New Spanish speech corpus database for the analysis of people suffering from Parkinson's disease

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Abstract

Parkinsons disease (PD) is the second most prevalent neurodegenerative disorder after Alzheimer's, affecting about 1% of the people older than 65 and about 89% of the people with PD develop different speech disorders. Different researchers are currently working in the analysis of speech of people with PD, including the study of different dimensions in speech such as phonation, articulation, prosody and intelligibility. The study of phonation and articulation has been addressed mainly considering sustained vowels; however, the analysis of prosody and intelligibility requires the inclusion of words, sentences and monologue.

In this paper we present a new database with speech recordings of 50 patients with PD and their respective healthy controls, matched by age and gender. All of the participants are Spanish native speakers and the recordings were collected following a protocol that considers both technical requirements and several recommendations given by experts in linguistics, phoniatry and neurology. This corpus includes tasks such as sustained phonations of the vowels, diadochokinetic evaluation, 45 words, 10 sentences, a reading text and a monologue. The paper also includes results of the characterization of the Spanish vowels considering different measures used in other works to characterize different speech impairments.

Keywords: Parkinson's disease, Spanish, database

1. Introduction

Parkinson's disease (PD) is a neurodegenerative disorder that affects 1% of people older than 65 (de Rijk et al., 2000) and about 89% of the PD patients develop speech disorders (Ramig et al., 2008). According to different clinical observations, the patients can develop problems in their breathing and swallowing processes, affecting several aspects in speech such as phonation, articulation and prosody (Skodda et al., 2011; Rusz et al., 2011).

Different works suggest that constant speech therapy can generate positive impact in the rehabilitation of PD patients (Sapir et al., 2007); however, the evaluation of the progress in the therapy is made subjectively and thus it depends on the experience of the expert. In this regard, most of the scientific community that is working on topics related to speech disorders is interested in new methods and tools for the objective evaluation of speech of people with PD. One of the first issues that must be addressed by researchers is the access to databases with enough recordings, useful speech tasks (vowels, words, sentences, etc.), good noise conditions, among other aspects. There are several works where different analyses of speech signals are presented considering private databases. In (Little et al., 2009) different acoustics and nonlinear measurements are used to evaluate sustained phonations of the English vowel /ah/ uttered by 23 patients with PD and 8 healthy controls. All of the participants were evaluated by neurologist experts and were labeled according the the Unified Parkinson's Disease Rating Scale (UPRDS) (Stebbing and Goetz, 1998) and the Hoehn & Yard scale (H&Y) (Hoehn and Yahr, 1967), which gives information about the real stage of the disease in the patients; however, note that the low number of participants limits the possibility of doing speaker independent validations and hence makes it difficult to generalize methods developed with it (Bayestehtashk et al., 2013). Deep analysis in articulation and prosody is not possible with this database because it only considers sustained phonations of the English vowel /ah/. On the other hand, in (Skodda et al., 2010) the authors analyze the impact of PD in speech through different stability and duration measures applied on the syllables /pa/ and /ba/ that are repeated at least 20 times by 73 patients with PD and 43 age-matched controls, all of the patients were native German speakers and were also evaluated by neurologist experts and were labeled following the UPDRS and H&Y scales. In (Skodda et al., 2011; Skodda et al., 2012) the authors take one subset of the database used in (Skodda et al., 2010) containing 68 patients with PD and 32 age-matched controls and present an analysis about the loss in the articulation capacity of people with PD. Such analysis is performed by means of two different measures mainly based on the first two formants (F1 and F2) of the voice spectrum: the Vowel Articulation Index (VAI) and the triangular Vowel Space Area (tVSA). Besides the sustained phonation of the German vowel /a/, the database used in these works also includes a set of isolated words, sentences, the repetition of syllables (/pa/, /ba/, /ka/, etc.), a reading text and a monolog. Additionally, in (Rusz et al., 2011) a study with different acoustic measures to characterize the speech of people with PD is presented. The database used includes a total of 46 Czech native speakers, 23 of them were diagnosed by neurologist experts with an early stage of idiopathic PD and the other 23 participants were healthy controls. This set of recordings also includes the repetition of syllables (/pa/, /ta/, /ka/), sustained phonation of the Czech vowel /i/, reading sentences and text, and monolog. Recently, in (Bayestehtashk et al., 2013) the authors evaluate different regression techniques to infer the severity of 168 patients with PD. The recordings were captured in three different clinics and the data includes also speech of 21 controls that were recorded in one of the clinics. All of the participants are English native speakers. The corpus includes three speech tasks: sustained phonation of the English vowel /ah/, the rapid repetition of the syllables /pa/, /ta/ and /ka/, and the reading of three standard passages ("The north wind and the sun", "the rainbow passage" and "the Grandfather passage").

