# DATA COLLECTION WITH "UYANIK": TOO MUCH PAIN; BUT GAINS ARE COMING

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## ABSTRACT

In this paper, we present data collection activities and preliminary research findings from the real-world database collected with "UYANIK," a passenger car instrumented with various sensors, CAN-Bus data logger, cameras, microphones, data acquisitions systems, computers, and support systems. Within the shared frameworks of Drive-Safe Consortium (Turkey) and the NEDO (Japan) International Collaborative Research on Driving Behavior Signal Processing, close to 9 Terabytes of driver behavior, vehicular, and road data has been collected from more than 50 drivers on a 25 km route consisting of both city roads and highway in Istanbul, Turkey. Challenge of collecting data in a metropolis with around 12 million people, famous with extremely limited infrastructure yet driving behavior defying all rules and regulations bordering madness could not be "PAINLESS." Both the experience gained and the preliminary results from still on-going studies using the database are very encouraging and give comfort.

## 1. INTRODUCTION

Every year, more than three million traffic accidents cause in excess of 40,000 deaths worldwide. Driver error has been blamed as the primary cause for approximately 80% of traffic accidents. For instance, in 2005 there were more than 3,200 fatalities and 135,000 plus bodily injuries in over 570,000 traffic accidents in Turkey according to the Turkish Traffic Education and Research Directorate. Furthermore, it has been estimated that the long-term economic loss emanating from these accidents is over US$6 Billion, which puts a rather significant burden on national budget. Albeit some variations, statistics from many other countries spanning the globe are very similar.

In 2004, Drive-Safe (DSC) Consortium, an academia and industry research partnership has been established in Turkey to create conditions for prudent driving on highways and roadways with the purposes of reducing accidents caused by driver behavior and to offer more amenities [1]. Drive-Safe objectives consist of but are not restricted to:

- DSP Technologies for driver identification based-on multi-sensory behavioral and analog driving signals.
- Driver modeling for personalization of driving environment.
- Framework for automated detection of abnormal driving behavior from multiple sensors (audio, video, and driving signals).
- Development of technologies for "passive" assistance to mitigate abnormal driving.
- Development of technologies for "active" assistance to reduce abnormal driving.
- Ad-Hoc vehicle-to-vehicle communication for driving assistance.

To achieve its objectives, collection of critical real-world data from multiple sensors (cameras, microphones, CAN-Bus and other means) is required to build a coherent database on driver behavior, vehicle and road conditions.

It is not difficult to guess characteristics in driving behavior differ from country-to-country according to their cultural and social backgrounds. Under the flagship of Nagoya University, an international alliance has been established in 2005 with several research groups in the U.S., Japan, Turkey, Italy and Singapore to share the worldwide driving, road and vehicle-specific data obtained from 450 drivers (NEDO Alliance). Towards that end, three vehicles -- "UYANIK" in Istanbul, "Nagoya Vehicle" in Japan and "UT-Drive" in Dallas, Texas, USA-- have been equipped in cooperation with each other [2,3]. Data collection is underway in three countries with potential of an ISO application in this area [4].

In this study, we will be focusing on the data collection effort with "UYANIK" and the preliminary findings by a number of members of the DSC in Turkey, who are also participating in the NEDO Alliance. Activities of alliance members from other countries are reported elsewhere in this biennial.

This paper is organized as follows. Section 2 discusses the instrumented vehicle, joint requirements of DSC/NEDO, sensors, and data acquisition systems. The selected data collection route, tasks, driver profile, and some challenges faced, --both resolved and un-resolved "pains"--is addressed in Section 3. Signal samples are presented in Section 4. Next, research activities of Drive-Safe consortium using collected data are highlighted in Section 5 as "Gains are Coming." In continuing, preliminary findings from the student projects are mentioned in Section 6. Finally, Section 7 concludes the planned study with future work.

## 2. "UYANIK" DATA COLLECTION VEHICLE AND SENSORS

**Vehicle:** "UYANIK," –awake—is a Renault Megane sedan donated to the consortium by OYAK Renault of Turkey after many task-specific retrofitting done in the factory to serve the needs in this project. (Figure 1) Modifications include special fortified front bumper, high power battery, 1500 watts DC-AC converter, CAN-Bus output socket, navigator seat and instrument bench, and re-wiring for power and signaling.


Figure 1. "UYANIK" Data Collection Vehicle

**Sensors:** The list of sensors are given in Table 1 and the complete system layout for sensors, data acquisition systems, and wiring is shown in Figure 2 at the end.

There are two sets of cameras –one set for daylight and another for night vision—configured to give facial shots of the driver from both sides (stereo vision applications and better tracking of the facial behavior) and a third one pointed to the road ahead as could be seen in Figure 3. Four audio recordings are made by a lapel microphone and/or a headset, and two microphones one on rearview mirror and another at the back of the head rest on the driver seat to capture the chamber noise and the conversation with the navigator. The human navigator is normally silent and keeping tract of recording process except assistance when needed. Fourth microphone is the audio recording made from the microphone of the mobile phone and located on the chest of the driver used for dialog.

An 180$^o$ laser scanner reads 181 x-y distances of the objects/vehicles in its range. Break pedal pressure reading from a sensor connected to the pedal, several sensor outputs from the CAN-Bus socket of the vehicle, acceleration in xyz directions by an IMU device, location information from a GPS receiver are recorded at the sampling rate of the CAN-Bus. A 20-channel portable EEG subsystem is available for ground truth experiments.


Figure 3. Sensors in the data collection vehicle upperleft clockwise: cameras, navigator area and lab bench for data acquisition systems, laser scanner, IMU XYZ accelerator, break pedal pressure sensor, headset/mics, and EEG cap.

**Joint Requirements:** In the data collection phase, the DSC/NEDO teams have come with the following desirable data set:

- 3 channels of video capture (left and right view of the driver and the road ahead) at 30 frames per second uncompressed initially and a fourth 360$^o$ dome camera in the future. This corresponds to 140-200 GByte of data per driver (BIG PAIN) for frame-accurate audio-visual face tracking and recognition tasks. For Nedo Alliance, only two channels of compressed video at 3.0 Mbits/s version was sufficient.

