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Leveraging expert-knowledge-aware machine learning, multi-objective optimization and GenAI for discovery of personalized path to speech fluency in hard-to-treat cases

Valeriy Gavrishchaka[1,2], PhD (Theoretical and Computational Physics)
Marina Orlova[2], MS (Biophysics)
Zhenyi Yang[2], MS (Financial Mathematics, Computer Science)
Andrey Makeyev[2], MS (Mathematics)
Rebecca Miao[2], MS (Financial and Applied Mathematics, Computer Science)
Victoria Smirnova[2], MS (Speech Psychology and Psycholinguistics)

1. West Virginia University, Physics Department, Morgantown, WV, USA
2. Applied Quantitative Solutions for Complex Systems (aqscs.com), Falls Church, VA, USA

SHORT INTRODUCTION

Stuttering is complex phenomenon with no known single cause that can be linked to multiple physical, psychological and psychosomatic factors [1]. Despite continuous research and significant improvements of practical therapies, there is still no reliable, research-backed “cure” that works consistently, over long periods, and for all people who stutter [1,2]. Nevertheless, there are many practical techniques to alleviate stuttering, including variety of speech modifications approaches [2].

However, existing approaches cannot warranty fast and persistent improvements in all cases. For example, although “Fluency Shaping” techniques demonstrated ability for a long-term impact on the auditory-to-motor pathways inside the human brain that is necessary for fluency, positive and persistent outcome is not always warranted.

Effectiveness of most speech modification and similar techniques strongly depends on multi-factor personalization especially in hard-to-treat cases, however, there are no systematic objective methods for their optimization. While strong speech modifications, e.g. singing, are effective but not practical, objective techniques for personalized discovery of targeted minimal speech modifications to achieve natural fluency are not available.

OBJECTIVE(S) AND METHODS

We proposal and test multi-expert framework for discovery of personalized path to persistent speech fluency in hard-to-treat cases leveraging expert-knowledge-aware machine learning (EKAML), multi-objective optimization and generative AI (GenAI)

For resolving existing gaps and challenges in handling hard-to-treat cases , we developed a multi-expert framework for discovery of personalized path to persistent speech fluency leveraging EKAML [3], multi-objective optimization and GenAI techniques.

The key edge of our framework is quantification and combination of the best speech modification techniques and data-driven discovery of new effective extensions using provided speech recordings as well as classification of evolving emotional states and estimation of their correlation with detected stuttering periods.

KEY OBJECTIVES AND EDGE

Main Goal: Discovery of optimal, fast and easy-to-follow personalized path to natural and persistent speech fluency

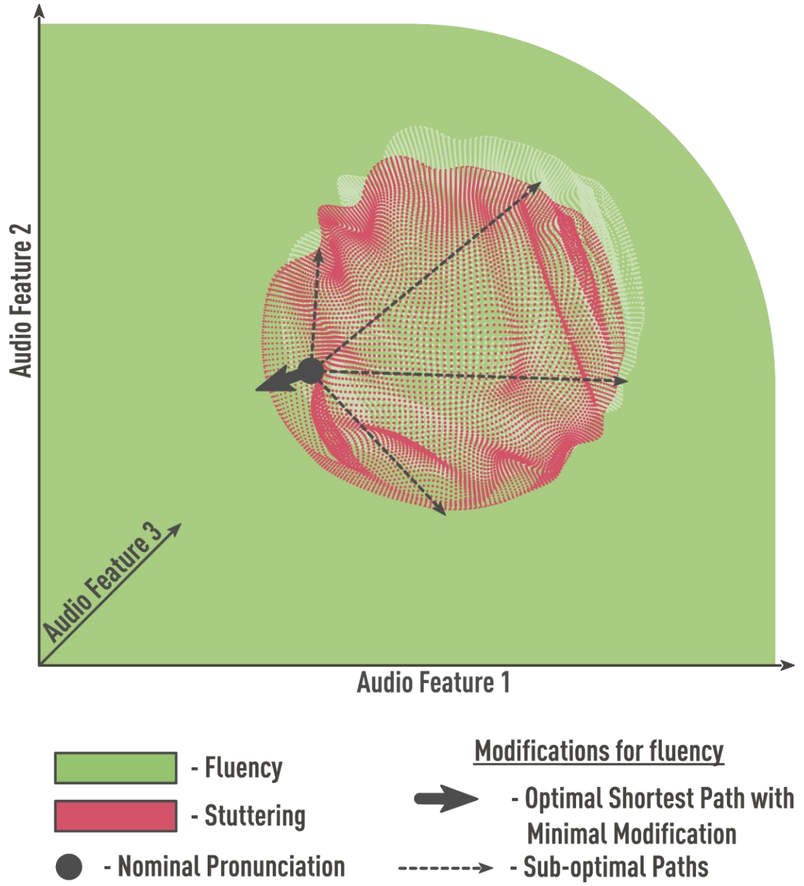
Key Edge: Quantification and optimal combination of the best speech modification techniques and successful personal path to fluency of one of the authors

