Background information for the HCI-2006 Mini project: “Mobile Diabetes Manager - MoDiaMan”
Introduction and References


- The first section contains a very short description of diabetes.
- The second section describes the Diasnet – a diabetes advisory system developed by researchers from AAU and deployed at Frederikshavn Hospital since 2002.
- Section 3 describes work towards a mobile version of the Diasnet service, which has been developed at AAU within the Magnet project.
- The final section is the actual description of the Mini Project

References:

Note! The list is not exhaustive; there may be references in the text not included in the list below:


1. Diabetes - A public health care issue

The purpose of the section is briefly to introduce diabetes, its symptoms, treatments, complications and impact on society. Basic knowledge about these factors is important to fully analyse and propose services within this area.

The nature of diabetes

Diabetes mellitus, or diabetes, is a chronic condition where the body is unable to keep the blood glucose concentration within normal limits, approximately 4.0-7.0 mmol/L. This is due to poor glucose metabolism, generally, on account of the body’s failure to produce insulin, insulin resistance or a combination of the two.

Insulin is a hormone and hormones are protein secreted by a gland. Insulin is secreted by the beta cells of the pancreas, and the hormone is necessary in order to transport blood glucose into the body’s cells. In the cells, the absorbed glucose is either converted directly to energy or stored for future use in the form of glycogen in liver or muscle cells. Total absence of insulin deprives the cells of energy. If a person does not produce insulin, insulin dependent
diabetes (type-1 diabetes) is developed, and insulin needs to be injected daily. As insulin is a protein it would be broken down and digested if it was administered by pill, therefore injection is necessary. Two main types of diabetes exist:

- **Type-1 diabetes**: Type-1 diabetes is also known as *juvenile-onset diabetes* or *insulin dependent diabetes*. Type-1 diabetes is usually developed and diagnosed in children, teenagers and young adults. This type of diabetes is characterised by the pancreas producing no or hardly any insulin at all. As a result, the diabetic needs to inject insulin on a daily basis. Symptoms (e.g. excessive thirst, increased fluid intake, frequent urination, weight loss, fatigue and blurred vision) of type-1 onset often appear in the course of just a couple of weeks in children and teenagers. In adults the symptoms are often more insidious and gradually become stronger in the course of some months.

- **Type-2 diabetes**: Type-2 diabetes is also known as *adult-onset diabetes* or *non-insulin dependent diabetes*. Type-2 diabetes can be developed at any age, and is characterized by insufficient insulin secretion and/or insulin resistance, i.e. a state where the body’s cells can not utilize the insulin properly. The disease is treated by diet and exercise, often combined with medicine - for some also insulin.

A constant concern of diabetic patients is their blood glucose concentration which needs to be regulated very carefully, in order to stay in the approximate range 4.0 - 7.0 mmol/L. Without adequate regulation, the blood glucose concentration rises beyond the normal upper limit and causes hyperglycaemia (elevated blood glucose concentration; explained in the bullet below), which over the years can lead to severe complications such as eye damages, infections, kidney failure and circulatory diseases. Administering insulin to lower the blood glucose concentration can lead to hypoglycaemia (low blood glucose concentration; explained in the bullet below) if the dosage is too high. Therefore, staying in the appropriate blood glucose concentration range requires daily balancing of diet and - for type-1 diabetics mainly - insulin.

- **Hypoglycaemia**: Means that the blood glucose level is too low, i.e. below approx. 3.5-4.0 mmol/L. A frequent complication related to insulin treatment, but may also occur in connection with treatment with other diabetes medicines. The symptoms of hypoglycaemia are: sweatiness, muscular twitching, hunger, fatigue, lack of concentration, dizziness, blurred vision and rapid heartbeat. This condition must be treated immediately by the intake of food with fast acting carbohydrates. If the blood glucose concentration keeps decreasing, insulin chock will occur, entailing unconsciousness, possibly accompanied by seizures. To raise the blood glucose concentration, injection with a glucose solution is most often necessary.

- **Hyperglycaemia**: Means that the blood glucose level is too high, i.e. above approx 7.0 mmol/L. Patients are not always able to feel when their blood glucose level is elevated and may in fact get accustomed to this condition. A patient may experience the following symptoms in connection with hyperglycaemia: fatigue, dryness of mouth, thirst and excessive urination. To bring down the concentration, insulin can be administered, which leads to glucose absorption in the cells.

