Models and simulation techniques for discovering diabetes influence factors

MOSAIC overview
Consortium presentation

EU-funded European ICT project carried out within the 7th Framework Program
Diabetes Figures

• **382 million** people have diabetes in 2013; by 2035 this will have risen to **592 million**
• The number of people with **type 2 diabetes is increasing** in every country
• **80%** of people with diabetes live in **low- and middle-income countries**
• The **greatest number** of people with diabetes are between **40 to 59** years of age
• **175 million** people (50%) with diabetes are **undiagnosed**
• Diabetes caused **5.1 million deaths** in 2013
• Diabetes caused at least **USD 548 billion dollars** in healthcare expenditures in 2013; **11% of total healthcare expenditures** in adults (20-79 years)
• **79,000 children** develop **type 1 diabetes** every year
Objectives

1. Early diagnosis of T2DM and prediabetic states
2. Improve characterization of the aforementioned patients
3. Evaluate the risk of
   • Developing T2DM and prediabetes
   • Developing associated complications

Integrating these into the MOSAIC management tool:
   • Stratification of the population at risk
   • Personalized treatments and definition of the care pathways
   • Enhanced professional decision support systems.
Databases

Probabilistic models

Population studies (VIVA, Botnia PPP, Botnia BPS) retrospective data

- Identification of variables of interest and fusion of the three datasets
- Bootstrapped Bayesian Networks analysis to find relations between known and potential T2DM risk factors

Continuous Glucose Monitoring Dataset (Opt2mise, METABO)

- Identify optimum indices of glucose variability

Temporal data mining model

- From the longitudinal hospital records
- To improve monitoring of diabetic patients and predict its complications
Data Centres

Clinical Studies Data
- Botnia Study
- PPP and BPS
- Viva Study

Hospitals and Health Care Agencies Data
- ASL
- FSM Hospital
- La Fe Hospital
- Hippokrateion Hospital
Data integration architecture

Data warehouse

Common Data Model – i2b2

MOSAIC system

Data warehouse

Data warehouse

Data warehouse
Predictive models developed

Cox Regression Model
It reveals the risk of a patient or a population of developing Type 2 diabetes in the next 2-12 years.

Bayesian Network
It reveals if an individual patient is diabetic and is currently undiagnosed.

Logistics and Naïve Bayes regressions
- Retinopathy, neuropathy and kidney disease in the next 3, 5 and 7 years from the first visit in the hospital.
- Temporary data mining to find relevant patterns for the prevention of complications.
MOSAIC results:
TOOLS
TOOL 1 - PREVENTION AND RISK DETECTION OF TYPE 2 DIABETES MELLITUS

TOOL 2 - PREVENTION AND ANALYSIS OF COMPLICATIONS IN TYPE 2 DIABETIC PATIENTS

TOOL 3 – DECISION SUPPORT SYSTEM IN FOLLOW-UP VISITS

TOOL 4 – DIAGNOSIS OF TYPE 2 DIABETES

TOOL 5 - MOSAIC PATIENT TOOL
TOOL 1 - PREVENTION AND RISK DETECTION OF TYPE 2 DIABETES MELLITUS

1st STEP

User: Prevention / Health Care Coordination / Ministry of Health

- In a given geographic area (e.g., Madrid), users can select by hospital and see the population they have. They can also apply filters to select the type of population to analyze.
- After this, the system provides percentages of the population assigned to selected hospitals at risk of developing TD2M (Cox regression model).
- The tool, as currently conceived, is enable to send a report to healthcare managers, informing the population at risk belongs to their hospitals.
TOOL 1 - PREVENTION AND RISK DETECTION OF TYPE 2 DIABETES MELLITUS

Users: Prevention/Health Care Coordinators/Insurers/Private hospitals

<table>
<thead>
<tr>
<th>Regions</th>
<th>Centers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valencia</td>
<td>Hospitals:</td>
</tr>
<tr>
<td>Hospital la Fe</td>
<td>Patients: 10750</td>
</tr>
<tr>
<td>Pavia</td>
<td></td>
</tr>
<tr>
<td>ASL</td>
<td></td>
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<td>FSM</td>
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<tr>
<td>Athens</td>
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<tr>
<td>Hippocrates</td>
<td></td>
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</tbody>
</table>

