PaceMaker

Cost Effective Real-Time Solution for Runners
MCA Team 7

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Recap

Motivation: Running is hard

"I get tired after running for a mile"

- Kristian Romero

"I can never meet my goal"

- Nina Rothenhaus

"I literally hate running … I get light headed"

- Monique Wongwatana

Recap

Proposed Idea: A cost effective real time feedback system for all runners

Garmin / Samsung

Personal Trainer
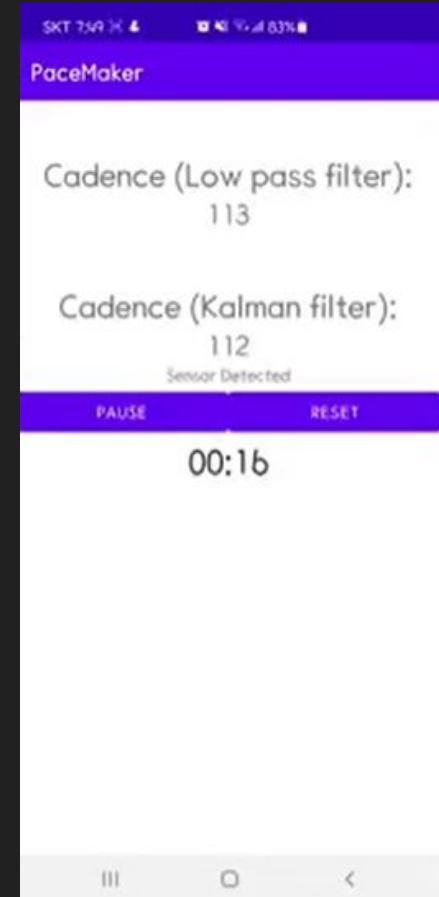
Recap

Novelty:

1. Feedback tailored to individual
2. Real time feedback
3. Help user achieve their goal
4. Smartphone-independent implementation

Demonstration

Previous Demo

- Device
  - Smartphone
- Function
  - Target cadence is fixed
  - Estimate cadence
    - LPF-based vs. **KF-based**
  - Feedback by vibration
    - Slow pattern & Fast pattern

Feedback for the Comment

Comment 1: Receive user input about the running goal

Feedback

    Assume that user input target pace (ex. 10km/h)

        → **Add additional feedback for the pace**

    To change the pace, step size should be changed

        Pace = cadence * step size (∵ cadence is fixed)

    Feedback by voice

        "Increase step size" & "Decrease step size"

보폭에 따른 코스별 기록표(케이던스 185기준)

보폭(m)	10km	하프	풀
1.00	0:54:03	1:54:02	3:48:04
1.05	0:51:28	1:48:36	3:37:13
1.10	0:49:08	1:43:40	3:27:20
1.15	0:47:00	1:39:09	3:18:19
1.20	0:45:02	1:35:02	3:10:04
1.25	0:43:14	1:31:13	3:02:27
1.27	0:42:39	1:30:00	3:00:00
1.30	0:41:34	1:27:43	2:55:26
1.35	0:40:02	1:24:28	2:48:56
1.40	0:38:36	1:21:27	2:42:54

Feedback for the Comment

Comment 2: Subdivide according to the gender, age, height, etc.

Comment 3: Utilize heart rate information

Feedback

    Optimal cadence might be different for each user

        → **Personalize the target cadence value!**

    Heart rate information can be used for personalization

        Find optimal cadence based on each user's heart rate

        (Minimize the heart rate while maintaining the pace)

    Feedback by target cadence update

        Increase target cadence & Decrease target cadence

Final Demo

- Device
  - Smartwatch (Galaxy watch 4)
- Function
  - Cadence feedback
    - Vibration (every 5 sec)

  - Pace feedback
    - Voice (every 5 sec)

  - Cadence personalization
    - Target value change (every 30 sec)

Final Demo

- Device
  - Smartwatch (Galaxy watch 4)
- Function
  - Cadence feedback
    - Vibration (every 5 sec)
    - (ex. 60~100 spm)
  - Pace feedback
    - Voice (every 5 sec)
    - (ex. 4~6 km/h)
  - Cadence personalization
    - Target value change (every 30 sec)
    - (ex. 80~120 bpm → +-5 spm)