**Diabetic complications and their treatment**

The overall principle of diabetic care is to gain the best possible control with blood glucose levels in order to prevent diabetic complications which are a direct result of prolonged
hyperglycaemia. At the same time it is important to sustain a high quality of life for the individual patient by avoiding a high frequency of incidents of hypoglycaemia. The treatment of type-1 diabetes requires the administration of one or multiple insulin injections every day. As part of a day-to-day routine the diabetic patients check their blood glucose levels, although it is up to the individual patient when and how often it is done (approx. 2-10 times a day). Patients who are diagnosed with type-1 diabetes receive individual education concerning the progress of the disease, human physiology, insulin treatment, diabetic diet and diabetic complications.

Diabetics will within 5-20 years after disease onset, start to develop a series of complications, but many the complications can be delayed or even avoided by proper disease management [IM 2003]. The following listing indicates the most common complications:

- **Eyes:** Diabetic retinopathy is a disease in the retina caused by malfunctioning blood supply in the retina. The disease can lead to impaired eyesight and blindness; but if identified in time, laser treatment (photo coagulation) can reduce the risk of eyesight impairments by approximately 50%. [IM 2003]
- **Kidneys:** Kidney failure can occur as a consequence of capillaries in the kidneys leaking protein. In Denmark, about 30-40% of the diabetics develop kidney damages. [IM 2003]
- **Nerves:** Diabetic neuropathy - inflammation of nerve endings - is a disease which occurs in the peripheral nerves of about 40% of all diabetics (statistics on Danish diabetes population). This leads typically to loss of sense of touch in lower legs and feet. [IM 2003]
- **Feet:** Diabetic patients (about 7% of Danish diabetics) are prone to feet ulcers, often owing to an impaired or non-existent sense of touch in the feet caused by diabetic neuropathy and atherosclerosis (arteries hardening), which reduces blood supply in the patient’s legs. [IM 2003] Surgical amputations are performed approximately 10 times more frequently in diabetics than in non-diabetics of the same gender and age [DNBH 1994].
- **Circulatory system:** Diabetics have an increased risk of developing atherosclerosis [DNBH 1994]. Blood clots in the brain may occur 2-4 times more frequently (in Denmark) in diabetics than in non-diabetics, and cardiac infarct 3-5 times as frequently (in Denmark) [DNBH 1994].

**Accessories for a diabetic**

As diabetes is a chronic disease, patients are taught to manage their own disease on a daily basis. Proper self management of diabetes requires typically:

- **Information:**
  - About diabetes in general and how to manage the disease.
  - About glucose metabolism and how to estimate the carbohydrate content in meals. Consumption of carbohydrates causes the blood glucose concentration to rise.
  - About insulin and the different types that exist and how to keep and administer the insulin.
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- About blood glucose in general, about blood glucose concentrations states of hypoglycaemia and hyperglycaemia. Information about how to measure the blood glucose concentrations and how to keep track of the readings.
- About the economical issues involved.

- Diary: Keeping a diary with daily entries of blood glucose measurements, insulin injections, carbohydrate intake, own notes etc. is an important tool for keeping track of the disease management, both for the diabetic and the involved medical team.

- Insulin pen: Injecting insulin is most commonly done with a special syringe called an insulin pen, but a catheter or an insulin pump can also administer it. The insulin pen holds an amount - typically 1.5-3.0mL - which is equivalent to 150-300 units. It is very individual for how many days this dosage suffices as each patient’s insulin regimen is individually planned with a health care professional.

- Blood glucose meter: Blood glucose readings are normally retrieved by applying a drop of blood on a paper strip which then is analysed in an electronic blood glucose meter (size of a small cell phone). The meter displays the current blood glucose concentration, and has normally the ability to store a number of time-stamped readings.

Prevalence and incidence

In Denmark, approximately 3.8% of the population, i.e. 200,000 people have diabetes [Henriksen et al. 2002]. About half of these diabetics are undiagnosed type-2 and of the diagnosed other half, 80-90% is type-2 and 10-20% is type-1.

Studies performed by the United States’ Centers for Disease Control show that the number of diagnosed diabetes incidents is increasing within all race and age groups in the United States [CDC 2004]. This indicates that the number of people diagnosed with diabetes may also increase in Denmark and other countries with similar lifestyles.

