Evaluation of a Real-Time Voice Order Recognition System from Multiple Audio Channels in a Home

Michel Vacher¹, Benjamin Lecouteux¹, Dan Istrate², Thierry Joubert¹, François Portet¹, Mohamed Sehili², Pedro Chahuara¹

¹LIG, UJF/CNRS/Grenoble-INP/UPMF, UMR5217, 38041 Grenoble, France
²ESIGETEL, 77210 Avon, France
³THEORIS, 75000 Paris, France

dan.istrate@esigetel.fr, mohamed.sehili@esigetel.fr, thierry.joubert@theoris.fr

Abstract

The SWEET-HOME¹ project aims at providing audio-based interaction technology that lets the user have full control over their home environment and at detecting distress situations. This paper presents the audio analysis system PATSH developed for this project and a user experiment in a smart home that evaluates the performances of the first revision of the system regarding vocal order recognition with realistic scenarios.

Index Terms: Real-time audio analysis, experimental in-situ evaluation, Smart Home, Home Automation, AAL.

1. Introduction

The development of smart homes and intelligent companions is seen as a promising way of achieving in-home daily assistance [1]. Despite, some smart home projects have considered speech recognition in their design [2, 3, 4, 5, 6, 7, 8], there are still important challenges to be overcome to set up this technology in a real environment [9].

Designing and applying speech interface in Smart Home to provide security reassurance and natural man-machine interaction is the aim of the SWEET-HOME² project [10]. The project addresses the important issues of distant voice command recognition and sound source identification to improve the robustness of voice-based home automation control. In this paper, we introduce the PATSH system which performs the real-time identification of the voice command anywhere in the home and sends the result to an intelligent controller in charge of making decision based on these [11].

2. The Audio Analysis System

The global architecture of PATSH is illustrated in Figure 1. The PATSH framework is developed with the .Net cross-platform technology. The main data structure is the Sound object, which contains a segment of the multidiimensional audio signal whose interpretation is continuously refined along the processing pipeline. PATSH deals with the distribution of the data among the several plugins that perform the processing to interpret the audio events. The execution can be done, in parallel, synchronously or asynchronously, depending on the settings stored in a simple configuration file. For a complete description of the system the reader is referred to [12].

In the SWEET-HOME configuration, PATSH runs plugins that performs the following tasks: (1) multichannel data Acquisition through the NI-DAQ6220E card (16bits, 16kHz, 7channels), (2) sound detection, (3) sound/speech discrimination, (4) sound classification, (5) automatic speech recognition (ASR) and extracting vocal orders, and (6) presentation, communicating the sound event to the Intelligent Controller. If a vocal order is detected and according to the context (activity and localisation of the user in the flat), an home automation command is generated to make the light up, close the curtains or emit a warning message thanks to a speech synthesizer.

3. Experiments in real conditions

Experiments were run in the DOMUS smart home at the Laboratoire d’Informatique de Grenoble [13]. The flat has been equipped with 7 radio microphones set in the ceiling for audio analysis. A specialized communication device, e-lio, from the Technosens company is used to initiate a communication between a senior and a relative [10]. The possible voice orders were defined using a very simple grammar:

- set an actuator on: (e.g. Nestor ferme fenêtre) key initateCommand object (e.g. Nestor arrête)
- stop an actuator: key stopCommand [object]
- emergency call: (e.g. au secours)

Our previous user study showed that targeted users prefer precise short sentences over more natural long sentences [14]. Each order belongs to one of three categories: initiate command, stop command and emergency call. Except for the emergency call, every command starts with a unique key-word (here “Nestor”) that permits to know whether the person is talking to the smart home or not.
To validate the system in realistic conditions, we built scenarios in which every participant was asked to perform the following activities: (1) Sleeping; (2) Resting: listening to the radio; (3) Feeding: realizing and having a meal; and (4) Communicating: going out of the flat to do shopping and having a talk with a relative thanks to e-lilo. Therefore, this experiment allowed us to process realistic and representative audio events in conditions which are directly linked to usual daily living activities. The participant had to use vocal orders to make the light on or off, open or close blinds, ask about temperature and ask to call his or her relative. The instruction was given to the participant to repeat the order up to 3 times in case of failure. A wizard of Oz was used in case of persistent problem.