From the information collected in this brief review of the literature, it is possible to note that one of the main issues that might be addressed by people who work on pathological speech analysis is the construction of databases or the access to speech samples recorded in appropriate technical conditions, following a well established recording protocol, and including recordings with different speech tasks. The construction of a speech database is particularly difficult if we consider the shortage of patients willing to participate in research programs and, in the specific case of PD patients, their mobility limitations. In this paper we present detailed information regarding the construction of a new database that can be used for the analysis of speech of people with Parkinson's disease. This database is built with speech recordings of 100 Spanish native speakers, 50 of them are diagnosed with PD and the rest are their age and gender matched healthy controls.

To the best of our knowledge, this is the first database that considers speech recordings of Spanish native speakers for the study of speech disorders related to PD. The corpus includes different tasks that were designed in collaboration with neurologists, linguists and engineers. In addition to the presentation of the database, in this paper the results of the preliminary characterization of the Spanish vowels are presented along with a classification experiment performed with a support vector machine with soft margin and a Gaussian kernel. The rest of the paper is organized as follows: Section 2. presents all of the details about the people who participate in the recording sessions. Information about the gender, age, and the extent of the disease on each patient is also provided in this session. Section 3. shows the tasks that were developed by the participants during the recording process. Section 4. includes the description of the experiments performed over the five Spanish vowels to classify between recordings of people with PD and healthy controls. Finally, in section 5. the conclusions derived from this work are presented.

2. Speech corpus

The database includes speech recordings of 50 people with PD and 50 healthy controls, 25 men and 25 women on each group. All the participants are Colombian Spanish native speakers. The age of the men with PD ranges from 33 to 77 years old (mean 62.2 $\pm$ 11.2), the age of the women with PD ranges from 44 to 75 years old (mean 60.1 $\pm$ 7.8). For the case of healthy controls, the age of the men ranges from 31 to 86 (mean 61.2 $\pm$ 11.3) and the age of the women ranges from 43 to 76 years old (mean 60.7 $\pm$ 7.7). Therefore, the database is well balanced in terms of age and gender. The recordings were captured in noise controlled conditions, in a sound proof booth that was built at the Clínica Noel, in Medellín, Colombia. The registers were sampled at 44100 Hz with 16 resolution bits, using a dynamic omnidirectional microphone (Shure, SM 63L) which is commonly used for professional applications. The recordings were captured using a professional audio card with up to 24 bits and such that supports up to 96Kbps of sampling rates (M-Audio, Fast Track C400). All of the patients were diagnosed by neurologist experts and were labeled according to the UPDRS and H&Y scales; the recording of the speech samples were done with the patients in ON-state, i.e. no more than 3 hours after the morning medication. None of the healthy control had symptoms associated to PD or any other neurological disease. This study is in compliance with the Helsinki Declaration and was approved by the Ethics Committee of the Clínica Noel, in Medellín, Colombia. A written informed consent was signed by each participant.

Details about UPDRS values, H&Y values, age, etc. of each speaker are given in Tables 1 and 2, for men and women, respectively. The left side of the tables include data from the patients and the right side from the control group.