Currently, the monitoring and treatment of diabetics is covering about 6% of the Danish health budget (approximately 335 million Euros).

By year 2000, the number of diabetes incidents worldwide was estimated to be at least 171 million (forecast to be 366 million by 2030); and 33.33 million in Europe alone (forecast to be 47.97 million by 2030).

2. DiasNet - An existing diabetes service

The purpose of this section is to analyse an existing diabetes service called DiasNet (Diabetes Advisory System), which currently is in pilot usage at Frederikshavn Hospital (Denmark) and Bournemouth Hospital (England). DiasNet is an active research project - and has been for the last 15 years - at the Institute of Health Science and Technology, Aalborg University. For additional information on the DiasNet research group and activities see [Hejlesen et al. 1997], [MI 2003] and [Hejlesen et al. 2000].

Introducing and analysing DiasNet is important for the MAGNET project, as it will constitute the foundation for the future MAGNET version of the system, i.e. DiasNet-PN (Diabetes Advisory System - Personal Networked).

Practical setting up of DiasNet
The setting-up of the Diabetes Advisory System took place in the beginning of January 2000 where the project was launched under the project “The Digital Hospital” under the IT Project Activity “The Digital North Denmark” that was under the auspices of that the Danish Government. The Digital North Denmark launched a number of collaborative projects involving partners from the private sector, from the County of North Jutland, from selected municipalities within the County and Universities. Each project was partly funded by the public financial resources, partly by the participating partners, and partly the state. The Digital Hospital project had - among others - Institute of Health Science and Technology at Aalborg University, the County of North Jutland and Vendsysssel Hospital as partners. [ASB 2003]

Since January 2000, the project has now gone through one full first phase, where the basic system has been put into test-operation at Vendsysssel Hospital, Denmark, and at Bournemouth Hospital, England. [ASB 2003]

Main objectives of DiasNet

The aim of DiasNet, Diabetes Advisory System, is to provide an IT-based solution that helps involve type-1 (insulin dependent diabetics) in disease self-management. This is to promote a better understanding of the disease as well as a more effective control and treatment of the disease and its complications.

DiasNet incorporates a Bayesian network model of the human carbohydrate metabolism. This modelling paradigm is able to cope with the inherent uncertainty which is present in, e.g. blood glucose measurements and physiological variations in glucose metabolism.

DiasNet facilitates that patients enter retrospective data on carbohydrate intake, insulin injections and blood glucose readings. Based on this information and information about expected future carbohydrate intake the system provides a graphical overview of the data and estimates the future blood glucose profile and appropriate insulin dosages. Hereby, the patient has the possibility to experiment with data and learn how to optimize future insulin dosages according to carbohydrate intake. If the patient encounters a specific problem or has a question which cannot be handled directly by DiasNet the associated professional diabetes team at the health care clinic can be contacted and the uploaded patient data can be reviewed. A diabetes team typically consists of a medical doctor, a nurse, a dietician and a secretary. In this way DiasNet has two distinct user groups, i.e. a professional medical group and a patient group. Both groups interface the system via a web browser on a desktop/laptop computer. DiasNet is implemented as a client/server architecture.

At Vendsysssel Hospital, DK, DiasNet has already been tested as a fully web-based system and a special version of the system has been implemented at Bournemouth Hospital, UK, where SMS functionality has been added. Here the patient can also enter data via SMS and in return get a receipt or error message.

In Bournemouth, a SMS interfacing facility for DiasNet has also been implemented. Up to now, patients have had to enter their data into DiasNet via a web browser running on a networked PC. The patient typically does this by entering the data immediately after the specific values were known, but that would require access to a networked PC more times a day. Therefore, a common way of entering data is to collect the data during the day, write the values down on a piece of paper and then later, e.g. in the evening, enter the data into DiasNet using a networked PC, for example, at home. This way of entering data is a bit troublesome because paper notes tend to disappear and the patient have to write down the same information twice which make writing errors more likely and causes a waste of time. As a simple improvement to address these problems, a special SMS facility has been implemented.
so that patients can enter data immediately by using the SMS functionality in a standard mobile phone.