Evolving Personalization: Using user-specific speech recordings, personal list of “hard” words and physiological data, our algorithms discover evolving personalized fluency regions and fine-tune optimal speech modification

No Confusing or Complex Descriptions: Discovered optimal speech modifications are directly presented to the user as modified audio files for each “hard” word

Reporting Objective Metrics: Stuttering rates / types and emotional states from speech recordings

- for quick optimal selection and performance monitoring of any fluency shaping technique
- for objective measuring of stuttering anticipation levels
- for discovery of best / worst emotional states for personal speech fluency and other fluency vs emotion correlations



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MULTIPLE METRICS AND INTEGRATED DECISION SUPPORT

Fluency Leap AI™: *Features, Components and Operation*

User Inputs – will work with any combination of provided inputs (all inputs are optional)

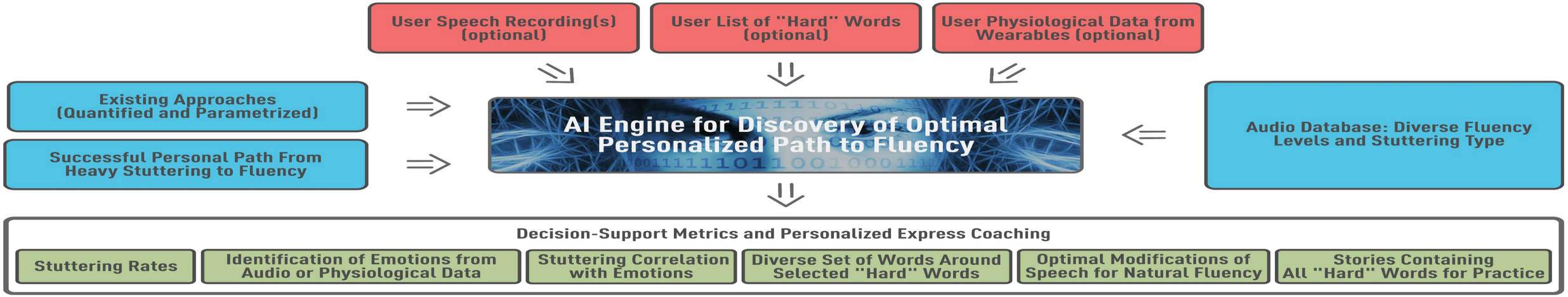
- Speech Recording(s)
- List of “Hard” Words
- Physiological Data from Smartwatches, fitness trackers and other wearables

Knowledge and Data used by AI Engine for Transfer Knowledge, Training and Fine-Tuning

- Quantified and Parametrized Techniques for Stuttering Alleviation Currently Used by Practitioners
- Knowledge from Successful Personal Path from Heavy Stuttering to Fluency (real experience of one of the system developers)
- Audio Data Sets with Diverse Fluency Levels and Stuttering Types (Public and Proprietary Data)

Multiple Decision-Support Metrics and Personalized Express Coaching Sessions Generated by the System

- Computed Stuttering Rates for Monitoring and Feedback
- Emotional States Identified from Audio or Physiological Data
- Correlation of Stuttering Rates with Emotional States
- Diverse Set of Words Around Selected "Hard" Words (Identified by Multiple Audio Features Optimized for this Application)
- Minimal Audio Modification of each “Hard” Word for Natural Speech Fluency (Personalized Multi-Objective Optimization)



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RESULTS
System Operation Example