M-PD				M-HC
Age	**UPDRS**	**H&Y**	**t**	**Age**
81	5	2	12	86
77	92	5	15	76
75	13	1	1	71
75	75	3	16	68
74	40	2.5	12	68
69	40	3	5	67
68	14	1	1	67
68	67	4	20	67
68	65	3	8	67
67	28	2	4	65
65	32	2	12	64
65	53	2	19	63
64	28	2	3	63
64	45	2	3	62
60	44	3	10	60
59	6	1	8	59
57	20	2	0.4	56
56	30	2	14	55
54	15	3	4	55
50	53	2	7	54
50	19	2	17	51
48	9	3	12	50
47	33	2	2	42
45	21	1	7	42
33	51	2	9	31

M-PD: Men-Parkinson's Disease, **M-HC**: Men-Healthy Controls and **t**: time post PD diagnosis (in years).

Table 1: Age, UPDRS, H&Y and time after the PD diagnosis of the men patients. For the case of healthy controls only the age is provided.

W-PD				W-HC
AGE	**UPDRS**	**H&Y**	**t**	**AGE**
75	52	3	3	76
73	38	2	4	75
72	19	2	2.5	73
70	23	2	12	68
69	19	2	12	65
66	28	2	4	65
66	28	2	4	64
65	54	3	8	63
64	40	2	3	63
62	42	3	12	63
61	21	1	4	63
60	29	2	7	62
59	40	2	14	62
59	71	3	17	61
58	57	2	1	61
57	41	3	37	61
57	61	3	17	60
55	30	2	12	58
55	43	3	12	57
55	30	2	12	57
55	29	2	43	55
54	30	2	7	55
51	38	3	41	50
51	23	2	10	50
49	53	2	16	49

W-PD: Women-Parkinson's Disease, **W-HC**: Women-Healthy Controls and **t**: time post PD diagnosis (in years).

Table 2: Age, UPDRS, H&Y and time after the PD diagnosis of the women patients. For the case of healthy controls only the age is provided.

3. Speech tasks

The recording protocol considers different tasks which were designed to analyze several aspects of the voice and speech of people with PD. Such tasks can be grouped into three aspects: phonation, articulation and prosody.
With the aim of be clearer the translation of every task is also included and marked in italics.

3.1. Evaluation of phonation

The evaluation of phonation is performed into two tasks:

1. Three repetitions of the five Spanish vowels uttered in a sustained manner.

2. The five Spanish vowels uttered changing the tone of each vowel from low to high.

3.2. Evaluation of articulation

The articulation capability of a person can be addressed not only considering sustained phonations of the vowels but also with the repetition of different words that contain phonemes whose pronunciation requires the movement of certain muscles and the velum that may be affected by PD. The tasks included in the protocol are:

1. Three repetitions of the five Spanish vowels uttered in a sustained manner (the same as for the evaluation of phonation).

2. The rapid repetition of the following words and phonemes (diadochokinetic evaluation) (Rusz et al., 2011): /pa-ta-ka/, /pa-ka-ta/, /pe-ta-ka/, /pa/, /ta/, /ka/.

3. Repetition of a set of different words grouped into three subsets:

   Set 1 - Words that form a phonological inventory of the Colombian Spanish: petaca, bodega, pato, apto, campana, presa, plato, brazo, blusa, trato, atleta, drama, grito, globo, crema, clavo, fruta, flecha, viaje, llueve, caucho, reina, ñame, coco, gato.

   Translation: petaka, cellar, duck, suitable, bell, dam, dish, arm, blouse, deal, athlete, drama, cry, balloon, cream, clove, fruit, arrow, trip, rains, rubber, queen, yam, coconut, cat.

   Set 2 - Motor verbs: acariciar, aplaudir, agarrar, dibujar, patalear, pisotear, trotar, sonreír, soplar, masticar.

   Translation: stroke, clap, grab, draw, stamp, trample, jog, smile, blow, chew.

   Set 3 - Nouns naming concrete objects: barco, bosque, ciudad, establo, hospital, luna, montaña, nube, puente, tractor.