In connection with a meal, for example at 12:30, a patient may typically have to collect the following information: Measured blood glucose, e.g. 7.2 mmol/L, insulin injection, e.g. 6 units, and carbohydrate intake in the meal, e.g. 60 grams. The patient then simply writes an SMS message and sends it to a phone number held by an SMS modem connected to the DiasNet server. The phone number will, for convenience, be stored in the mobile’s phone book, and the server identifies the patient using a lookup table with information about the patients’ phone numbers. In this example, the message would be ‘b7.2 i6 m60’, and unless the patient includes info on the time in the SMS message, e.g. ‘t1230’, the server will automatically time stamp the data based on the time of the SMS. This way of entering data may solve the problem of the lost paper note, but it does not completely solve the problem of erroneous data. Even though the server may do some consistency checking on the message, it can not remove the risk of errors in the data.

The SMS functionality opens up for primitive, but truly mobile, interactions between the user and the system. Data can be entered and the user can receive an SMS feedback from the server if the server, for example, can not interpret the message, or as a confirmation of receipt. More sophisticated feedback is also, in principle, possible, but has so far, not been implemented.

**Introducing patients to DiasNet**

The introduction of DiasNet causes major changes in the way diabetes is controlled both by clinical staff and patients. The listing below summarizes a normal procedure when using DiasNet:

1. Patient enters retrospective data on carbohydrate content in meal(s), insulin injection(s) and blood glucose reading(s) if these data are not already present in the DiasNet database. Patient enters information on expected future meal(s) - or indicates that the future meal(s) will be identical to the previous. The data can be entered from any internet connected web browser.
2. Patient prompts DiasNet for advice on future insulin dosages. DiasNet could be running on a server at the outpatient clinic.
3. DiasNet calculates future insulin dosages and returns result to patient.
4. Patient encounters a specific problem/question which can not be handled automatically by DiasNet. So patient contacts the health care clinic and asks for personal assistance.
5. In the normal case, where the patient has not got a question that needs urgent attention, the patient will receive a periodical email feedback from the diabetes team when they have analysed the newly entered data. The diabetes team may also call the patient in for a routine check at the outpatient clinic.

The above-mentioned approach reflects a model and summary account of the practical uses of DiasNet. The individual elements of the model will be specified in greater detail below so as to give an idea of what it is DiasNet can do and how. In addition to the day-to-day practice outlined above, the patients are invited to attend an introductory course, called the diabetes school, in order to give the patients a good grasp of the programme before running it. Below
is a brief introduction to the programme and the ideas behind the diabetes school are presented. [ASB 2003]

**How patients can enter DiasNet data**

Each patient picks a three-day period that reflects a typical everyday routine in terms of sleep, exercise, food intake, etc., so as to prepare the required profile. Over the three days and nights, the patient will then complete the forms illustrated in Table 1 so that these data may subsequently be entered into DiasNet. The forms are handed out at the diabetes school. Table 1 shows a typically completed form.
<table>
<thead>
<tr>
<th>Time</th>
<th>Meal</th>
<th>Blood glucose [mmol/L]</th>
<th>Insulin units [S=short acting] [L=long acting]</th>
<th>Carbohydrates [g]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early morning: 645/700</td>
<td>½ slice of rye bread with cheese</td>
<td>14.2</td>
<td>S_3 / L_8</td>
<td>10</td>
</tr>
<tr>
<td>Late morning: 945</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lunch time: 1230</td>
<td>1 slice of rye bread + salad</td>
<td>17.1</td>
<td>S_6</td>
<td>20</td>
</tr>
<tr>
<td>Afternoon: 1530</td>
<td>Roll</td>
<td>8.7</td>
<td>S_3</td>
<td>35</td>
</tr>
<tr>
<td>Evening meal: 1730/1800</td>
<td>Potatoes + turkey + gravy</td>
<td>12.7</td>
<td>S_4 / L_10</td>
<td>40</td>
</tr>
<tr>
<td>Late evening: 2030</td>
<td>Chocolate</td>
<td>4.6</td>
<td>S__</td>
<td>20</td>
</tr>
<tr>
<td>Night: 2230</td>
<td></td>
<td>8.3</td>
<td>S__</td>
<td></td>
</tr>
<tr>
<td>Early morning: 700</td>
<td>½ slice of rye bread with cheese</td>
<td>18.5</td>
<td>S_6 / L_8</td>
<td>10</td>
</tr>
<tr>
<td>Late morning: 945</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lunch time: 1130</td>
<td>1 slice of rye bread + 3 sweets</td>
<td>15.3</td>
<td>S__</td>
<td>30</td>
</tr>
<tr>
<td>Afternoon: 1515</td>
<td>Chocolate &quot;snowball&quot;</td>
<td>5.7</td>
<td>S__</td>
<td>14</td>
</tr>
<tr>
<td>Evening meal: 1730</td>
<td>Vegetables, rissoles and rye bread</td>
<td>7.2</td>
<td>S_4 / L_10</td>
<td>40</td>
</tr>
<tr>
<td>Late evening: 2015</td>
<td>½ cheese roll</td>
<td>5.1</td>
<td>S_8</td>
<td>40</td>
</tr>
<tr>
<td>Night: 2245</td>
<td></td>
<td>4.8</td>
<td>S__</td>
<td></td>
</tr>
<tr>
<td>Early morning: 700</td>
<td>½ slice of rye bread with cheese</td>
<td>18.5</td>
<td>S_6 / L_8</td>
<td>10</td>
</tr>
<tr>
<td>Late morning: 1000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lunch time: 1300</td>
<td>1 slice of rye bread + greens</td>
<td>9.3</td>
<td>S_4</td>
<td>20</td>
</tr>
<tr>
<td>Afternoon: 1600</td>
<td>?</td>
<td>5.5</td>
<td>S__</td>
<td>8</td>
</tr>
<tr>
<td>Evening meal: 1730</td>
<td>Pasta salad + bread</td>
<td>8.9</td>
<td>S_4 / L_10</td>
<td>40</td>
</tr>
<tr>
<td>Late evening: 20</td>
<td>Ice cream + bread</td>
<td>9.9</td>
<td>S_2</td>
<td>45</td>
</tr>
<tr>
<td>Night: 2315</td>
<td></td>
<td>13.8</td>
<td>S_2</td>
<td></td>
</tr>
</tbody>
</table>