Sixteen healthy participants (including 7 women) were asked to perform the scenarios without condition on the duration. Before the experiment, the participant was asked to read a text of 25 short sentences in order to adapt the acoustic models of the ASR for future experiments. The average age was 38 years (19-62, min-max) and the experiment lasted between 23min and 48min. While the scenario included 15 vocal orders more sentences were uttered because of repetitions.

During the experiment, audio data were recorded and saved in two ways. Firstly, the 7-channel raw audio signal was stored for each participant to make subsequent analysis possible. In total, 8h 52min 36s of data was recorded for the 16 participant. Secondly, the individual sound events automatically detected by PATSH were recorded to study the performances of this framework. Overall, 4595 audio events were detected whose 993 were speech utterances.

In this study, we are only interested in recognizing vocal orders or distress sentences. All other spontaneous sentences and system messages were discarded. Therefore, only the syntactically correct vocal orders were annotated. The average SNR and duration are 15.8dB and 1s with is far from the recording studio condition. Thanks to this annotation, an oracle corpus was extracted. The comparison between experimental real-time results with thus obtained with the same ASR on the oracle corpus will allow to analyse the performance degradation introduced by the PATSH system.

4. Results

4.1. Discrimination between speech and sounds

All the results presented take into account the performances of the detection because the signals are extracted automatically by the system. The sound/speech discrimination badly classified 108 sound and 232 speech occurrences which gives a total error rate of about 7.4% which is correlated with our previous results [12]. 23.4% of speech occurrences were missed speech and 3% of the detected speech was actually sounds. These poor performances are explained by the fact that PATSH was not successful in selecting the best audio event among the set of simultaneous sound event records. These fill the sound object queue, which is the system bottleneck, and thus slow down the processing while real-time performances are required. To increase the performance and free this bottleneck, we had implemented a filtering strategy to remove low SNR audio events as well as too delayed events. The preliminary results showed a significant increase in performance. In a second step, PATSH will be modified to allow in real-time a multiasource ASR thanks to the Driven Decoding Algorithm [15].

Although the 16 participants had to repeat, sometimes up to three times, the voice commands, they did not complained about the reaction time nor about the syntax. They were overall very excited about commanding their own home by voice. The next experiment, will involve aged participants and a more controlled evaluation of their feeling and reaction about the system in order to compare with our previous user study [14] and conclude about the potential of the state of the art speech technologies for Ambient Assisted Living.

<table>
<thead>
<tr>
<th>ID</th>
<th>Spk. ID</th>
<th>Nb.</th>
<th>Expec. (%)</th>
<th>Oracle (%)</th>
<th>Spk. ID</th>
<th>Nb.</th>
<th>Expec. (%)</th>
<th>Oracle (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S01</td>
<td>20</td>
<td>80</td>
<td>23</td>
<td>32</td>
<td>12.5</td>
<td>6.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S03</td>
<td>22</td>
<td>22.7</td>
<td>22.7</td>
<td>S04</td>
<td>26</td>
<td>23</td>
<td>7.7</td>
<td></td>
</tr>
<tr>
<td>S05</td>
<td>26</td>
<td>15</td>
<td>3.8</td>
<td>S06</td>
<td>24</td>
<td>21</td>
<td>8.3</td>
<td></td>
</tr>
<tr>
<td>S07</td>
<td>19</td>
<td>79</td>
<td>52.6</td>
<td>S08</td>
<td>33</td>
<td>30</td>
<td>33.3</td>
<td></td>
</tr>
<tr>
<td>S09</td>
<td>40</td>
<td>40</td>
<td>22.5</td>
<td>S10</td>
<td>40</td>
<td>67</td>
<td>38.5</td>
<td></td>
</tr>
<tr>
<td>S11</td>
<td>46</td>
<td>27</td>
<td>S12</td>
<td>26</td>
<td>21</td>
<td>7.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S13</td>
<td>21</td>
<td>43</td>
<td>19</td>
<td>S14</td>
<td>27</td>
<td>48</td>
<td>29.6</td>
<td></td>
</tr>
<tr>
<td>S15</td>
<td>28</td>
<td>71</td>
<td>55.5</td>
<td>S16</td>
<td>22</td>
<td>18</td>
<td>13.6</td>
<td></td>
</tr>
</tbody>
</table>

Average 28 38% 23.9%
6. References