- Three audio recordings –lapel/headset, rearview mirror, chamber noise, and the dialog over the mobile phone at 16,000 samples per second with 16-bit resolution.
- Vehicle speed, engine RPM, steering wheel angle, head distance, location, EEG (only for grown-truth experiments), break pedal and gas pedal status readings sampled at 1.0 kHz rate. It was desirable to have vehicle-based ones directly from the CAN-Bus (BIG PAIN).
- CAN-Bus Readings: Even though, most manufacturers claim that their unit complies with the standards but the formatting (data packaging) is proprietary. Break pedal status (pressed/idle) and gas pedal percentage (engagement percentage) are to be recorded together with the speed and RPM at the rate permitted by the manufacturer. Renault Megane is designed to sample either at 10 Hz or at 32 Hz. They need to be re-converted to 1000 Sa/second off-line.
- Break pedal pressure sensor readings were initially recorded just like audio (BIG PAIN). This signal is now digitized by an independent 2-channel A/D and incorporated into the data recording system in a laptop together with CAN-Bus signals. In the next phase of the data collection effort, the accelerator pedal pressure will be digitized by the unused 2nd channel of this A/D
- Data collection route to include both city roads and highways and not to exceed 30 km and 45 minutes.
- Free driving, query dialog with an human operator at the base station and an automatic speech recognizer (ASR), road sign/navigational message readings, and music search. In DSC, a reliable music search subsystem could not be developed and postponed to the second phase. (PAIN)

**Data Acquisition Systems:** Data is collected by three acquisition systems synchronized with each other.

- **Video Acquisition:** Uncompressed digital recordings of video from three cameras with 30 frames per second and a frame size of 640x480 was achieved by a semi-custom StreamPix digital video recorder from NORPIX. Each video channel is recorded into a separate 750 GB HD with a separate firewire connection and the total HD budget per driver is about 150 GB. At the end of each week, the data is archived into HQ tapes. (TOO MUCH PAIN)
- **Audio Acquisition:** Alesis ADAT HD24 Data Acquisition System is used for audio recordings. Four microphone channels and a sync signal between the two acquisition systems were sampled at 48 kHZ and 24 bits per sample. Later these are converted to 16 KHZ and 16 bits off-line. (PAIN) In addition, break pedal pressure reading was initially fed into this system, but the signal was unacceptably noisy and it became useless. (PAIN)
- Acquisition of CAN-Bus signals, laser scanner, GPS receiver, break pedal sensor and IMU XYZ Accelerator was realized over USB and RS232 PCMCIA ports of a notebook computer using a custom software developed by two of the authors listed above from the Mekar Labs and Autocom Center at the Technical University (ITU) of Istanbul, -- a DSC partner. (TOO MUCH PAIN)
- At the time of this writing, the following data --common to DSC and NEDO-- is recorded at 32 samples per second: Engine speed, RPM, steering wheel angle, break pedal status, percent gas pedal position, break pedal pressure, gas pedal pressure (not connected yet), clutch status, rear gear engagement status, and individual tire speeds. In addition, the laser scanner readings (one per second), IMU readings and GPS location information is recorded by this notebook. Undependable behavior of the GPS receiver was overcome by a second location tracking system donated by Satko, a DSC sponsor. This alternate location information is tracked and recorded at the base control center located at the ITU campus.

## 3. DATA COLLECTION: PAINS AND FUN

**Route:** Data collection has started and ended at the OTAM Research Center in the ITU Campus in Ayazaga, where UYANIK was housed. The navigator and the server for data storage are also located there. The data collection route is little over 25 km.

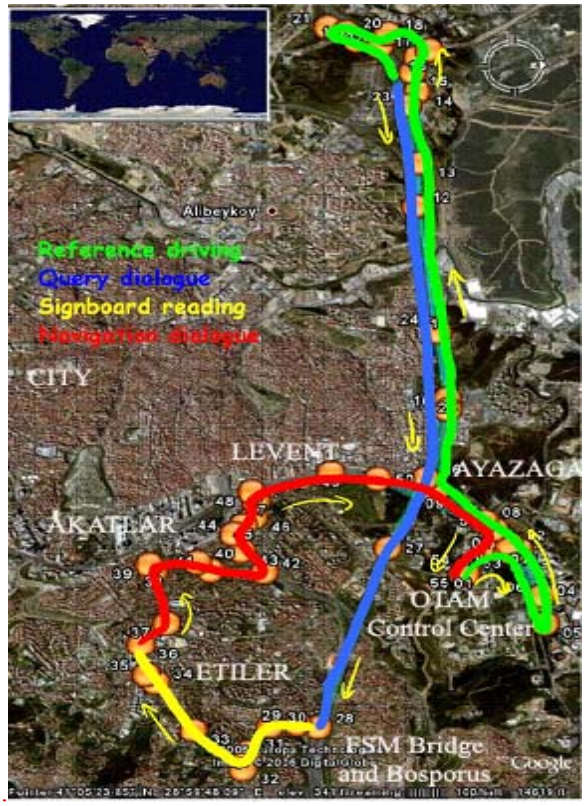


Figure 4. DSC/NEDO Data Collection Route in Istanbul.

It consists of a short ride inside the campus, followed by two 1.5 km very busy city thoroughfare sections, where a major construction is taking place to build a metro station.

Next comes the TEM Motorway towards the Airport. The route exits the first exit and makes a U-turn and travels towards the FSM Bridge. The route exits at the Etiler exit and the rest of the route goes through city streets in Etiler, Akatlar, Levent, 4.Levent, Ayazaga, and back to OTAM at ITU campus. The last segment is very busy with bumper-to-bumper local traffic. Data collection in this route has been a major challenge in a city of around 12 million, famous with extremely limited infrastructure, full of drivers defying all rules and regulations, and the complete lack of courtesy to other vehicles and pedestrians around. Hence, the driving experience can be described as an art bordering madness.

**Data Collection Tasks:** As marked on the route map, there are four primary tasks each driver goes through:

(1) **Reference Driving**: Here the driver gets used to the vehicle, the route and the tasks. Most drivers turn on the radio and they tune to their favorite station. It was planned to have an ASR-based music query in this segment. A homegrown package was experimented but the results were not satisfactory. For the second half of the data collection phase, a commercially available music search engine is being sought after.

(2) **Query Dialogue:** In this segment, each driver performs on-line banking using the cell phone mounted on the dashboard, which is programmed for speed dialing. He/she queries market prices of several national stocks using the on-line ASR-based service of a national bank. Here is a synopsis of the dialog:

ASR: **Please tell the full name of the stock after beep.**
Driver: **Arcelik**
ASR: **6 YTL & 58.** (if successful, a female operator)
ASR: **I did not understand please repeat after beep.** (if unsuccessful, a male operator)

(3) **Signboard Reading and Navigational Dialog:** The driver announces the road signs and other signs posted on boards and buildings. At the Etiler exit on TEM, the base station is dialed and the next phase of the route is verified. Sign reading continues for about 2 km together the license plates of the vehicles around. Both audio signals from the input and the speaker of the cell phone are recorded.

(4) **Pure Navigational Dialog:** After completing the very busy segment of the road in Etiler, the driver frequently contacts the navigator and conducts a human-to-human dialog.

Final segment of the route on Buyukdere Caddesi is again free (reference) driving. The experiment ends in front of the OTAM where the driver completes a couple of forms and a questionnaire.

**Driver Profile:** In the first half of the Istanbul data collection effort, 53 drivers (50 were required) have driven the vehicle in the 25 km route, 15 of them were female and the remaining 38 male. The age range for female drivers was 21-48, and the corresponding male range was 22-61. Driver population was mostly pulled from the academic partners of the DSC together with their family and friends. However due to equipment malfunction and a major disk crash affected data from 5 female and 1 male is not reliable or incomplete. This brings the usable driver size to 47 in total[4]. In the second phase, additional 53 complete and consistent data sets will be collected during the summer of 2007.