Table 1: Three-day profile of diabetic patient [ASB 2003]
Upon expiry of the three-day diary period the patients log on to DiasNet on the web site www.diasnet.dk by means of a designated user name and password. This prompts the screen layout in Figure 1, which constitutes the main window for patient actions and entries.

Figure 1: When logging in, the main window of the DiasNet user interface appears.

In the main window the patient enters his recorded diary data into the data entry fields which are seen in the lower left part of Figure 2.
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Carbohydrates

Data entry fields

Blood glucose

Long acting insulin

Short acting insulin

**Figure 2: DiasNet main window with entered patient data**

When the data has been entered into the data entry fields they will be graphically displayed in the top half of the window. The green bars show the carbohydrate content in the consumed meals, the red dots show the entered blood glucose concentrations, the bright and dark blue bars indicate the intake of long acting and short acting insulin respectively.

The data can now be used for analysis by the patient, the professional diabetes team at the clinic and DiasNet. How the analysis is conducted is described in the next section.

**How the clinic can analyze entered DiasNet patient data**

Once the patient has entered his three-day profile in DiasNet, the next step is a review by the diabetes team. At Vendsyssel Hospital (Denmark) this took place in weekly joint sessions attended by the nurses and the doctor in order to evaluate the previous week’s data entries. Every patient was given a specific contact with the team of diabetes nurses and the doctor throughout the programme. After the weekly session, every patient would be notified, usually by email, by their individual contact concerning possible adjustments in insulin dose or blood glucose testing frequency. [ASB 2003]

Firstly, the data will be reviewed for episodes of counter-regulations, which is the body’s natural way of reacting to hypoglycaemia. Approximately 6 hours after an episode of hypoglycaemia the body elevates the blood glucose concentration and this elevation may last for up to 18 hours. Currently DiasNet can not predict and simulate the effect of counter-reaction, so that effect has to be handled manually in order to have DiasNet provide proper guidelines for insulin dose adjustments. In the data set used here there is most probably a case of counter-regulation, which can be identified as the discrepancy between the peaks at the arrows in Figure 3.
Figure 3: DiasNet’s prediction of blood glucose concentration vs. actual concentration

The red curve shows the blood glucose prediction generated by DiasNet and the red dots interconnected by black lines show the actual blood glucose measurements. It is not within the scope of this project to elaborate on the accuracy of the prediction, but in general, it seems that the prediction follows the trace of the actual concentration, although somewhat in advance in the Monday and Tuesday time slices.

After handling the counter-regulation manually DiasNet can now perform a proper simulation which reflects the normal response to carbohydrate and insulin intake.

