Wearable Inertial Sensor for Jump Performance Analysis

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Overview

• Jump performance is frequently used to monitor training progress in athletes or injured patients.

• Measurements are typically captured in clinic with accurate but expensive instrumentation.

• We propose the use of a versatile low-cost wearable device
  – Equipped with inertial sensors
  – On-board estimation of jump height
  – Easily employed at home
Wearable Devices

Wearable devices: we all know they are having a huge diffusion in consumer applications

• **Pros:** low cost, ease of use, unobtrusive
• **Cons:** not highly accurate and not validated

Healthcare Applications

• Medical applications need **high accuracy** and **clinical validation**, thus they still suffer a **gap in the inclusion of new technologies** and wearable devices [Lee14].

• A new trend is the diffusion of **at home** and **personalized** therapy practices, which leverage the use of existing technologies (wearables, mobile) [Pantelopoulos10].
  – e.g. Exergaming platforms based on wearable sensors or Kinect

• The **research** and **development** of such solutions is a challenging topic
  – Low cost and accurate sensing solutions
  – Patient interfaces and biofeedback
  – Web interface for the clinician
Jump Analysis

- Jumps are extensively used to evaluate the physical condition of patients and athletes [Kale09, Herbst15].

- Accurate and expensive (1k÷10k$) technology is used for jump evaluation in clinics:
  - Multi-camera motion capture systems
  - Force plates [Bosco83]
  - Inertial-based systems, e.g the MyoTest [Nuzzo11, Choukou14]

- Alternative solutions have been studied using wearable inertial sensors [Picerno 11] or smartphones [Balsalobre14].
Our Solution

Wearable device for the evaluation of jump performance

- Self-contained wearable device with on-board processing
- Low-cost (≈100$) and easy to use
- Analysis of two jump types:
  - Counter-Movement Jump (CMJ) used for explosive force assessment
  - PlyoMetric Jump (PMJ) used for reactivity assessment
- Validated against a commercial clinical device
System Description

Wearable low cost sensor node equipped with:

- ARM Cortex M3 MCU – STM32F1, 78MHz
- Inertial Measurement Unit (9-Axis IMU by Invensense, 300Hz)
- Bluetooth
- Button, LED, buzzer
Counter-Movement Jump (CMJ)

CMJ: one jump performed with a counter-movement starting from the upright still position

- 5 jump phases: counter-movement, take-off, flight, landing, recovery
- Jump height is the performance metric
CMJ Height Estimation

- Low pass filter: 20 sample mean filter
- Features: acceleration variance to estimate if the user is still/in motion
  - To initialize the algorithm the user is required to stand still before a jump
- The orientation of the device is constantly updated
  - Initialized when still with accelerometer
  - Updated integrating the gyro during jump
- The vertical inertial acceleration $a^G$ is obtained by rotating the measured acceleration and subtracting $g$
- Jump phases are identified by thresholds: when in flight, $a^G$ is set to -$g$
- $a^G$ is double integrated to estimate the jump height
CMJ Height Estimation

Algorithm output:

- Acceleration [m/s²]
  - X
  - Y
  - Z

- Orientation [°]
  - Roll (X)
  - Pitch (Y)
  - Yaw (Z)

- Vertical Acc. [m/s²]

- Jump Height [m]

Time [s]
PlyoMetric Jump (PMJ)

PMJ: sequence of 4 jumps performed in rapid succession
• The mean height of the last three jumps and the total contact time are used as performance metric
• Same segmentation and estimation algorithm as for CMJ
• At each landing interference acceleration peak due to impact on the floor
  – Difficult to filter out, hence we apply a correction step at each jump
PMJ Height Estimation

Algorithm output
Experimental Validation

- The proposed system was validated against the MyoTest Pro 2
  - Clinically validated wearable device for jump assessment
- Dataset of jumps collected while wearing both devices:
  - 40 healthy subjects (32/8 male/female)
  - Different fitness levels (from sedentary to trained athletes)
  - Each performed 3 CMJs and 2 PMJs
  - Total: 120 CMJs and 80 PMJs
Results

CMJ:
• Height: mean difference 0.7cm, max: 1.6cm (2.6%)
Results

PMJ:

- Height: mean difference: 0.6cm, max: 1.5cm (1.9%)
- Contact time: mean difference 23ms, max: 33ms (9%).
Conclusion

• This work presented a wearable system for the evaluation of jump performance
  – Low cost solution targeted for autonomous use at home
  – CMJ and PMJ jumps analysis
  – Validation against a clinical device on 200 jumps

• The results show that our system is accurate
  – Mean error: CMJ = 0.7cm, PMJ = 0.6cm

• Future development:
  – Integration in rehabilitation practices at home
  – Evaluation and test for use at home
Thank You!

Questions...?

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References