1. Upload the audio file to generate the Stuttering reports

Select a sound file (.wav): Browse... test.wav

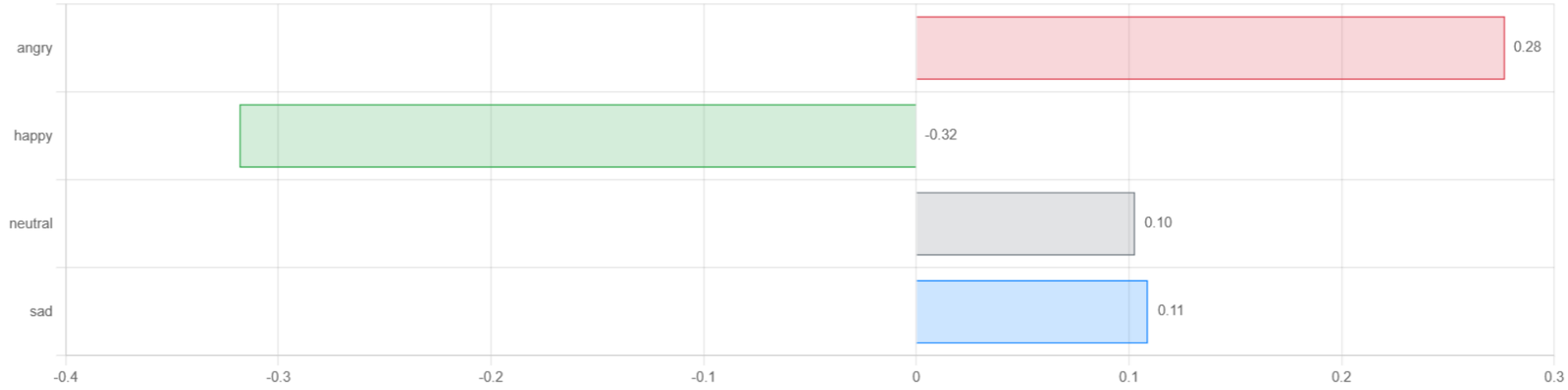
2. Choose the Language

English

Stuttering Fraction (0 to 1) and Emotional State Probabilities

File	Stuttering Fraction	Emotion Probabilities Happy Angry Neutral Sad
test.wav	0.132	Happy: 0.3686830188679245 | Angry: 0.152173584905660 | Neutral: 0.3762886792452829 | Sad: 0.1028547169

Correlation of Emotions with Stuttering Rate



ML/DL-based computation of multiple objective metrics from speech recordings including stuttering rates / types and emotional states

- for quick optimal selection and performance monitoring of any fluency shaping technique
- for objective measuring of stuttering anticipation levels
- for discovery of best / worst emotional states for personal speech fluency / stuttering
- for discovery of any persistent correlations of fluency / stuttering with evolving emotional states