Figure 4: Analysis and experiments with a single day

In the scenario illustrated in Figure 4, it has been chosen to analyse and experiment with the third day of the three-day profile, i.e. the day on the right in the top half of the screen. This
screen dump does unfortunately not exist in an English version, hence this Danish version. As
the simulation now shows in the lower half of the screen, DiasNet suggests that the patient on
this specific day, with this specific carbohydrate intake, could well have reduced his morning
insulin dose from 6 to 2 units; altogether omitted the 6 units injected at 10.00 a.m. and
increased the evening insulin from 4 to 6 units. This very brief analysis alone does not justify
a change in the patient’s insulin dose, but if a pattern emerges in the analysis of several days
over a longer period of time, a change in the insulin regimen would be worth considering.

Although DiasNet does not model the effect of counter-regulation it still provides a good
graphical tool for visualising the episodes. This helps to improve the patient’s ability to
prevent the episodes of hypoglycaemia that occur 12-18 hours before the elevated blood
glucose concentration sets in, and the treatment may be aimed at these episodes of
hypoglycaemia. This is preferable to treating the elevated blood glucose levels with insulin,
which is often the case today.

When the diabetes team has completed the above-mentioned analysis of patient specific data,
one of three possible follow-up options is selected: 1) The patients receive feedback by email.
2) If major adjustments are required, the patient is summoned for consultation at the clinic. 3)
If the patient specific data are satisfactory, there is no reason to waste resources on a clinical
review and the patient may thus not necessarily be contacted again until the renewed entry of
a three-day profile via DiasNet, which will again be analysed by the diabetes team.

3. **DiasNet Mobile - Vision**

This section illustrates some of the visions for the DiasNet Mobile service and thus some of
the issues being worked towards.

Figure 5A illustrates how DiasNet Mobile generally is envisioned in a MAGNET context and
Figure 5B shows a close up of the patient’s P-PAN. See [D1.2.1 2004] for a detailed
explanation of the set-up. Abbreviations used in Figure 5:

- **VR-Dev**: Vibrating Receiver Device. Robust device able to alarm the diabetic with
  vibration, sound and/or light when preset events occur, e.g. hypo-glycaemia and
  hyper-glycaemia. Used when doing sports or in any other situation where
  monitoring/alarming is wanted.

- **IM-Dev**: Intelligent Monitoring Device: A wearable device which in the future is
  build discretely into, e.g. a wrist watch or a standard mobile phone. The IM-device
  communicates data via manual user input and automatically via the wearable
  Intelligent Blood Glucose meter (IBG-meter) and via the Intelligent Insulin pen (II-
  pen).

- **IBG-Meter**: Intelligent Blood Glucose Meter: The IBG-meter continuously measures
  the glucose concentration and wirelessly transmits the readings to the II-pen and the
  IM-device. An appropriate insulin dosage is calculated by the IM-device and the
  results are forwarded to the II-pen so the patient can administer the correct insulin
  dosage. If the patient decides to administer the advised insulin dosage the IM-device
  logs the dosage; if the patient decides to administer a dosage different from the
  advised one, the IM-device logs both the advised and the administered dosage.

- **II-Pen**: Intelligent Insulin Pen: For administering insulin dosages and logging dosage
  quantity time and date.
Figure 5: A. Envisioned DiasNet Mobile in a MAGNET context. B: Patient’s P-PAN close-up. (From [D1.1.2 2004])

Table 2 lists some of parameters for the setup shown in Figure 5.