   Translation: ship, forest, city, stable, hospital, moon, mountain, cloud, bridge, tractor.

3.3. Evaluation of prosody

Although most of the works related to the analysis of speech of people with PD have been focused on extracting features from the voice signal seeking mainly phonatory and articulatory information, it is well known that the communication ability is one of the most affected skills in these kind of patients (Ramig et al., 2008); therefore this protocol considers the inclusion of different tasks oriented to analyze the loss of prosody properties in the speech of people with PD. The evaluation considers the following tasks:

1. Repetition of different complex and simple sentences (from the syntactic point of view):

   (a) Mi casa tiene tres cuartos. (Simple)
   Translation: My house has three rooms.

   (b) Omar, que vive cerca, trajo miel. (Complex)
   Translation: Omar, who lives near, brought honey

   (c) Laura sube al tren que pasa. (Complex)
   Translation: Laura gets on the passing train

   (d) Los libros nuevos no caben en la mesa de la oficina. (Simple)
   Translation: The new books do not fit in the office's table

   (e) Rosita Niño, que pinta bien, donó sus cuadros ayer. (Complex)
   Translation: Rosita Niño, who paints well, donated her paintings yesterday

   (f) Luisa Rey compra el colchón duro que tanto le gusta. (Complex)
   Translation: Luisa Rey buys the hard mattress that is so fond her

2. Reading of a dialog between a doctor (**D**) and a patient (**P**). This text is phonetically balanced and contains all of the Spanish sounds (spoken in Colombia). The dialog is as follows:

   P: Ayer fui al médico.
   D: Qué le pasa? Me preguntó.
   P: Yo le dije: Ay doctor! Donde pongo el dedo me duele.
   D: Tiene la uña rota?
   P: Sí.
   D: Pues ya sabemos qué es. Deje su cheque a la salida.

   Translation
   P: *Yesterday I went to the doctor.*
   D: *What happened to you? He asked me.*
   P: *I said him: ah doctor! Where I put my finger it pains me.*
   D: *Do you have the nail broken?*
   P: *Yes.*
   D: *Then we now know what is happening. Leave your check at the exit.*

3. Reading of sentences with additional emphasis in particular words (marked with capital letters). The sentences are detailed below:

   (a) Viste las noticias? Yo vi GANAR la medalla de plata en pesas. Ese muchacho tiene mucha fuerza!
   Translation: Did you see the news? I saw to WIN the silver medal in Weightlifting. That boy is very strong!

   (b) Juan se ROMPIÓ una PIERNA cuando iba en la MOTO.
   Translation: Juan BROKE his LEG when was driving his motorcycle.

   (c) Estoy muy triste, ayer vi MORIR a un amigo.
   Translation: I am very sad, yesterday I saw a friend DIE.

   (d) Estoy muy preocupado, cada vez me es más difícil HABLAR.
   Translation: I am very concerned, it is increasingly more difficult to TALK.

4. Spontaneous speech: monolog with an average duration of 44.86s

   The patients are asked to speak about what they commonly do in a normal day, i.e. at what time they wake up, what kind of activities they do during the morning and in afternoon, etc.

This evaluation protocol only takes between eight to ten minutes and allows the phoniatry experts to perform other kind of particular evaluations or exercises that they do during a normal clinical evaluation.

4. Experiments and results

The recordings collected on this database open the possibility to perform many studies with the speech of people with PD in the Spanish language. Deep analysis on phonation, articulation and prosody can be addressed with this corpus. In this paper we present the results of preliminary experiments we have done considering only the five Spanish vowels.
The speech recordings are divided into frames and different features are calculated on them. After that, four statistics are calculated per feature on every recording: mean value, standard deviation, kurtosis and skewness.
The details of the features that are calculated on the speech recordings are presented in the following subsections.

