

# Image Acquisition System to Monitor Discomfort in Demented Elderly Patients

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**Abstract**—Epidemiological research shows that 5% up to 10% of the population older than 65 years is suffering from dementia. With the increased live-expectation, the chance of obtaining dementia, is increasing too. One important and underestimated aspect is discomfort (pain) in our target group. Recognition of pain is therefore an important issue for the caregivers. The purpose of our project is to present a way of monitoring the non-verbal expressions of patients with severe dementia by means of a vision system and to identify discomfort in real-time by means of pattern recognition techniques. This system can constantly monitor the patient and alarm a caregiver when the patient reaches a certain critical level of pain.

This paper describes the setup of the acquisition system to obtain high quality stereo images of the patient's face together with pain indicator information provided by a pain expert. This acquisition system must meet the requirements enforced from technical point of view (frame rate, resolution, etc.) as well as from medical point of view (simple to use, do not disturb the natural look of a patient room, etc).

**Index Terms**— discomfort, pain, monitoring, dementia, image acquisition system

## I. INTRODUCTION

IT is commonly known that the number of elderly in the western countries, also in Flanders, is increasing. As dementia is strongly related with age the number of patients with dementia are increasing. Indeed Roelands M. et al [1] and the results of the Belgian National Institute for Statistics, published in Pfizer [2], have shown that the number of elderly with dementia increases from 160 000 in the year 1995 to 173 000 in the year 2000 in Flanders. These studies expect that about 215 000 persons in Flanders older than sixty years suffer from dementia in the year 2010.

In our study we are focusing on the patients who are

suffering from severe dementia. These patients are dependent on the caregivers, bedridden, and not able to verbally communicate with their environment.

One important and underestimated aspect is pain in this group of patients. Several studies prove that about 70% of the people living in nursing homes struggle with pain. Almost half of them have chronic pain [3]. Pain defined by the International Association for the Study of Pain (IASP) is an unpleasant sensory and emotional experience associated with actual or potential tissue damage, described in terms of such damage defined.

As demented elderly cannot communicate verbally anymore [4] – [6], pain is often underestimated for this group [3], [7]. Recognition of pain is therefore an important issue for the caregivers [7] – [9].

To quantify pain there are a lot of tools available. These tools, also known as pain scales, are developed and validated for a specific target group. But each pain scale has its own application area, and requires trained experts to use them.

Pain scales are not often used in the nursing field for our target group (elderly patients suffering from severe dementia) as they are experienced not to be user friendly. Most of the time the caregivers rely on their “subjective” experience to quantify pain. The most important factor in their decision to quantify pain is the facial expression of the patient. Several studies have shown that facial expressions are useful pain indicators for elderly [5], [9]. It also has been shown that facial expressions are even more correlated with physiological indicators of pain than e.g.: heartbeat and blood pressure [5]. However, the interpretation of these facial expressions by the caregivers is not objective and not on a continuing basis.

The overall goal of our project is to setup a low-cost vision system which can continually identify discomfort in real-time by means of facial pattern recognition techniques. In this paper we discuss setting up a vision system to monitor the patient's face and to store the recorded images.

## II. PATIENTS

### A. Patients

Our target group is defined as demented elderly suffering from Alzheimer dementia. Referring to the “Diagnostic and Statistical Manual of Mental Disorders” (DSM) [10] and the

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“Global Deterioration Scale” (GDS) [11] we are focusing on patients suffering from severe dementia. On the GDS our target group is classified with level 7, which is the highest level available on this scale. Using the “Functional Assessment Staging” (FAST) [12] our target group can be situated between 7b – 7f which means they can not speak anymore (FAST 7a [12]), they have lost all intelligible vocabulary (FAST 7b [12]), they are non-ambulatory (FAST 7c [12]), they are unable to sit up independently (FAST 7d [12]), they are unable to smile (FAST 7e [12]), and they are unable to hold up their head (FAST 7f [12]).

As soon as retirement home residents were classified level 7 on the GDS [11] and their family gave an informed consent, they were included in the study.

### B. Assessment Tools

To be able to quantify pain on a valid way there are pain assessment tools available. These tools a nurse or a pain expert can use to exam the patient during a predefined period and fill out the corresponding items on the pain scale. The result will indicate the level of pain the patient currently struggle with.