<table>
<thead>
<tr>
<th>Device no.</th>
<th>Data flow</th>
<th>Position</th>
<th>Type</th>
<th>Data block size</th>
<th>Block rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0↔1</td>
<td>As a normal cell phone</td>
<td>IM-Dev</td>
<td>Arbitrary</td>
<td>Arbitrary</td>
</tr>
<tr>
<td></td>
<td>0↔2</td>
<td></td>
<td></td>
<td>1024 bit</td>
<td>1 bl/min</td>
</tr>
<tr>
<td></td>
<td>0→3</td>
<td></td>
<td></td>
<td>1024 bit</td>
<td>1 bl/s</td>
</tr>
<tr>
<td></td>
<td>0↔4</td>
<td></td>
<td></td>
<td>64 bit</td>
<td>0.5 bl/s</td>
</tr>
<tr>
<td>1</td>
<td>1↔0</td>
<td>Body worn</td>
<td>II-Pen</td>
<td>1024 bit</td>
<td>1 bl/min</td>
</tr>
<tr>
<td></td>
<td>1↔2</td>
<td></td>
<td></td>
<td>1024 bit</td>
<td>1 bl/s</td>
</tr>
<tr>
<td>2</td>
<td>2↔0</td>
<td>Body worn</td>
<td>IBG-Meter</td>
<td>1024 bit</td>
<td>1 bl/s</td>
</tr>
<tr>
<td></td>
<td>2↔1</td>
<td></td>
<td></td>
<td>1024 bit</td>
<td>1 bl/s</td>
</tr>
<tr>
<td>3</td>
<td>3↔2</td>
<td>Body worn</td>
<td>VR-Dev</td>
<td>64 bit</td>
<td>0.5 bl/s</td>
</tr>
<tr>
<td></td>
<td>3↔0</td>
<td></td>
<td></td>
<td>1024 bit</td>
<td>10 bl/s</td>
</tr>
</tbody>
</table>

Table 2: Description of some of the parameters for the DiasNet Mobile envisioned set-up. (See WP3 work for further details.)

The end-user workshop conducted in August 2004 at AAU (see [D1.2.1 2004]) yielded the basic idea of having at least four different diabetes service profiles, one for each of the four different stages in life. The principle is shown in Figure 6 along with keywords for each stage. See [D1.2.1 2004] for further details.
Figure 6: Four stages in a diabetic's life should be represented in the service's profile. (From [D1.2.1 2004])

3.1 **SW - Overall system architecture**

This section describes the overall system architecture of DiasNet Mobile. The main components and their communication protocol of the system are illustrated in Figure 7.
Figure 7: Overall system architecture. It is possible to connect several cell phones and desktop PCs to the server simultaneously.

The architecture consists of two types of networks: HTTP and Bluetooth. The HTTP network is made up of one server and a number of cell phones that function as clients. The Bluetooth network consists of one blood glucose meter and one cell phone. In this implementation the nodes and their interconnecting link is fixed and thus is a simulated MAGNET ad-hoc network. In later implementations this fixed setting should be dynamic and established according to the underlying MAGNET network technologies.

Each user of the system has one cell phone and one blood glucose meter. When the user performs a measurement on the meter the cell phone is able to automatically collect the value of the measurement from the meter. After collecting the measurement the cell phone sends the measurement to the server where it is stored in a central database. Besides this automatic collection from the meter it is possible to manually enter comments and measurements of insulin dosage, carbohydrate intake, minutes of physical exercise (and intensity of exercise) and blood glucose concentration values. Manually entered data are, like the automatic collected blood glucose measurements stored in the central database.

At any given time, the user of the cell phone is able to retrieve stored measurements from the server. The user must specify a period of time and the measurements from this time period will be presented in form of a table or a graph. In case of a graph representation of the
measurements an associated simulation of the blood glucose level will be visible along the graph. Also, a forecast based on fictive expected data can be provided for pro-active disease management. The server can connect to a DiasNet simulation-server, which is able to perform blood level simulations based on a set of measurements. Furthermore, all measurements send from the cell phone can be stored on DiasNet using a user’s account provided that the username and password to the DiasNet account is known in the central database.

Table 3 sums up the functionalities of DiasNet Mobile.

| 1. Automatically collect blood glucose concentrations via Bluetooth from a blood glucose meter and store these measurements in a central database. |
| 2. Accept manually entered blood glucose measurements and other disease related data to be send and stored in the central database. Disease related data are the following: |
| a. Insulin intake: Type, amount, date and time. |
| b. Blood glucose concentration: Measured concentration, date and time. |
| c. Carbohydrate intake: Amount, date and time. |
| d. Physical exercise: Duration, intensity, date and time. |
| e. Comment: Any string of text, numbers and special characters to comment on any event, date and time |
| 3. Simulated blood glucose concentrations can be calculated on basis of entered and/or expected data in order to provide pro-active disease management. |
| 4. Graphically present stored data within a certain period of time as |
| a. Tables: Data sorted by date, time and type (type sorting is an option). |
| b. Graphs: Blood glucose measurements with an associated simulation of the blood concentration, insulin intake and carbohydrate intake. |
| 5. Settings: The user can set different options like make/model of short and long acting insulin, username, level of verification of incoming and send data etc. |
| 6. All functionalities (except no. 1) are also present in a desktop version of DiasNet. Health care clinics are using the desktop version whereas diabetics may use both. |