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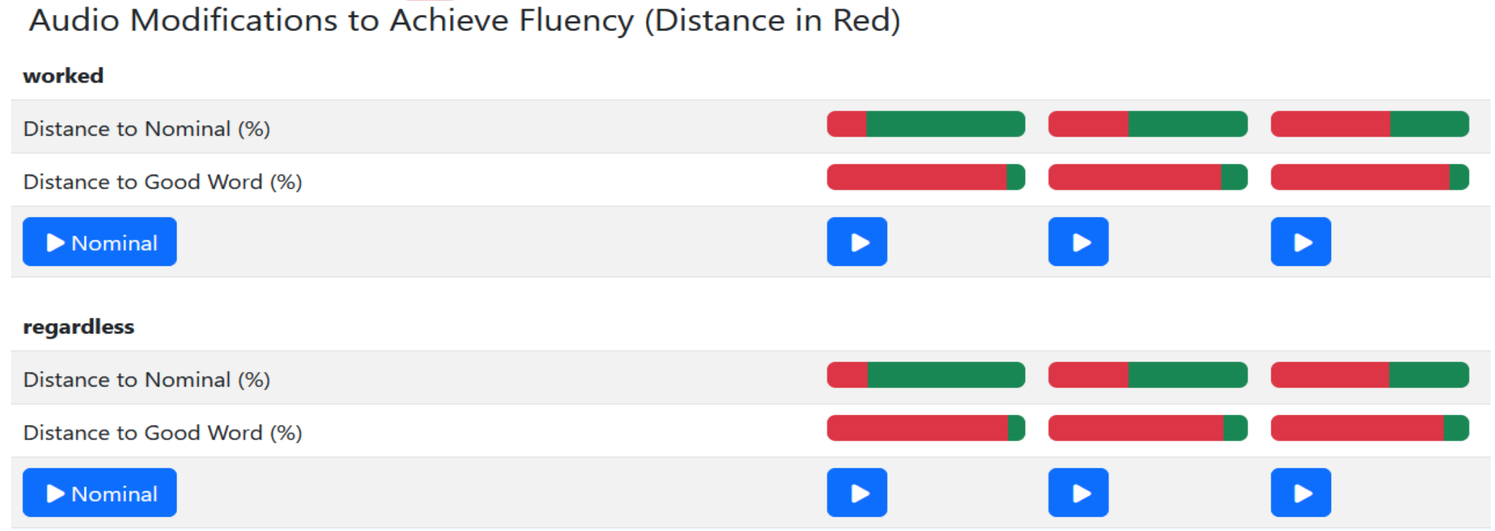
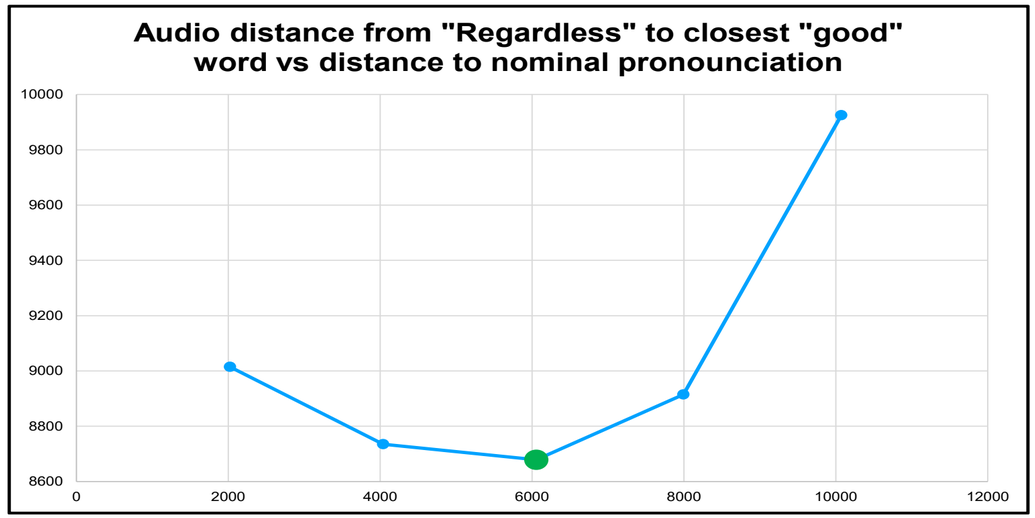
RESULTS
System Operation Example





Generated Text with Hard Words for Fluency Practice (with increasing difficulty)

I worked hard on my project, regardless of the challenges I faced. There were times when I didn't believe I could finish it, especially when things got tough. If only I had more time, I thought, I might have been able to perfect every detail. Being in a creative field means that you often put your heart and soul into your work, and that can be both rewarding and exhausting. I tried to stay positive, reminding myself that every effort I put in would be worth it in the end. So, I took breaks when I needed to clear my mind, allowing myself to re-energize and return to the task with fresh eyes. It's important to be patient with yourself during such times, as the process of creation can be unpredictable. In the end, I learned that the journey is just as important as the destination. It's about growth, learning, and finding joy in what you do. I hope that others can find the same fulfillment in their work, because it truly is a wonderful feeling to see something you've created come to life, regardless of the obstacles you overcame along the way.

So often in life, we find ourselves reflecting on the choices we made and the paths we followed. If only we had worked harder or taken a different direction, perhaps things would be different. Regardless of the decisions that brought us here, we must recognize the value of being present in the moment. It can be easy to dwell on the past, but that only leads to frustration and a sense of regret. Instead, we should focus on what we can control: our actions and attitudes in the present. Did we seize opportunities, or did we let them slip away? If we can learn to embrace our experiences, even the difficult ones, we can find strength and wisdom. Life is not just about the outcomes; it is also about the journey we undertake along the way. Each moment provides an opportunity to grow and evolve, so let's strive to be the best versions of ourselves. In this way, we can create a future that reflects our true potential. If only we remember that it's not too late to change course and make the most of our time, we can achieve greatness beyond our imagination.