The following pain assessment tools are chosen: “Pain Assessment Checklist for Seniors with Limited Ability to Communicate” (PACSLAC) [13], the “Pain Assessment IN Advanced Dementia” (PAINAD) [14], and the “Discomfort Scale – Dementia of Alzheimer Type” (DS-DAT) [15]. This because these pain scales has a lot of facial expression related items which must be scored to quantify pain.

## III. IMAGE ACQUISITION SYSTEM

The first step of this study is to observe and record the patient’s face based on the input of two cameras, one at each side of the bed as at least one of the two cameras should capture a frontal view of the patients face. To get a complete overview of the width of the bed, the position of the cameras and the lenses must be chosen carefully. It is also important to create some overlap in the two camera views. This additional (overlap) information is useful as we want to get three-dimensional information of the face.

During the time a patient is monitored, a pain expert will quantify (rate/score) the pain using a software version of the selected pain assessment tools (pain scales). As a software version of the pain assessment tools is developed, pain indication items (labels) are stored automatically in a general database with additional an exact time indication of occurrence. This way the software is not only taking notice of the presence/absence, intensity or total time of a pain indicator but also the relative timing of every pain indicator. Although few attempts are made to prove the relation between the timing of expressions and emotion of a person it is assumed very valuable. Including timing information is a new trend in the field of automatic spontaneous expression classification [16] [17] with very promising results.

### A. Camera

We have chosen high-end cameras as it is yet not clear whether the performance of the image processing algorithms is dependent on the image quality. The main requirements for the camera to provide these high quality images are: resolution, speed (images per second), color, format (acquisition of raw images must be available), connection, and the ability to trigger the camera. An image resolution of 1032 x 778 pixels seems to be sufficient. Also these images must be taken at high speed (thirty frames each second is our guideline) to identify short twitches in the facial expression. It is also not efficient to speed up the frame rate because a human eye can not see faster movements as long as our eye is the golden reference to interpret images. Due to these constraints there will be a huge amount of data to be collected and handled in a short time frame. Therefore a fast and dedicated communication line, like IEEE 1394 FireWire, between the camera and recording device is required, if we want to avoid the usage of a frame grabber.

These requirements led us to the AVT Guppy F-080C of Allied Vision Technologies GMBH. This color camera is very compact (48,2mm x 30mm x 30mm (L x W x H) without tripod and lens) and can be triggered externally which is useful since we want to have synchronized images.

### B. Acquisition System

The recording device is a simple computer configured for recording and storing the images, as well as for storing the label information provided by a pain expert during a recorded pain assessment session. Because the recording device will be located in the patient’s room, the noise produced by the recorder must be as low as possible.

As base configuration we have chosen a Dell Dimension 9200 Core 2Duo E6300 1.86GHz (1066MHz) 2048MB Dual Channel DDR2 533MHz.

Because of the Guppy F-080C cameras we should provide two FireWire connections on the recording computer. We have inserted two PCI-FireWire cards to have one FireWire controller for each camera separately. Although FireWire is a synchronized bus running at a maximum of 400MBit/sec, the “Digital Camera Specification” (DCAM) protocol is used. The use of this protocol limits a maximum throughput of 30-40MBit/sec per controller.

When we are recording at thirty frames each second, at full resolution (1032 x 778 pixels) in color, the hard disk is storing about 60Mb/second recording data (from the two camera’s tighter). To improve the capacity and writing speed of the hard disk we have chosen to setup a RAID-0 configuration. (Redundant Arrays of Independent Disks: RAID 0: also known as a striped configuration which provides an improved performance and additional storage but no fault tolerance.) The recording computer does now consist of three hard-disks and a RAID-controller which is configured as RAID-0 together with the three hard disks. This allows us to have a writing speed and capacity about three times more than the speed and capacity of one single hard disk. The raid-controller



Fig. 1. Flexible camera stand placed in the patient's room

used is an Adaptec RAID 1430SA with an a PCI Express x4 slot. This controller supports up to four SATA hard disks.