4.1. Noise measures

The noise measures are calculated on voice frames of $40ms$ of length with an overlap of $20ms$. The first feature calculated is the HNR, which is a measure of the noise content in the phonation (Yumoto et al., 1982); then, the Cepstral version of HNR ($CHNR$) (de Krom, 1993) is also measured; thereafter, Voice Turbulence Index (VTI) is calculated in order to estimate the turbulence components caused by incomplete or loose abduction of the vocal folds (Yumoto et al., 1982). Soft Phonation Index (SPI) is included with the aim of evaluate the poorness of high-frequency harmonic components (Deliyski, 1993); NNE is calculated to measure the energy of the noise present in the voice respect to the total energy of the signal (Kasuya et al., 1986); and finally, GNE is measured to calculate the amount of excitation voice due to the vibration between the vocal folds versus the excitation noise caused by turbulence in the vocal tract (Michaelis et al., 1997). Note that the feature vector with the noise measures is composed by a total of 24 values (four statistics calculated on six features).

4.2. Periodicity and stability measures

For these features, the recordings are divided into frames of two different lengths. One group of measures uses frames of $40ms$ of length and $20ms$ of overlap. This group includes the variation of the maximum amplitude of the pitch period (shimmer) (Baken and Orlikoff, 2000) and the variation of the maximum time of the pitch period (jitter) (Feijoo and Hernández-Espinosa, 1990). The second group uses voice frames of $150ms$ of length and $75ms$ of overlap. This length is taken to ensure segments of the signal with at least 12 pitch periods. The features included in the second group are: Relative Average Perturbation (RAP) that quantifies how much period-to-period difference exists if period duration are smoothed over three adjacent cycles (Boyanov and Hadjitodorov, 1997); PPQ that is the variability of the pitch period evaluated in five consecutive cycles (Godino-Llorente et al., 2000); and the APQ which is the average difference between the amplitude value of five preceding pitch periods and their respective five successive (Godino-Llorente et al., 2000). In this case, the feature vector is composed by a total of 20 values (four statistics calculated on five features).

4.3. Classification

The classification process is done with a support vector machine (SVM) as in (Orozco-Arroyave et al., 2013). This classifier is trained using a radial basis Gaussian kernel with

band-width σ and it is tested following a $10-$fold cross-validation strategy. It is important to note that even though the folds are taken randomly, on each fold the balance of age and gender of the speakers is guaranteed during the processes of training and testing.
A SVM is used here due to its validated success in similar works that address the problem of the automatic detection of pathological speech signals (Marier et al., 2009; Arias-Londoño et al., 2011; Orozco-Arroyave et al., 2013).

4.4. Results

Table 3 shows the results obtained with the noise measures and table 4 shows the accuracy values obtained with the stability and periodicity measures. The accuracies obtained with noise features are around 77% when the vowels /a/ and /i/ are evaluated. For the case of the stability and periodicity measures, note that all of the accuracies are above 80%. The highest accuracy is 91.3% which is obtained with the vowel /a/.
These results indicate that with noise measures calculated on just one sustained vowel, it is possible to reach accuracies near 80%. For the case of the periodicity and stability measures the accuracy is increased up to 91.3%; it suggests that the variability of the pitch is a very good cue that must be considered to characterize vowels uttered by people with PD.

	Accuracy %	**Specificity** %	**Sensitivity** %
/a/	77.0 ± 6.6	78.7 ± 13.6	75.3 ± 11.8
/e/	74.7 ± 6.3	72.0 ± 13.6	77.3 ± 15.8
/i/	77.0 ± 7.8	75.3 ± 9.9	78.7 ± 15.6
/o/	73.7 ± 8.1	71.3 ± 8.9	76.0 ± 13.8
/u/	72.0 ± 7.7	68.7 ± 17.8	75.3 ± 18.1

Table 3: Results with noise measures

	Accuracy %	**Specificity** %	**Sensitivity** %
/a/	91.3 ± 6.3	92.0 ± 6.9	90.7 ± 12.3
/e/	81.3 ± 6.1	85.3 ± 12.9	77.3 ± 14.8
/i/	84.0 ± 9.7	82.0 ± 20.4	86.0 ± 17.9
/o/	86.3 ± 9.3	85.3 ± 12.1	87.3 ± 15.2
/u/	86.0 ± 6.8	89.3 ± 14.5	82.7 ± 13.4