Being in a world where challenges are omnipresent, one might ponder on the idea of success, questioning whether it is an inherent trait or a product of relentless effort. If only we could unravel the mysteries of perseverance and innate talent! So many individuals have worked tirelessly, disregarding the naysayers, forging ahead with unwavering resolve. Did we ever stop to consider the myriad distractions that lurked in the shadows, attempting to divert our focus? Regardless of the obstacles that appear on our path, the true measure of one's character often lies in the response to adversity. If only we could embrace failures as stepping stones rather than milestones of despair! To be resilient is to recognize that setbacks are but fleeting moments in the grand tapestry of our journey. In this intricate dance of life, we must not merely exist on the periphery but actively engage in our aspirations. If only the fear of failure did not paralyze so many, we might witness a world brimming with untapped potential. Ultimately, the pursuit of greatness beckons; we must step forward, armed with conviction, for each moment holds the power to transform dreams into reality.

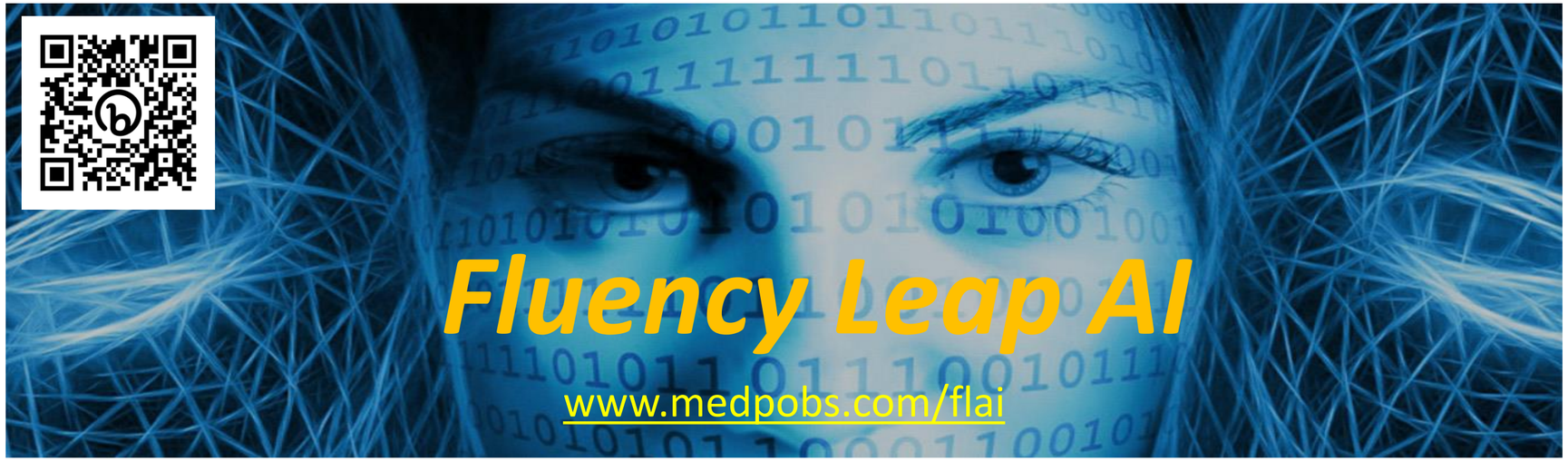
- One of key features of our system include discovery of personalized fluency regions and detection of “hard” words from provided audio recordings to generate minimal optimal modifications for such words facilitating fluency even for difficult words.
- We also select words close to such “hard” words from our database using weighted multi-component distance measure incorporating key audio features. Currently it is based on customized “Dynamic Time Warping”.
- Modification is multi-objective optimization problem where we try to minimize distance to nominal pronunciation, while moving to personalized “fluency” region, i.e. find minimal modification that moves pronunciation to fluency region. See chart above where proxy distance to fluency region is defined as a distance of the modified “hard” word to the closest “fluent” word of the individual.
- Currently extreme values of noise reduction filter are used to soften consonants to produce modifications. More general modifications based on gradient boosting with multiple domain-specific constraints combining multiple audio features (not just consonant softening) will be adopted soon, where we also maximize distance to a list of typical “hard” words.
- Finally, for practice we provide customized call to ChatGPT to generate texts of increasing difficulty containing discovered “hard” words and those close to them.

CONCLUSIONS

Multi-expert AI-driven framework for the discovery of personalized path to persistent speech fluency is proposed and encouraging results are demonstrated.

Further research and development efforts as well as practical applications to hard-to-treat cases are warranted.

Information about new versions of the system and summary of application results will be provided at **https://www.medpobs.com/flai**



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