**Challenges Faced:** As it was mentioned earlier, data collection on live traffic with human subjects is a major challenge by itself, which should NOT be seen as a natural extension of experiments conducted with simulators in a controlled lab environment. They are effected by equipment failures, technical difficulties, climate and weather, traffic density and type, driving local culture, effectiveness of law enforcement and probably the most critical ones are the driver's physical and mental conditions and his/her driving behavior. In this undertaking, there were challenges in each area and many of them came all at once. Some examples with their current status/solution in parenthesis are:

- Digital recording of uncompressed video at 30 frames/s with 640x480 resolution (Ans.: 3-ch StreamPix system).
- Synchronization of 3 different data logging systems (Ans.: common system clock and sharing a sync signal)
- Data store archive approximately 9 Terabytes of data from 53 drivers and their backup into tapes. It was solved by employing FT engineer and part-time students to archive data into HQ digital back tapes on an HP back-up subsystem. Each experiment of 40-50 minutes requires 4-5 hours to access, align, and write into a tape.)
- Off-line compression of data into MPEG4 format and alignment of various sensor readings. (Ans.: custom designed software package for aligning, compressing and browsing/re-recording)
- CAN-Bus data readings (Ans.: special software package)
- CAN-Bus data cannot be read at a programmable rate, it fluctuates around either 10 Hz. Or 32 Hz. Earlier experiments were done at about 10 Hz. At present, it is fairly stable around 32 Hz. (Ans.: rate for each run is recorded and re-sampling is done subsequently by users of the database.)
- Unacceptably noisy signal from break sensor pedal pressure. (Ans.: semi-custom designed A/D for this signal is now working as expected. Accelerator pedal unit is being installed at the writing of this report.)
- More reliable location information (Unresolved).
- ASR for Music Search, i.e., query (under study).
- Complaints from drivers using with pedal sensors. (Ans.: this is mitigated by opening the gap between pedals at the Renault manufacturing plant and advising drivers to use light weight shoes!)

- Complaints from drivers in "multi-tasking" and loosing attentiveness (Ans.: Do on-line banking on the curb side or earlier inside ITU campus.)
- Wrong turns from unfamiliarity with the route, which results in significant time loss and the stored data size, -- up to 280 GB data has been observed! (Ans.: Emergency assistance by the navigator and frequent assistance by the operator a via the cell phone.)

Needless to state that the DSC team are having fun whenever a troubling issue is satisfactorily eliminated and it continues to give the feeling well-done.

## 4. SIGNAL SAMPLES

A screenshot[1] from driver IF1014 is shown in Figure 5.n Feeds to cameras located in the vehicle to generate stereo image of the driver and a third one towards the road showing a residential neighborhood in the route are displayed together with four speech waveforms down-sampled to 16 kbits/s and 16-bit resolution (recorded in wav format). Video feeds could be either uncompressed or compressed with MPEG4 at 3 MB/s avi format using DivX codec.

In addition, steering wheel angle in degrees, vehicle speed in km/h, and the engine RPM are illustrated with dials. There are four visible dots on the needle of speed dial, which represent the actual tire speeds. Normally, they move together. However, they register different values during skids and slides in inclined weather or surface, and sudden breaks. Vehicle related signals recorded from CAN-Bus data is also synchronized with video but the re-sampled versions are not recorded, i.e., originals kept.

In Figure 6, the vehicle speed, break pedal pressure, gas pedal percentage, engine RPM, individual wheel speeds, yaw rate, steering wheel angle and its rotational speed among the CAN-Bus readings taken at 34 Hz plots are shown for an interval of 640 seconds long test run. There are few other readings form the CAN-Bus reporting the status of clutch, rear gear, and break pedal.

181 distance measurements between UYANIK and other vehicles/objects around are available at the rate of 1 Hz and Figure 7 shows both the plot and the actual photo at that instant, which is explicitly marked.

In addition, steering wheel angle velocity, yaw rate, clutch status, and rear gear status readings are recorded from the CAN-Bus[2]. IMU readings showing the XYZ directional accelerations and the location information from GPS receiver are recorded into separate files. A number of application-specific plots are illustrated in several complimentary works either reported elsewhere in this biennial [5-8] or briefly discussed in Section 6.

In the next phase of the data collection, the break pedal and accelerator pedal pressure readings will be integrated in to the software developed and recorded as it is done in Nagoya and the UT-Drive vehicles.

Finally, we have recorded in a number of experiments 16-channel EEG signals to act as grown-truth for fatigue and attention/inattention determination. For the driver shown in Figure 3, plots from 8 channels –specifically, C3, C4, F3, F4, O1, O2, A1 and A2—which are important for fatigue prediction-- are shown in Figure 8. On the other hand, EOG channels are recorded for the estimation and the rejection of eye blinks. ECG and EMG are also used for both artifact rejection and fatigue estimation. Alfa signal power and signal power ratio between right and left hemispheres are used for fatigue prediction from EEG measurements after rejection of ECG, EMG and EOG artifacts, the importance of these are currently understudy.

For fatigue and distraction understanding, long-run simulator experiments (3-4 hours long or more) with/without EEG are in progress.

## 5. GAINS ARE COMING: PART 1

Using the database generated in the first phase of the data collection process, our colleagues at Sabanci University and their students are reporting their preliminary findings from four on-going projects elsewhere in this biennial:

- Automated Road, Lane, and Car Detection for Autonomous Driving by Birdal et. al [5]
- Audio-visual speech recognition using multi-classifier approach in car noise by Karabalkan et. Al [6]
- 3D Head Tracking for Detecting Driver Behavior by Akan et. al [7]
- Graphical Model Based Facial Feature Point Tracking: in Car Environment by Cosar et. al [8]

In addition, we were envisioning contributions from other partners of the DSC but that did not materialize at this time.

## 6. GAINS ARE COMING: PART 2

Along with the four applications above [5-8], four additional projects are under study by several students at Sabanci University. Because, these studies are still in progress, the team has decided not to present them independently. Here we will identify their problems and present preliminary findings. Hopefully, present them in future meetings or publish them in journals. They are:

(1) Intra-gender and inter-gender break and accelerator pedal engagement behavior of drivers and its correlation with head-distance measurements.
(2) Score-level fusion for driver verification using speech recognition and fingerprint.

[1] An Interactive Multi-channel Multimedia Management System for Vehicular Applications is being developed independent of these activities. Here ,we report only the browser, signal aligner and compressor version customized for DSC/NEDO applications.

[2] These readings are information rich for projects carried by the partners at the Mekar Labs and OTAM Center of ITU.

(3) Improved and reliable license plate identification based on OCR and speech recognition.
(4) Graphical methods for geosynchronous behavior analysis of drivers.