Table 3: Overall functionalities of the DiasNet Mobile service.
4. **MoDiaMan - The Mobile Diabetes Manager**

### 4.1 Contents:
Based on the information given in this note and the presentation by Christian Fischer Pedersen, your task is to design a mobile support service for diabetics (denoted “users” in the following description). The platform could be a mobile phone (with a minimum graphical display), a smartphone, a PDA or similar. Assume that GPRS (max. 20 kbits/sec transfer rate, 10 kr/MByte) are available on the device for communication with the server.

It should interface to the “DiasNet” WWW service outlined in the previous sections and facilitate the recording, storing and presentation of information important to the user. Basically, the core functionality should be similar to that of DiasNet.

Examples of core functionalities are:

- Blood glucose level (may be entered directly by Bluetooth or manually by the user)
- Insulin injections
- Food consumption (carbon hydrate)
- Exercise
- “Unusual behaviour” (e.g. comments about alcohol consumption, other diseases or drugs, etc)

Additional functions, such a warning system and a messaging service may be included.

The service must be capable of presenting these parameters in a way easily perceived and accessed by the user (using e.g. graphics, tables, etc). The information must be uploaded to the DiasNet server, and a clear indication must inform the user that this has happened.

Some of the important design requirements, which you must take into account, are:

- Consistency with the existing DiasNet service – it is important that users can recognise the parameters and usage patterns independently of the platform
- Error messages (for e.g. failed upload) must be presented to the user so s/he always knows the status of the measurements
- Consider the environment – the service is mobile, and will be used in many different contexts and places. E.g. outside network coverage, so a temporal local storage must be available.

### 4.2 Tasks in the Miniproject:

- **Analyse** the requirements of the intended users, the tasks and the contexts in which MoDiaMan will be used in order to build a conceptual model. In addition to this note you can also take a look at [http://www.diasnet.dk](http://www.diasnet.dk) ([http://www.b-dec.com/index.asp](http://www.b-dec.com/index.asp)). We have made a test account available for you on the Diasnet server so you can inspect the user interface and functions.
- Define the functionality and constraints in detail based on the above.
- Start the design based on the requirements and the conceptual model. Make a first prototype using simple paper sketches, e.g. showing the sequence of screens and operations by connecting them by arrows or similar. This is called a **Lo-Fidelity Prototype**.
• **FIRST MILESTONE:** Present your conceptual model, the requirements, metaphors, you based your design on, plus of course your Lo-Fi prototype at plenum in MM5 (alternatively MM6).

• **Design** the user interface in details. Note! It is not sufficient just to draw a number of GUI screens. Each drawing/screen shot must be described and the functions explained in a level of detail to ensure that those seeing it can understand the design. This must be done in a short report or even included in a powerpoint presentation documenting the miniproject.

• **Implement** the second prototype. We recommend that you use MS-Powerpoint or similar to implement the final (hi-Fidelity) prototype, as this has capabilities for animations, links, etc. making it a good tool for rapid prototyping. If you have the time, or prefer to do so, you might instead build part of the interface in Java, C#, html, php, etc using e.g. a browser or an emulator to run it. **However, as the focus is on design we do not expect you to actually implement the ModiaMan!!** One of the important points about UI design is that you can actually test a lot of the design without/before you actually implement it. See below.

• **Evaluation:** All the groups’ designs must be tested in the usability lab. Each group will act as test persons for other groups’ designs.

• **SECOND MILESTONE:** The final prototype and test results will be presented in plenum in MM10, and made available at the course homepage.

**HI-Fidelity prototype development:**

About the Implementation: The main focus is on the UI design, so there is no requirement for you to actually fully implement your mini project. However, this can be achieved by a relatively small extra effort, either by using MS-Powerpoint to simulate the service, as mentioned above. Alternatively, you can use the html, php, asp or similar to create a interactive GUI with the chosen form factor, but displayed in a standard browser.

**4.3 A Final Note**

The HCI course is a PE course and therefore there is no explicit exam. However, we encourage you to participate actively in the mini project, as your gain from the course is highly dependent on yourself being active. HCI can only be thoroughly understood by actual “experiencing it on your own body”.