Filters:
- Gender: Both, Male, Female
- Age: All, 0-20, 20-40, 40-60, 60-80, >80
- Education Level: All
- BMI: All, <20 - Underweight, 20-25 - Normal Weight, 26-29 - Slightly Overweight, >30 - Overweight, >40 - Extremely Overweight
- Comorbidities: All, CVD (Hypertension, Angina, AMI, Stroke), Neuropathy, Nephropathy, Retinopathy, Dyslipidemia
- Family History of Diabetes: All, Yes, No
- Gestational Diabetes History: All, Yes, No
Selected population for risk assessment of T2DM
TOOL 1 - PREVENTION AND RISK DETECTION OF TYPE 2 DIABETES MELLITUS

<table>
<thead>
<tr>
<th>Filters</th>
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<tbody>
<tr>
<td><strong>Gender</strong></td>
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<tr>
<td>- Both</td>
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<tr>
<td>- Male</td>
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<tr>
<td>- Female</td>
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<tr>
<td><strong>Age</strong></td>
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<td>- All</td>
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<td>- 0-26</td>
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<td>- 40-60</td>
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<td>- 60-80</td>
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<td>- &gt;80</td>
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<tr>
<td><strong>Education Level</strong></td>
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<tr>
<td>- All</td>
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<tr>
<td>- High Level</td>
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<tr>
<td>- Medium Level</td>
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<tr>
<td>- Low Level</td>
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<tr>
<td><strong>BMI</strong></td>
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<tr>
<td>- All</td>
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<tr>
<td>- &gt;30 - Overweight</td>
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<tr>
<td>- &gt;40 - Extremely Overweight</td>
</tr>
<tr>
<td><strong>Comorbidities</strong></td>
</tr>
<tr>
<td>- All</td>
</tr>
<tr>
<td>- CVD (Hypertension, Angina, AMI, Stroke)</td>
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<tr>
<td>- Neuropathy</td>
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<tr>
<td>- Nephropathy</td>
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<tr>
<td>- Retinopathy</td>
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<td>- Dyslipidemia</td>
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<tr>
<td>- Cholelithias</td>
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<td>- Neprolithias</td>
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<tr>
<td>- Obesity Hyperventilation Syndrome</td>
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<tr>
<td><strong>Family History of Diabetes</strong></td>
</tr>
<tr>
<td>- All</td>
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<tr>
<td>- Yes</td>
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<tr>
<td>- No</td>
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</tbody>
</table>

**Gestational Diabetes History**
- All
- Yes
- No

**Execution Model For Risk Calculation**

- Possibility of filtering
TOOL 1 - PREVENTION AND RISK DETECTION OF TYPE 2 DIABETES MELLITUS

<table>
<thead>
<tr>
<th>Year</th>
<th>Low Risk</th>
<th>Medium Risk</th>
<th>High Risk</th>
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</thead>
<tbody>
<tr>
<td>2nd year</td>
<td>11.8%</td>
<td>84.8%</td>
<td>3.4%</td>
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<tr>
<td>3rd year</td>
<td>18.3%</td>
<td>68.9%</td>
<td>2.8%</td>
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<tr>
<td>4th year</td>
<td>39%</td>
<td>55.3%</td>
<td>5.7%</td>
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<tr>
<td>5th year</td>
<td>20%</td>
<td>46.1%</td>
<td>33.9%</td>
</tr>
<tr>
<td>6th year</td>
<td>18.6%</td>
<td>46.7%</td>
<td>34.7%</td>
</tr>
<tr>
<td>7th year</td>
<td>50.8%</td>
<td>30.8%</td>
<td>18.4%</td>
</tr>
<tr>
<td>8th year</td>
<td>28.6%</td>
<td>28.6%</td>
<td>42.8%</td>
</tr>
<tr>
<td>9th year</td>
<td>31.3%</td>
<td>18.7%</td>
<td>50%</td>
</tr>
<tr>
<td>10th year</td>
<td>19.9%</td>
<td>19.9%</td>
<td>60.2%</td>
</tr>
</tbody>
</table>

- Results obtained: Probability of developing T2DM in the future.
User: Hospital Endocrinology/General practitioners

- The head access to the system and finds a list of patients. They can select a patient and see their clinical and demographical variables, etc. which has been self-filling.

- At this point, the second predictive model (Bayesian Network) is applied.

- This predictive model will indicate the current risk of each patient to be already diabetic, based on the automatic estimation performed on the results that would give us an oral glucose tolerance and HDL-C (cholesterol high density lipoprotein).
System impact

- This process allows to identify patients at risk from a general population to the individual and focus the diagnostic tests for T2DM detection to those patients that indeed are in high risk of developing the disease, increasing the success rates in tests like Oral Glucose Tolerance Test.