**Pedal Engagement Behavior:** In Figure 9, we illustrate a sample of break pedal and gas pedal engagement status for a driver and from the correlation of these two waveforms, we obtain zero-crossings per minute (zero-crossing rate) indicating the transitions in the pedal engagement from break-to-gas and vise versa (pedal shift). Also, the head distance between the test vehicle and other vehicles ahead is depicted in Figure 7[3].

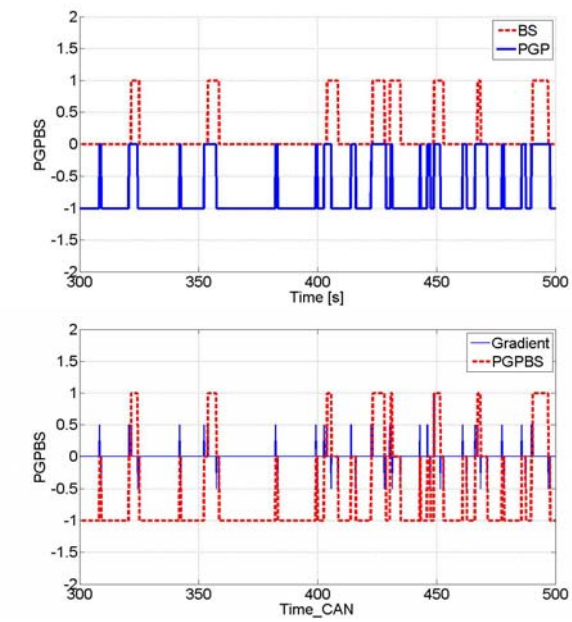


Figure 9. Break and gas pedal status plots in the interval 300-500 seconds into the trip.

This multi-sensory information is explored for understanding the gender-specific behavior of drivers to the traffic ahead by obtaining the statistics of intra-/inter-gender zero-crossings per minute rates for several male and female drivers in the database. Interesting patterns have been observed but not ready to interpret them until more extensive studies are done. However, one local folk theorem is proven!

The average inter-gender pedal shifts per minute at various speeds are shown in Figure 10. It is clearly observable that the female drivers in Turkey are driving more smoothly across all speeds when compared to their male counterparts. Furthermore, male drivers are very impatient and make frequent break/gas shifts at a wide-range of speeds 40-80 km/h. So, let us leave the driving to ladies in Turkey!

[3] Vehicle identification at a given time is done manually by studying the picture and the coordinates of the distances to the objects recorded by the laser scanner simultaneously.

**Speaker Verification and Fingerprint Recognition:** In this application, drivers use their fingerprint and speak their names to start the vehicle. The purpose of this application is two-fold: (a) access/deny to the vehicle with one physical and one behavioral signature –fingerprint and speech -- for improved performance; (b) still access/deny in the case if only one of the sensory modes is available.

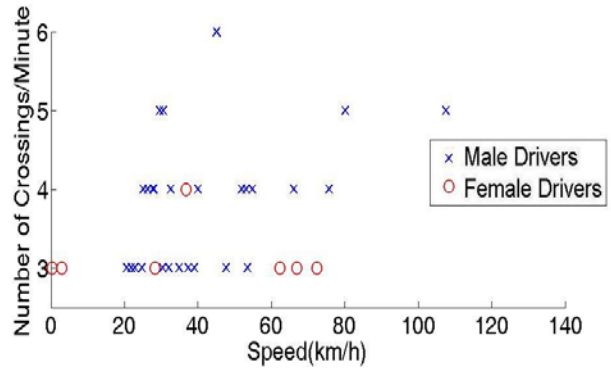


Figure 10. Gas/break pedal zero-crossing frequencies for female and male drivers.

In biometrics, signal processing, and forensics communities, performance evaluation of biometric verification systems is measured by using Receiver Operating Curve (ROC) which is related False Accept Rate(FAR) to False Reject Rate (FRR) at different threshold values [9].

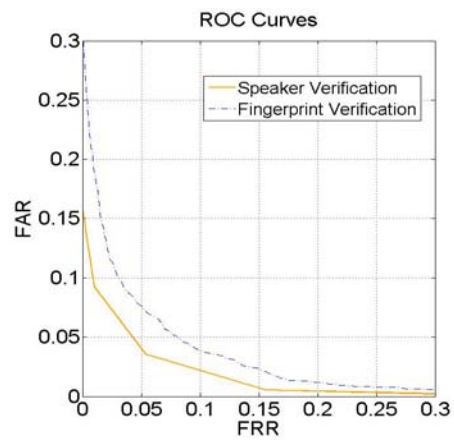


Figure 11. Individual ROC curves for fingerprint and speaker verification before score-level fusion.

In Figure 11, we show the false-acceptance (FAR) versus false reject (FRR) rates obtained for several drivers. Individual equal error rates are approximately 4-7% for these two signatures, which are very similar to results reported in the literature. At the time of this writing, reliable and meaningful score-level classifier experiments are performed to fuse the results with the anticipation of improved performance as it was reported in many data fusion applications classification and in person/object

identification problems including the works by some of the authors [4,9].

**License Plate Recognition using OCR and Speech Recognition:** A novel approach is developed to recognize license plates by merging character recognition and speech recognition results coming from a video camera and a microphone in a moving vehicle to decrease errors in reporting on-line and to continue the task even if one of the sensory modes is totally lost. The end result is to increase the reliability of the system in law-enforcement applications. In Figure 12, we have the picture of the vehicle to be recognized and reported by an officer to an agency, i.e., the DMV, police, or other agencies or the company officials in the case of a commercial application.


Figure 12. Picture of the vehicle to be recognized.


Figure 13: (a) License plate picture, (b) preprocessed image before filtering and (c) final filtered image in black and white.

As it can be observed for the picture, the license plate is not very clear and the reports and the statements are regularly challenged in courts . The original image together with few enhancement steps are shown in Figure 13 and character identification and recognition stage follow these. Three different templates of each character --numbers, letters-- that can be found in Turkish plates are stored in this way to be used in the identification stage. After all of the objects are extracted and ordered from left to right, they are individually compared with the templates previously stored. The sum of absolute differences (SAD) is found between the test character and the template and the SAD values are added up for each letter and the number. The object is identified as the letter or number which has the lowest total SAD value and its specific location in the plate is also stored for later use.

Speech recognition part is still in development. A freeware Turkish speech recognizer tool is used for testing some concepts but the final developments will be ported on the Hidden Markov Model Toolkit (HTK) toolkit, ubiquitous in the speech community. The program requires a dictionary for the words and letters that will be recognized and it is very successful in recognizing long words. However single letters are prone to be misrecognized and error rate is very high at the time of this report. To mitigate this, letters are to be read using their phonetic alphabet to reduce the error rate significantly. Unfortunately, this was not done in the first phase of the data collection. In the next phase, license plate reading will be performed as such. Therefore, only the preliminary results from OCR side is ready at this time: Overall license plate recognition is around 87 percent[4].

