within both supported MIS – OpenEMR and OpenMRS.

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