To be able to make full advantage of the AVT Guppy F-080C camera we use StreamPix4 as recording software. StreamPix 4 is a specialized program designed to provide real time digital video recording to computer memory or hard disk. StreamPix 4 also allows the use of native AVT drivers so all the capabilities of the camera can be used. Providing the hardware is adequate, video may be streamed at full frame rate of a camera without dropping any frames. StreamPix 4 allows us to record the un-compressed images directly on the hard disk in StreamPix proprietary sequence files (\*.seq). One sequence file contains all the images taken during one recording session together with the absolute timestamp of each individual image taken (millisecond resolution). A sequence file can be converted afterwards into more common formats like JPEG, compressed or uncompressed AVI files etc. Another advantage of the usage of StreamPix's sequence file is the optimal disk usage because the images are stored into one big file in stead of separate images, which leads into inefficient usage of disk space.

Synchronization of the images (made by the two cameras) can be guaranteed by using the external triggering port of the AVT Guppy F-080C cameras. A self-made trigger circuit based on a simple timer 555 (LMC555 CMOS Timer of National Semiconductor) realizes a-stable multi-vibrator which generates a block-wave with a frequency adjustable between 4Hz and 40Hz. This block-wave is the input for the two cameras, enabling them to synchronously take images.

The recording equipment also exists of a simple and flexible camera stand which we had to design. It may not disturb the "domestic" atmosphere of the rooms at the retirement home. An initial design is illustrated in figure 1.

Finally, to inform the nurses that a recording is taking place, we have provided small indicators, by means of LEDs. Several settings are possible: "powered-on and ready to record" (green LED), "recording" (orange LED), or "an error

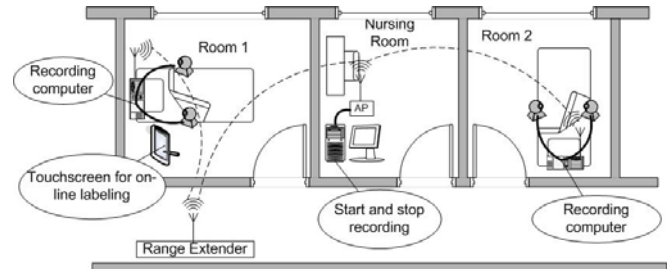


Fig. 2. Overview of the position of the recording devices communicating via a Wireless Local Area Network

occurred" (red LED). These LEDs are controlled by the recording tool (which will be discussed in the next paragraph). Via a simple Velleman USB (K8055) experiment board we control 4 digital outputs. Three outputs are used for the LED indicator, one is used to start and stop the trigger circuit.

### C. Software

To make recording easy for non-technical staff, we developed a recording tool. This tool consists of two major parts, a client and server part. The client controls the recording equipment (start and stop the recording sessions) and runs on a central computer which is located on a central place, in this case the nursing room. The computer in the nursing room (client) will communicate with the recording computer (server) in the patient's room via a secured Wireless Local Area Network (WLAN). An overview is provided in figure 2. On the recording computer, the client program controls the status LEDs, the trigger circuit. StreamPix 4, as recording software, is also running on this computer and is responsible to record and store the images.

As last tool we have developed a labeling tool. This is a software program running on the computer located in the patient's room and provides an "automated" way of filling out the selected pain scales. We have developed a Graphical User Interface (GUI) where a trained pain expert just has to click a button as an event of a pain indicator occurs, according the definitions explained in the pain scale. The GUI is displayed on a touch screen which makes it the pain expert as comfortable as possible. All the information which is collected during this session will be stored in a database. In that way we can also trace the exact time when some event occurs, just by adding a timestamp into the database record for this event.

## IV. CONCLUSION

A stereo-vision acquisition system with high-end cameras is built for the purpose of detecting discomfort by patients with dementia. It is tested and it provides us the images we want to develop the algorithm. Furthermore a software labeling tool with touch-screen is developed to facilitate labeling and providing additional timing information of indicators. This tool enables the pain experts to perform bed-side labeling.

## V. FUTURE WORK

Detection algorithms will be developed in MATLAB, based on the images taken by the acquisition system described in

this paper. The recorded images are labeled by pain experts using validated pain classification tools, to quantify the pain (discomfort). This golden standard data-set will be used to develop pattern recognition algorithms to identify discomfort. These algorithms need to be translated and integrated into an application running on a simple computer, or even on some programmable hardware devices such as an FPGA and DSP. These devices must be able to process the images in real-time and reduce the data transfer to the caregivers.

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