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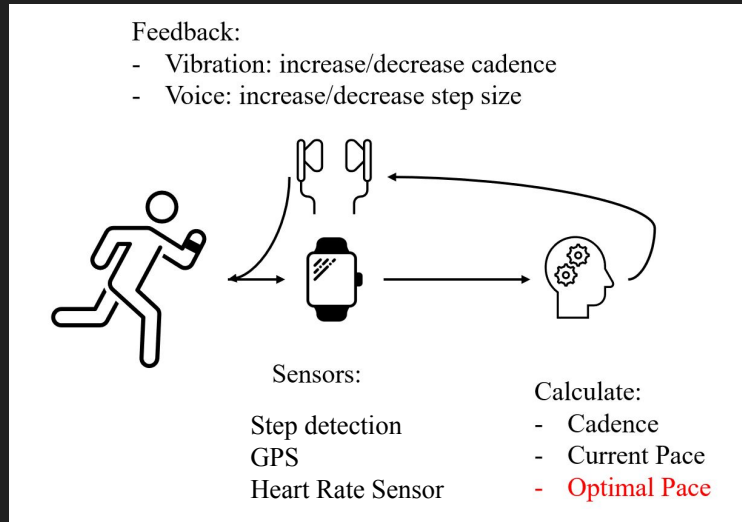
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Technical Details

System Architecture Overview

Phone-Independent architecture (standalone watch app)

- Cadence, pace detection
- Real-time vibration/voice-based feedback

Feedback:
- Vibration: increase/decrease cadence
- Voice: increase/decrease step size

Sensors:

Step detection
GPS
Heart Rate Sensor

Calculate:
- Cadence
- Current Pace
- Optimal Pace

Technical Challenges

1. Wear OS provides limited documentation
   a. No clear way to implement HR sensors, Inertial sensors, etc.

2. Feature extraction using a watch
   a. HR: multiple error-inducing cases
      (i.e. watch is detached from wrist, sweat makes PPG difficult, etc.)
   b. Pace: watches have weaker GPS detection strength than smartphones
      => pace detection is harder
   c. High battery usage

3. Lack of knowledge in fitness
   a. Providing "optimal" pace for users

Solutions

1. Wear OS provides limited documentation:
   a. Multiple trial and error to find right sensors

2. Feature extraction using a watch
   a. HR: Implement various error checking methods to check if watch is properly aligned and functioning
   b. Pace: Use both step detection data and GPS data to approximate pace when GPS is poor (however, still need to have good GPS connection…)
   c. Inefficient battery: Still a work in progress! Maybe implement what we learned in class?

3. Lack of knowledge in fitness
   a. Read/research multiple papers to understand optimal pace
   b. Using heart rate to determine intensity

Success Criteria

✅ Use case applicable for mobile

✅ Implemented for mobile devices

✅ Gives feedback appropriately

✅ Gives real-time feedback

Project Management

Scope of the Project

Added:

- Heart rate detection + HR-based feedback
- GPS-based pace detection

Removed:

- ML-based personalization
  - Non-rule based DNN-based personalization was difficult to implement using limited data
  - Heuristic-based personalized pace follows expert recommendations
- Smartphone dependency
  - Smartwatches were capable of necessary calculations (Kalman filters, GPS-based pace calculation)
  - Smartphones add weight to runners (bad use-case scenario)

Timeline

Task	Duties (Initials)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Team Phasing																
Team Creation	ALL			■												
Ideation	ALL				■											
Market Research	ALL					■										
Researching																
Existing & Alternative Solution	ALL				■	■										
Design Research	ALL					■										
Phase 1 Feedback	ALL										■					
Phase 2 Feedback	ALL													■		
Estimate Competition	ALL														■	■
Implementation & Prototyping																
Application Design	Design Team						■									
Order Potential Parts	ALL							■								
Development Phase 1	Dev Team								■	■						
Testing Phase 1	ALL										■					
Planning Phase 2	ALL															
Development Phase 2	Dev Team											■	■			
Testing Phase 2	ALL													■		
MVP Kick-off	ALL														■	■

Roles and Contributions

길광연	- Created initial android app
김영석	- Developed GPS-based pace calculation algorithms - Debugged various features and calculations - Implemented app with Galaxy Watch (created demo)
이상민	- Developed vibration feedback - Implemented cadence calculation algorithm
손성욱	- Developed HR based feedback system - Debugged various app features
송재헌	- Developed voice feedback - Developed HR detection system - Implemented wear OS version of completed app (+ UI)

Insights

Lessons Learnt

- Smartwatches have better computation capabilities than expected
    - Personalization is somewhat possible with real-time feedback
    - However, it is still very hard for smartwatches to run DNN-based algorithms
    - Furthermore, sensors & various calculations drain smartwatch batteries very quickly

Many optimizations are needed to balance smartwatch battery life with sensor detection and calculations

Thank You!
Q/A

Comment from Mid-term Presentation

1. Receive user input about the running goal
2. Subdivide according to the gender, age, height, etc.
3. Utilize heart rate information
4. Set up the target cadence differently for each section
5. FTP test (?)