**Graphical Methods for Geosynchronous Behavior Analysis of Drivers:** Here the aim is to identify and classify driver behavior by studying data from four different sets of sensors --CAN-Bus readings, laser scanner and GPS information in addition to the road picture-- in a geosynchronous fashion, i.e., the same route segment, the same time interval but different drivers.

A first obstacle to overcome in this problem is the temporal synchronization of four chosen sensors. CAN-Bus readings and GPS signals are sampled at the same time, but with varying frequencies ~10 Hz or 32 Hz. In UYANIK, the laser scanner operates at about 1Hz. So, the time clock for CAN-Bus data is selected as a reference and data from other sensors are appended into a single file. Any missing data is generated via linear interpolation.

Next, a novel algorithm is used to geo-synchronize the data. Geosynchronization is important as it will permit the analysis of the reactions of drivers to a particular characteristic of the road segment. The challenge in geosynchronization is the lack of the ordering relation (< and >) of the 2-D space. The GPS data is given in latitudes and longitudes. So, by definition, the similarity measure of this space is the geodesic distance. However, given the scale in which the data collection is done, the Euclidean distance is an acceptable approximation. As the data samples are temporally ordered, we can assume that: (i) locally, the subjects never go back as time moves forward, (ii) subjects never deviate from the same line, and (iii) sampling intervals are equal.

Let us now define the binary ordering relation **a** > **b**; that is, **a** is after **b**" as follows:

[4] Results depend heavily on the clearness of the image. At this stage, plates with imagery too small or very noisy for reading are not included.

$$\forall a_0, a_1, b_0 \in (\Re^2)^3$$

we have $a_0 > b_0$ if and only if $\|a_1 - b_0\|_2 > \|a_0 - b_0\|_2$, where **a** and **b** are the 2-D signals that represent the coordinates of the data from subjects **a** and **b**, respectively, and $a_i, b_i$ are $i^{th}$ samples from their relevant signals.

The first and third assumptions are satisfied by design of the experiment or the provider of the data. However, the second one is not satisfied, primarily because of the noise in the GPS data as shown in Figure 14. This could come from either the resolution of the GPS device or the channel noise.

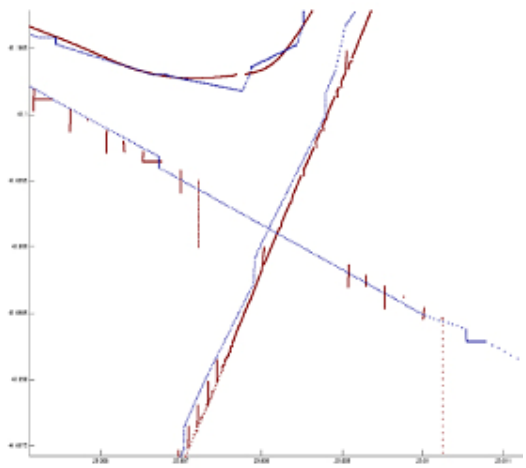

Figure 14. An example to the Noisy GPS data (IF1006).

We apply a nonlinear regression algorithm to obtain the track line and project the coordinates to the nearest points of this line. The algorithm has three steps:

1. Determination of the pivot
2. Alignment to the pivot
3. Geosynchronization

The pivot is taken to be the first coordinate of the first sample of an arbitrary subject. After the pivot is determined, other subjects are aligned to this point. Alignment is the process of flushing all the data that is *before* the pivot coordinate. This way, after the alignment process, all of the coordinates of the remaining data samples are *after or equal* to the pivot point. Next step is geosynchronization, which consists of writing the current pivot to the resulting file, selecting the nearest point to the pivot as the next pivot, until one of the data sources are depleted.

At the time of this report data analysis with geo-synchronized data was starting, which will permit us to study driver behavior at the same place and the same time.

## 7. CONCLUSION AND FUTURE WORK

In this paper we report the progress on real-world data collection with "UYANIK" in Istanbul (Turkey) as part of an international collaboration research with Nagoya University (Japan) and the University of Texas in Dallas (USA) and in partnership with the Drive-Safe Consortium in Turkey. 53 drivers participated in the experiment to date resulting at a data storage size of close to 9 Terabytes with very rich information on driver behavior, the vehicle performance, and the road and traffic conditions on a 25 km route in Istanbul.

We will continue the data collection to complete the driver set to 100 and focus on number of on-going applications reported above and elsewhere in this biennial. Combined experiments with road and simulator data will be utilized in studying the driver fatigue and distraction.

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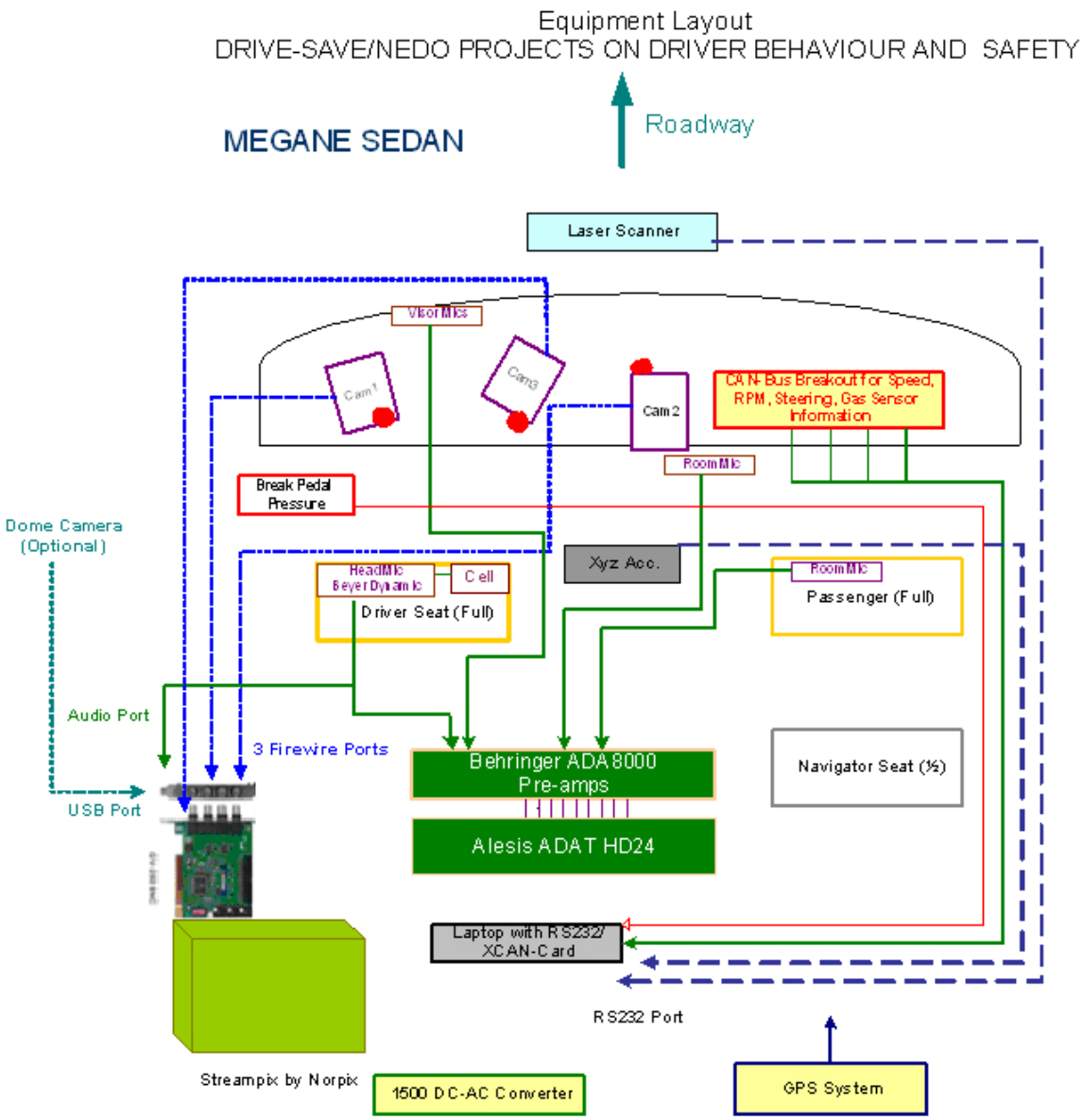