Table 4: Results with stability and periodicity features

Figures 1 and 2 show the receiver operating curves (ROC) obtained with the stability and periodicity features and with noise features, respectively. These curves are displayed to show the results in a more compact way and also because they are commonly used to analyze the performance of different medical decision systems. The better performance obtained with the stability and periodicity features can be evidenced from these curves. Note also that the best results are obtained with vowel /a/ in both sets of features.

5. Conclusion

A new database with speech recordings of Spanish native speakers with Parkinson's disease and their respective controls matched by gender and age has been presented. The data is collected in noise controlled conditions, using a professional microphone and sound card. The evaluation protocol that was followed for the recording of the speech samples was designed in collaboration with phoniatry experts, linguists and neurologists. According to the state of the art, this is the first database recorded in Spanish and considering people with PD and matched controls. This corpus will open the opportunity to perform analysis of phonation, articulation, prosody and intelligibility in speech of patients with PD.
Preliminary experiments, only considering the sustained phonation of the five Spanish vowels, are also included in this paper. According to the obtained results, the measures that quantify the variability of the pitch and the stability of the phonation are good features to detect the presence or absence of PD.
It is important to note that the development of tools and methods to detect and to follow the extent of PD from speech independent of the spoken language will be possible

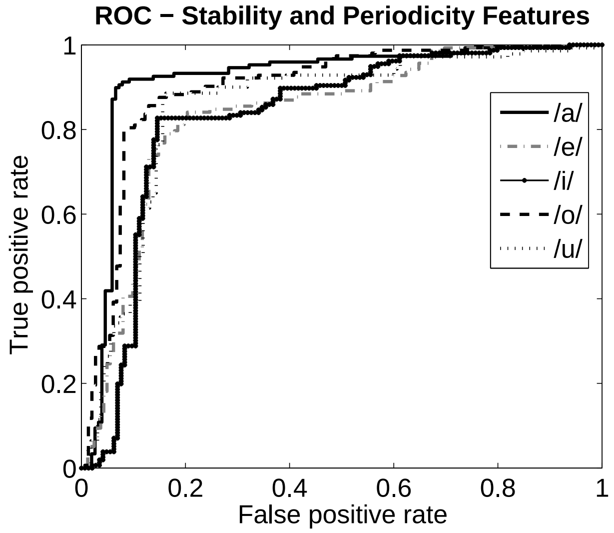

Figure 1: ROC curves obtained with the stability and periodicity features

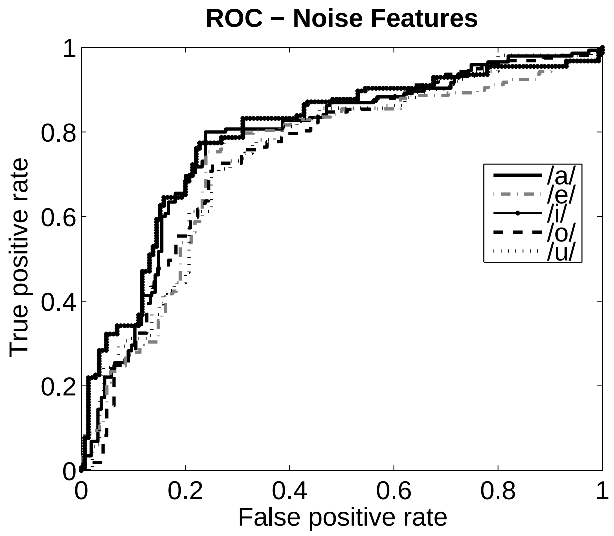

Figure 2: ROC curves obtained with the noise features

in the future; especially because there are other databases with recordings people in German, Czech and English that contain recordings that allow the evaluation of phonation, articulation, prosody and intelligibility.

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