Apkinson: a Mobile Solution for Multimodal Assessment of Patients with Parkinson's Disease

J. C. Vásquez-Correa[1,2], *T. Arias-Vergara*[1,2,3], *P. Klumpp*[1], *M. Strauss*[1], *A. Küderle*[4], *N. Roth*[4],
S. Bayerl[5], *N. García-Ospina*[2], *P. A. Perez-Toro*[2], *L. F. Parra-Gallego*[2], *C. D. Rios-Urrego*[2],
D. Escobar-Grisales[2], *J. R. Orozco-Arroyave*[1,2], *B. Eskofier*[4], *E. Nöth*[1]

[1]Pattern Recognition Lab, Friedrich-Alexander-Universität, Erlangen, Germany.
[2]Faculty of Engineering, Universidad de Antioquia UdeA, Medellín, Colombia.
[3]Department of Otorhinolaryngology. Ludwig-Maximilians-University, Munich, Germany.
[4]Machine Learning and Data Analysis Lab, Friedrich-Alexander-Universität, Erlangen, Germany.
[5]TH Rosenheim, Rosenheim, Germany.

juan.vasquez@fau.de

Abstract

Parkinson's disease is a neurological disorder that produces different motor impairments in the patients. The longitudinal assessment of the neurological state of patients is important to improve their quality of life. We introduced Apkinson, a smartphone application to evaluate continuously the speech and movement deficits of Parkinson's patients, who receive feedback about their current state after performing different exercises. The speech assessment considers phonation, articulation, and prosody capabilities of the patients. Movement exercises captured with the inertial sensors of the smartphone evaluated symptoms in the upper and lower limbs.

Index Terms: Parkinson's Disease, Phonation, Articulation, Prosody, Longitudinal Assessment.

1. Introduction

Parkinson's disease (PD) is a neurological disorder that produces motor and non–motor impairments. Motor symptoms include bradykinesia, rigidity, resting tremor, and different speech impairments, which are called hypokinetic dysarthria. The motor symptoms progress differently among patients, thus it is important to monitor their symptoms individually and continuously. The continuous monitoring is not always possible for many PD patients, especially those with low accessibility to health-care services i.e., those who live in remote rural areas [1]. There is a need for a system to track the disease progression individually and continuously. A smartphone application that combines speech and movement analysis could be a suitable mechanism to monitor the disease progression of the patients.

In the past years, various smartphone applications were developed to monitor PD symptoms [2]. However, most of them only consider the evaluation of upper and lower limbs using inertial sensors embedded in the smartphone [2, 3]. There are few applications to evaluate speech symptoms of PD patients [4, 5]. In the *mPower* for iPhones [4], the patients respond to a subset of questions from the Unified Parkinson's disease rating scale (UPDRS), and perform short activities such as finger tapping or the phonation of the sustained vowel /a/. In the *HopkinsPD* [5] the patients have to perform 5 exercises related to the phonation of the vowel /a/, finger tapping, gait, balance, and reaction time. These applications considered a small subset of exercises for the assessment of the patients, especially for the symptoms related to speech, where only the phonation analysis of sustained vowels is considered. On the other hand, related studies have shown that it is possible to evaluate the speech impairments of PD patients using signals captured with smartphones [6, 7]. However,

such studies consider the smartphone to record only the speech data, and do not provide a feedback mechanism to the patient about the current state of the disease. A first version of Apkinson was introduced previously [8]. The previous version only considered the evaluation of the phone calls made by the patients, which is no longer possible due to recent privacy restrictions in the last Android versions. In addition, it is necessary to evaluate several aspects of the speech and movement of the patients for an accurate assessment of the general neurological state, and the dysarthria severity. This paper introduces a new version of Apkinson, which is able to evaluate continuously the speech and movement symptoms of PD patients. Additionally, the new version provides a feedback mechanism about the current stage of the disease of the patients.

2. System Description

Apkinson is an open source[1] Android application to monitor the state of the disease of PD patients. The patients are asked to do different exercises everyday, using their smartphones. Then, Apkinson evaluates the performance of the exercises, and keeps a register of the results from previous sessions. The main screen of Apkinson is divided into four sections to be accessed by the patients, caregivers, or the medical examiners: profile, settings, exercises, and results (see Figure 1a).

Profile: The patients can visualize in this section information related to the medication intake and to the number of completed exercise sessions (see Figure 1b).

Settings: This section (see Figure 1c) allows to manage general aspects of Apkinson like updates of the demographics or medication information of the patients, or to change the time of the notifications to remind the patients to do the daily exercises. In addition, when the patient attend a medical appointment, Apkinson allows the medical examiner to export the information from the patients, and to update the exercises that the patient has to perform on a daily basis.