Figure 2. System Block Diagram for Sensors and Data Acquisition Systems for Drive-Safe/NEDO Instrumented Vehicle

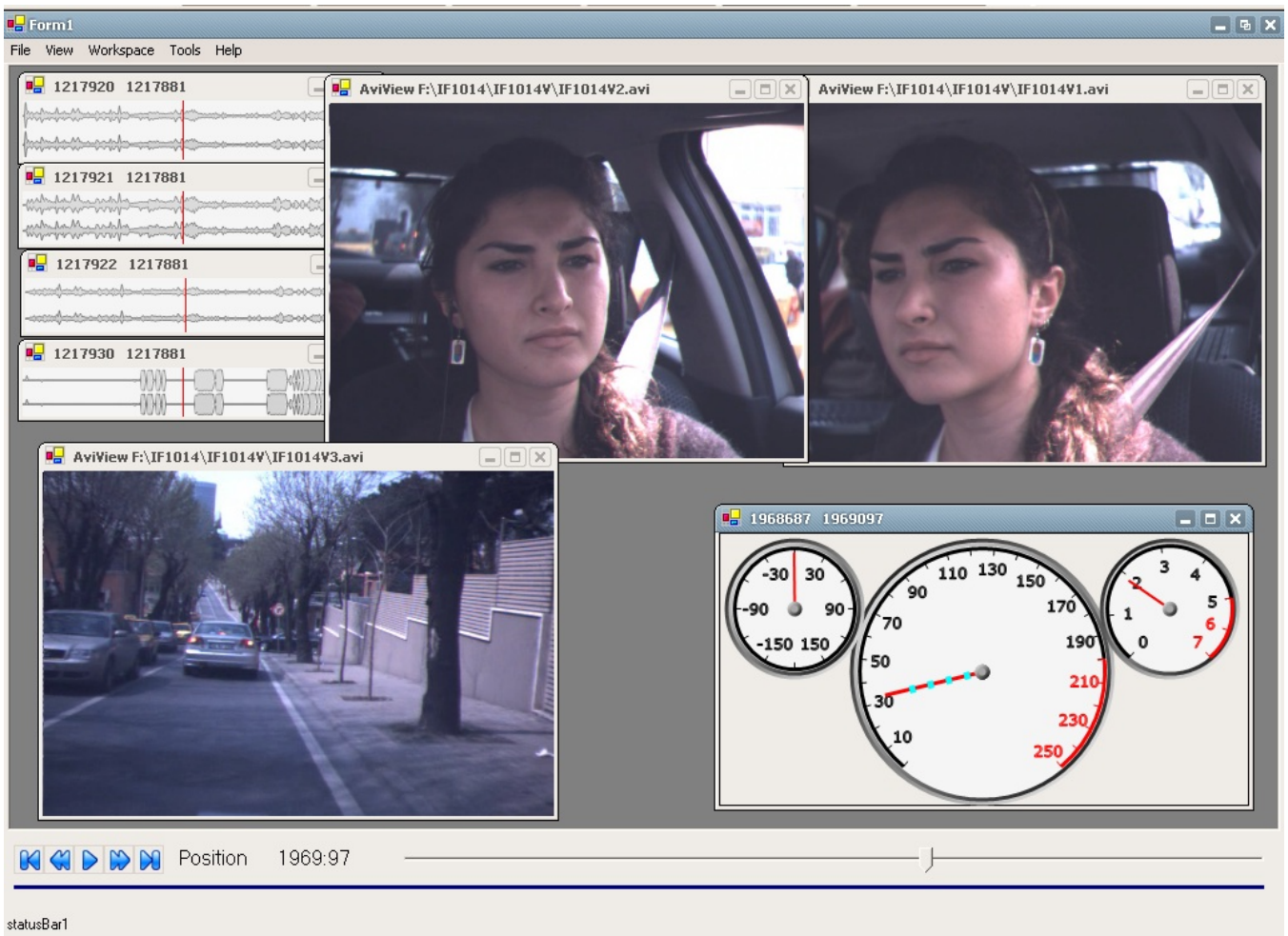
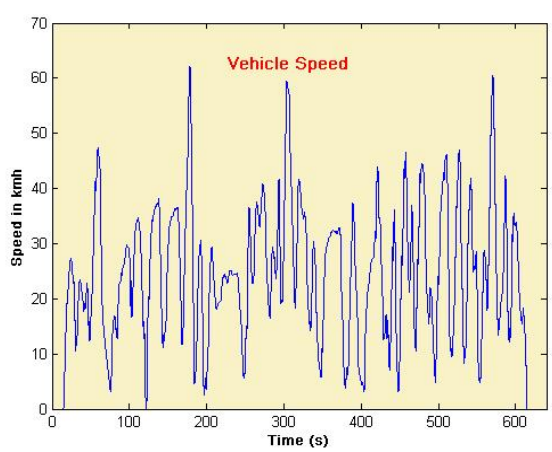
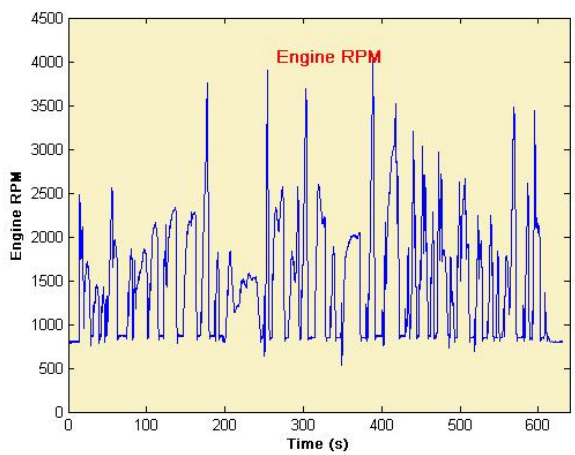



Figure 5. The browser synopsis of the Multi-channel Multimedia Display for Driver IF1014. Three video feeds and 4 audio waveforms together with steering wheel angle, vehicle speed, and engine rpm dials are included in this pictures. In addition four blue dots represent the individual speeds in each tire of the vehicle.