- A better detection and diagnosis of T2DM in early stages will enable to start activities of secondary prevention and healthy lifestyle before the patient starts to develop the associated complications of this chronic disease. (Micro and macro vascular complications).
TOOL 2 - PREVENTION AND ANALYSIS OF COMPLICATIONS IN TYPE 2 DIABETIC PATIENTS

- MOSAIC use large databases available on long-term monitoring of diabetic patients with the goal of providing health services with innovative methods and tools to monitor the evolution of patients, facilitating the control and management of the disease.

- Any center collecting information from patients about lifestyle, physical parameters, clinical values, hospitalizations, etc. take advantage from a tool such as MOSAIC, which exploits the integration of different sources of information, to provide several useful features from a clinical, strategic and organizational perspective, of each healthcare organization based on the needs of their patients.
TOOL 2 - PREVENTION AND ANALYSIS OF COMPLICATIONS IN TYPE 2 DIABETIC PATIENTS

MOSAIC users will open the tool and they will find information about their diabetic patients classified by:

- Gender
- Age at diagnosis
- Body Mass Index (BMI)
- Cardiovascular risk (last visit)
- Complications
Once the users have select in the first screen the group on which they want to have more information, they will access to the 2nd screen where they will find information from the patients group selected regarding:

- **Complications**: History of the complications suffered by the patients group selected, as well as the order in which they have appeared, temporarily placing taking into account the days of disease progression.
The medication received for their patients during their illness
TOOL 3 – DECISION SUPPORT SYSTEM IN FOLLOW-UP VISITS

- **Users:** General Practitioners or diabetologists – Professional coordinator of the disease.

- With this tool the users will be able to insert the patient ID and the system provides *clinical information about the patient* in a friendly and intuitive way, organized by:
  - Clinical data
  - Traffic lights
  - Therapies
TOOL 3 – DECISION SUPPORT SYSTEM IN FOLLOW-UP VISITIS

- **Clinical data:** provides information about the chronological evolution of the patient regarding HbA1c, weight, etc. in a graphical way.
Traffic lights: using traffic lights graphs the users can see the evolution of their patients from the previous follow-up visit so far, taking into account key parameters for an adequate control of diabetes, as well as the risk of developing certain complications.

Therefore, the tool identifies patients at risk, enabling HC providers to recommend some kind of intervention, either lifestyle changes, medication or a consultation with the specialist.
**TOOL 3 – DECISION SUPPORT SYSTEM IN FOLLOW-UP VISITS**

- **Therapies:** in those systems where information about purchasing drugs prescribed by physicians is collected, the tool is enable to track the treatment adherence of their patients.
TOOL 4 – DIAGNOSIS OF TYPE 2 DIABETES

• This tool allows to identify undiagnosed T2DM patients at individual level
• The process is very simple, and would require:
  1. Enter the ID number of the patient.
  2. Check that clinical, demographic and lifestyle data are correct and if not correct them
  3. Activate the system.

• System Response: the most likely value resulting from a Oral Glucose Tolerance Test (OGTT) in this patient in particular based on a predictive model (Bayesian Network) which takes into account all the other clinical variables of the patient.
• One of the most powerful features of the system is that estimates those variables (clinical, demographic and lifestyle) not available. (While it is true that the more variables available the system have, the more accurate diagnostic response will be given)
TOOL 5 - MOSAIC PATIENT TOOL

• **Concept:**
  A web tool to calculate the risk of developing diabetes within 2 and 12 years (best results at 6 years).

• **Path (Ongoing):**
  • The user opens the Mosaic web page and press on an icon (link to the MOSAIC tool).
  • In a new web page users inserts information used by the models. (The user will be able to fill just the known required information and can leave some fields empty).
  • The Mosaic tool calculates the risk of having diabetes and prompts a short feedback / advise.
Currently under validation

Continuous concept validation during the life of the project
- Interviews, focus groups + workshops with clinicians

Scientific value + impact
- Assessment of the MOSAIC models
- Evaluation of the methods in two hospitals:
  - La Fe in Spain
  - FSM in Italy
- MOSAIC Prospective Study based in CGM data to feed and improve the models
Follow us!

www.mosaicproject.eu

coordinator@mosaicproject.eu

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