Exercises: The list of exercises to be performed by the patient is shown in this section (see Figure 1d). The patient will receive a daily notification as a reminder to do the exercises. The daily exercises are selected from an exercise bank, which contains a total of 35 exercises (5 different tasks per day during a week). The speech exercises (21) include tasks such as the phonation of sustained vowels, diadochokinetic (DDK) utterances, several sentences that the patient has to read, and the description of images that appear in the screen. These tasks evaluate the phonation, articulation, and prosody impairments
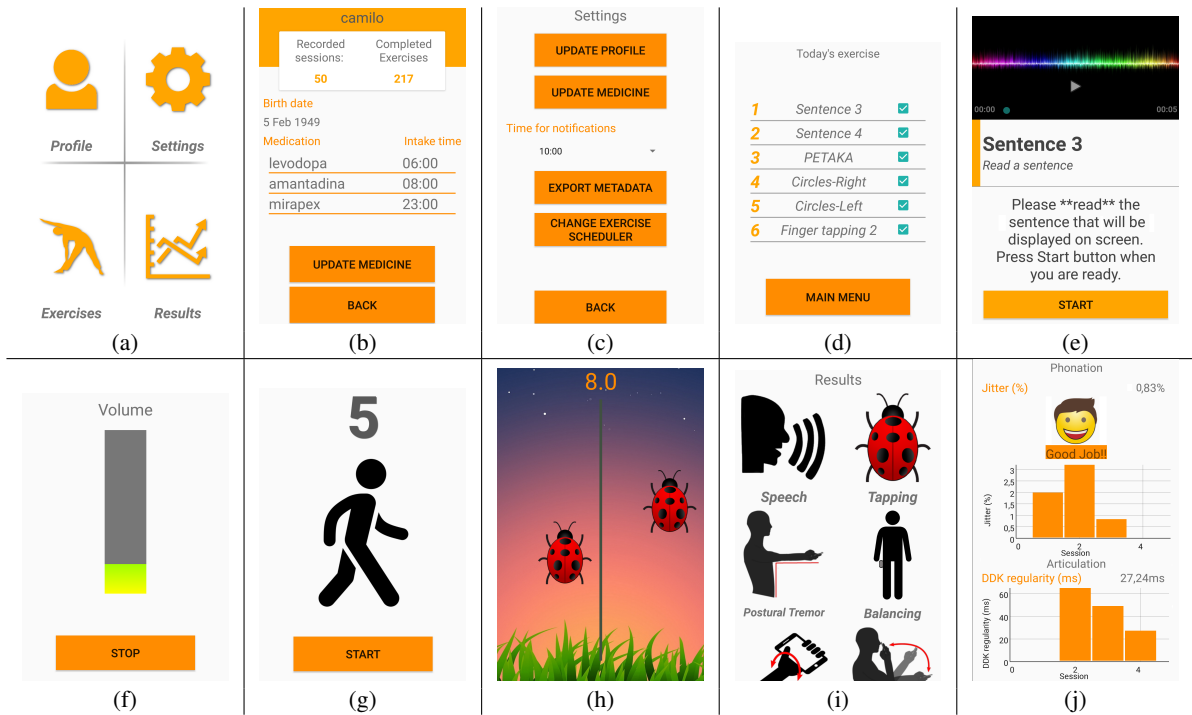
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[1]https://github.com/jcvasquezc/SMA2

Figure 1: *Different screens from Apkinson for multimodal and longitudinal assessment of the state of the patients.*

of the patients. On the other hand, movement exercises based on the UPDRS scale are captured using the inertial sensors of the smartphone to evaluate symptoms such as postural tremor, kinetic tremor, finger tapping, gait deficits, among others. The patient will receive instructions via video and text (see Figure 1e). Then, they follow a set of screens to perform the speech and movement exercises (see Figures 1f, 1g and 1h). Particularly, for the finger tapping exercise from Figure 1h, the patient has to touch the lady-bugs with two fingers in an alternate way.

Results: Patients can see their performance after doing the exercises, and to compare the results w.r.t previous sessions. Figure 1i shows the interface to access the results for the different exercises. Figure 1j shows the result screen for the speech analysis, and include the phonation assessment using perturbation measures like jitter, and the articulation assessment with features like the DDK regularity. The bar plots from Figure 1j indicate the longitudinal assessment of the speech symptoms, in the three sessions performed by the patient.

3. Evaluation of patients

At the moment, a group of 20 patients in Medelln, Colombia is testing the functionalities of Apkinson. They performed all the speech and movement exercises and received the feedback about the performance obtained. The speech state of the patients is evaluated in terms of phonation, articulation, and prosody, while the assessment of movement deficits is evaluated according to the tremor amplitude and the stability of the movements.

4. Conclusion

We introduced Apkinson, an open source Android application for the continuous assessment of the state of PD patients. Apkinson is designed to capture speech and movement signals of the smartphone of PD patients when they perform different exercises. The patients receive feedback about their performance. Further releases of Apkinson will include robust models to pre-dict the neurological state of the patients, and the speech deficits in the phonation, articulation, and prosody dimensions.

6. References

[1] B. H. Quittenbaum and B. Grahn, "Quality of life and pain in parkinson's disease: a controlled cross-sectional study," *Parkinsonism & Related Disorders*, vol. 10, no. 3, pp. 129–136, 2004.

[2] G. Postolache *et al.*, "Smartphone sensing technologies for tailored parkinsons disease diagnosis and monitoring," in *Innovations in Communication and Computing*. Springer, 2019, pp. 251–273.

[3] C. Stamate *et al.*, "The cloudupdrs app: A medical device for the clinical assessment of parkinsons disease," *Pervasive and mobile computing*, vol. 43, pp. 146–166, 2018.

[4] B. M. Bot *et al.*, "The mpower study, parkinson disease mobile data collected using researchkit," *Scientific data*, vol. 3, p. 160011, 2016.

[5] A. Zhan *et al.*, "Using smartphones and machine learning to quantify parkinson disease severity: the mobile parkinson disease score," *JAMA neurology*, vol. 75, no. 7, pp. 876–880, 2018.

[6] T. Arias-Vergara *et al.*, "Unobtrusive monitoring of speech impairments of parkinson's disease patients through mobile devices," in *Proc. ICASSP*. IEEE, 2018, pp. 6004–6008.

[7] J. Rusz *et al.*, "Smartphone allows capture of speech abnormalities associated with high risk of developing parkinsons disease," *IEEE Trans. on Neural Systems and Rehabilitation Engineering*, 2018.

[8] P. Klumpp *et al.*, "Apkinson-a mobile monitoring solution for parkinson's disease." in *Proc. INTERSPEECH*, 2017, pp. 1839–1843.