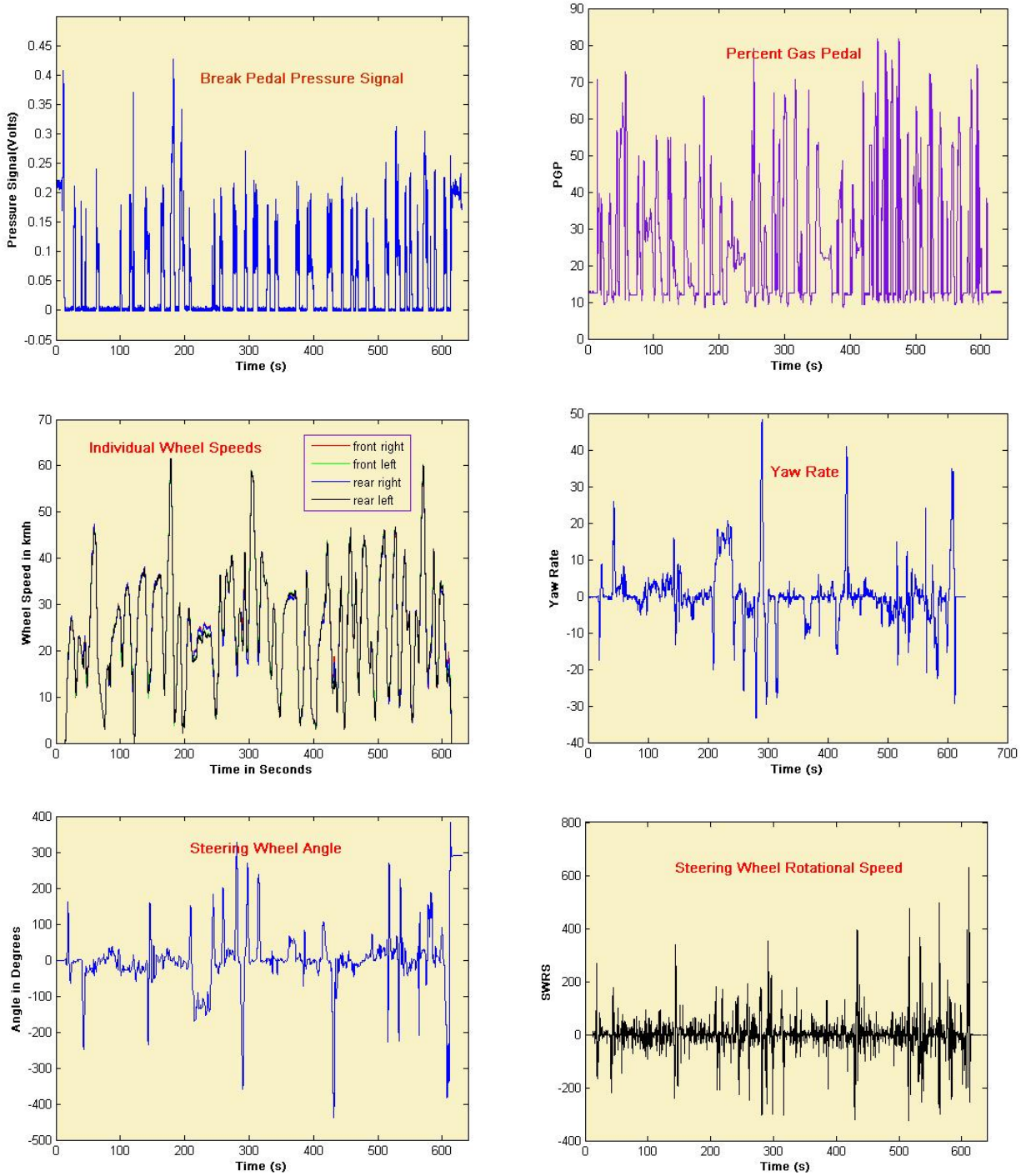



Figure 6. Vehicle speed, break pedal pressure, gas pedal percentage, engine RPM, individual wheel speeds, yaw rate, steering wheel angle and steering wheel rotational speed plots are shown for the interval 380-560 seconds into the test.

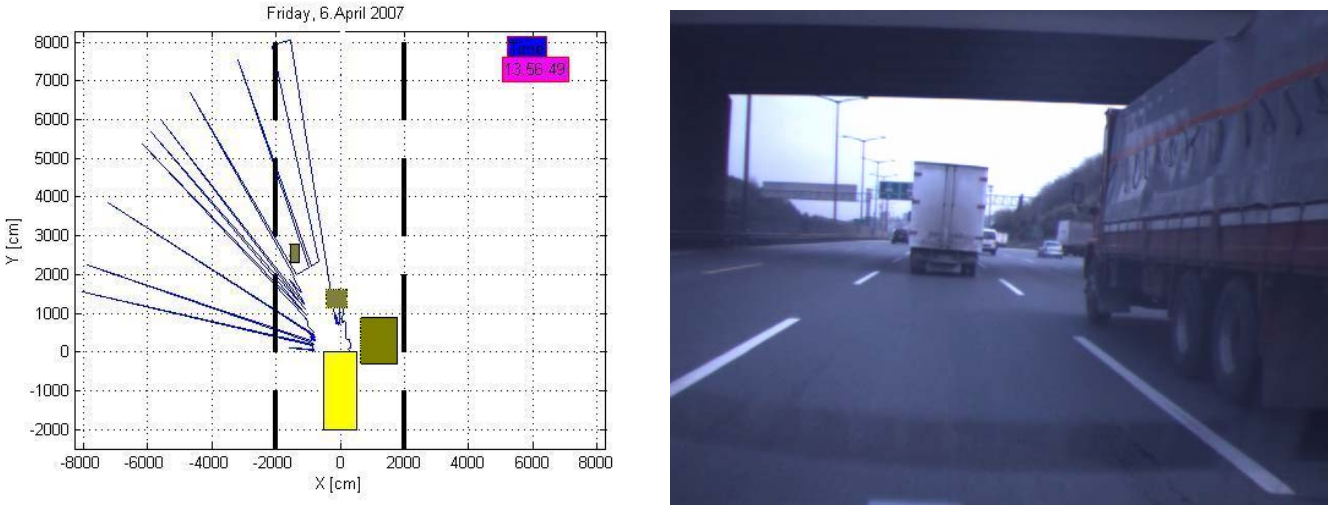



Figure 7. Laser Scan Reading and the photo for Driver IF1015 recorded at 12:56 PM on April 6, 2007. Truck on the right is between -200 to +800 cm, the white truck is away 22 meters, and the vehicle on the next lane (left) is about 23 meters ahead.

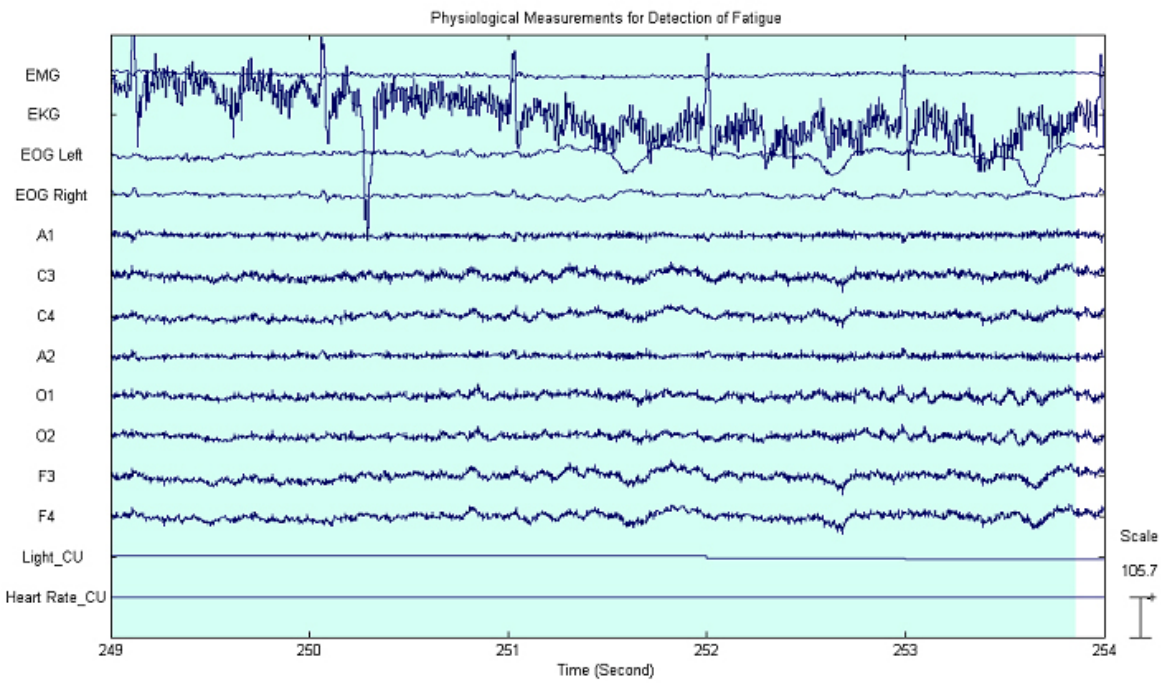



Figure 8. Eight Channels of the EEG recordings for the driver in Figure 3.

**Table 1. UYANIK Sensor List and Characteristics**

| Unit | Sensor/System | Model/Manufacturer | Supply Socket | Power Budget (Watts) | Interface |
|---|---|---|---|---|---|
| 1 | High resolution camera | Basler A601fc-2 | Firewire | 0 | Firewire |
| 1-A | Night vision camera | Basler A601fc-HDR | Firewire | 0 | Firewire |
| 2 | High resolution camera | Basler A601fc-2 | Firewire | 0 | Firewire |
| 2-A | Night vision camera | Basler A601fc-HDR | Firewire | 0 | Firewire |
| 3 | High resolution camera | Basler A601fc-2 | Firewire | 0 | Firewire |

| | | | | | |
|---|---|---|---|---|---|
| 3-A | Night vision camera | Basler A601fc-HDR | Firewire | 0 | Firewire |
| 4 | Video Image Acquisition system | NORPIX-StreamPix, digital video recording software version 3.20.1, USB product key, Pentium 4 computer | 220/110V AC | 250 | Inputs:1 parallel, 1 eSATA, 6 USB 1 optic, 5 firewire, 1 ethernet, 4 line out sound, 2 line in sound, 1 VGA, 1 Gamepad |
| 4-A | Mon. + Human Int. Dev. | | | | |
| 5 | XYZ accelerometer | IMU 400 Crossbow | 9-25 V DC | 3 | 15 PinD Output Connector Male / 6 Digital Input or DB-9 Standard Com Port |
| 6 | 2D laser scanner | LMS221-30206 | 24 V DC | 20 | DB-9 Std. COM Port Output / Input |
| 7 | EEG | GRASS TELEFACTOR AURA24 | Self Powered | 0 | RS232 (?) |
| 8 | 24 channel Data Acquisition Device | Alesis ADAT HD24 | 110 / 220 VAC | 60 | Audio inputs = 24 x 1/4" TRS jacks, Audio outputs= 24 x 1/4 TRS jacks |
| 9 | 8-channel Input Signal Mixer Amplifiers to convert 8 audio channels in Alesis | Behringer/UltraGain Pro8 Digital ADA8000 ADC/DAC | 110V AC | 25 | MIC IN->XLR Female LINE IN->1/4" TRS LINE OUT-> XLR Male DIGI IN-> Toslink-Optical DIGI OUT-> Toslink-Optical |
| 10 | Driver headset/ microphone | Beyer Dynamic | | | Stereo Audio IN/OUT |
| 11 | Visor microphone | Sony ECM-C115 | li. batery CR2025 | 0 | L shape Male Stereo Jack |
| 12 | Lapel microphone | Sony ECM-C115 | li. batery CR2025 | 0 | L shape Male Stereo Jack |
| 12-A | Chamber microphone | Sony ECM-C115 | li. batery CR2025 | 0 | L shape Male Stereo Jack |
| 13 | Break Pedal Pressure Sensor | Kyowa LPR-A-S-1 | | 0 | Special Connector |
| 13-A | Pre-amp for Break Pedal Pressure Sensor | Kyowa | 12 DC | 0 | Special Connector |
| 14 | GPS Receiver | Trimble Pathfinder Pro XRS + Omnistar VBR 1 | 10-32 VDC | 7 | DB-9 Std. COM Port Output / Input |
| 14-A | GPS antenna | | | | |
| 15-20 | Megane Layout and Sensors for distance measurement | SensComp 600 Package (2x4 pcs) | 4,5-6,8 VDC | 53.2 | JST Polaroid Connector Output / 4 Digital Input |
| 21 | Laptop | Toshiba Tecra Sonoma | AC-DC | | |
| 22 | PCMCI/Serial converter for laptop | Quatech QSP-100 4 port RS-232 PCMCIA Card | | | 4 port RS-232 |
| 23 | Cellular Phone | Sony Ericson W800i Walkman, Nokia Phone | Self Powered | 0 | Handset microphone and headphone |
| 24 | 12V DC - 220 AC Power Inverter | Pure Sine Wave 1500 W S1500-212E3 | 12 DC | 1500 W | Special Cable to Megane Battery; 220 Volts |
| 25 | 360$^{o}$ Panoramic and remote camera | RPU C2512 FG Panoramic Camera + RPU SP Remote Control | | | |