Not-So-Dumbbells – Augmenting free-weights to enhance awareness in fitness applications.

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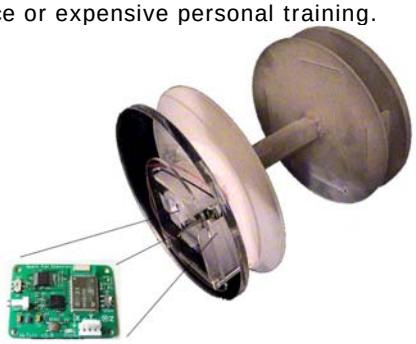
Introduction

Now, more than ever, there is an increasing need for people of all ages to become more physically active. Technology continues to redefine lifestyle habits, allowing us to complete everyday tasks quicker and with more efficiency; however, these advancements have significantly replaced our everyday movements. To counteract the effects of these sedentary environments each year millions of Americans begin various fitness plans yet only a fraction achieve adequate results. How can we take advantage of technologies to instead enhance our fitness experiences, giving more efficient and educated workouts?

The Not-So-Dumbbells attempts to begin providing intelligent fitness equipment by integrating a 3-axis accelerometer into each dumbbell in order to provide real-time monitoring and feedback. Such data, when properly analyzed, may promote the appropriate execution of exercises without the need for extended practice or expensive personal training.



Augmented Dumbbell prototype

When executed properly, free-weights provide the most efficient and productive workout since their lack of constraint requires the user to call on many more supporting stabilizing muscles. However, novice exercisers avoid the use of free-weights because they lack the proper knowledge and are unsure if they are performing the maneuvers properly, decreasing sufficient results and increasing the risk of injury. Consistent feedback is an essential component of proper execution, which is typically acquired visually through mirrors. Still, to the novice user there are many cues that go unnoticed (proper controlled acceleration, body stability, balanced movements, and tempo) usually requiring a second pair of experienced eyes to guide them through the movements. Not-So-Dumbbells attempts to be those eyes by sensing each dumbbell's acceleration in multiple directions and notifying the user when improper patterns are observed.

Current personal training

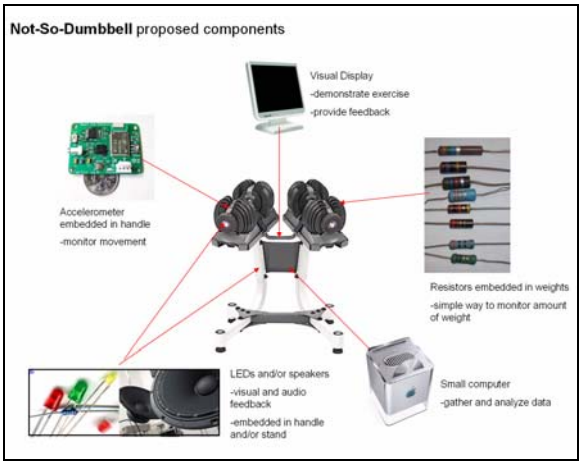
Virtual personal training proposal

Vision

Though the current phase of this project simply begins to study the feasibility and platform of the Not-So-Dumbbells, the vision of the fully functioning product encompasses a complete system that can foster virtual personal training via visually demonstrated instructions, sensors, visual and audio feedback and analytical abilities to dynamically create unique workout programs over time. To see how the envisioned system may work, let us observe a probable user scenario:

Joe, in his mid-thirties, is a busy consultant and is in satisfactory physical condition. Nevertheless, after his last physical his doctor suggested he become more active to assist in aiding support of his sore lower back and joints. He acquires the Not-So-Dumbbells system in order to perform brief workouts while he is home. After completing a brief profile questionnaire, the first exercise and suggested weight is displayed on a small LCD screen located on the dumbbell stand. Joe performs the series of displayed exercises one by one. As he progresses through the program towards more difficult maneuvers, he notices that the ends of the dumbbells are glowing bright amber. This alert cues Joe to view the LCD screen which suggests him to lower the weight by five pounds and try to "maintain a slower consistent tempo." These alerts encourage Joe to sustain proper form as fatigue sets in. After multiple sessions, Joe becomes more aware of his faulty habits when lifting free-weights and now only requires brief visual cues to remind him to maintain proper form. Over time Joe has begun to notice sufficient results and wants to preserve his improved health. Making sure not to loose interest from redundant exercises, Joe downloads some of the latest intermediate and advanced programs to follow. Although these new exercises are completely novel to him, Joe is confident that from the assistance of the visual cues and displayed feedback that he will be able to master the movements in no time.

The full Not-So-Dumbbell training system will be comprised of the following:



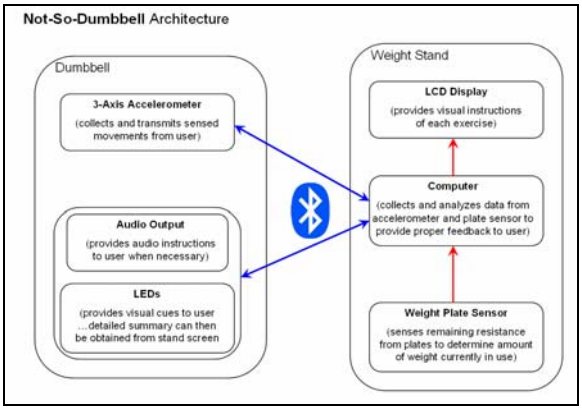
Proposed components

3-Axis Accelerometer collects and transmits sensed movements from user.
LCD Display provides visual instructions of each exercise.
Weight Plate Sensors have resistors embedded in each of the selectable weights allowing the system to always know what amount of weight the user has in the exercise.
Computer collects and analyzes data from accelerometers and plate sensors to provide the suitable feedback.
Visual and/or Audio Feedback comprised of speakers embedded in the dumbbells that can be used to provide instructions whereas LEDs are used to cue the user when audio is not desired.

The dumbbells used in this application are to be weight selectable (instead of assigning individual sets of weights) embedding the sensor and alerting technology in the two handles of the dumbbells. This way there are no redundant systems and the core valuable components can be utilized for every weight and exercise needed. Subsequently, placing resistors in each of the free-weighted plates that accompany the dumbbell handle will allow reading of the combined resistances (voltage divider). This will allow the training program to always know what weight is being used in order for it to better assess the situation and coach the user.

Implementation

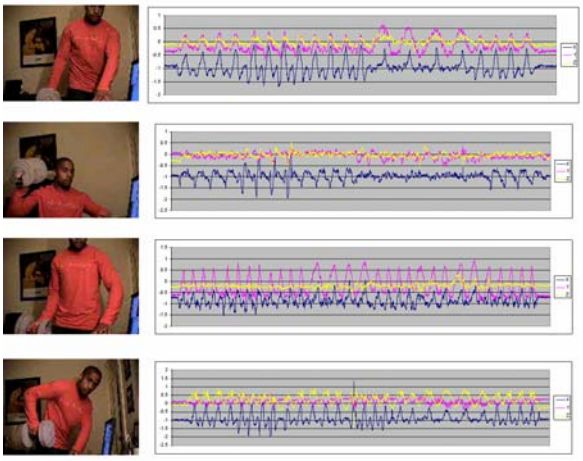
The following is the basic schematic illustrating how all the components of the Not-So-Dumbbell will interact:



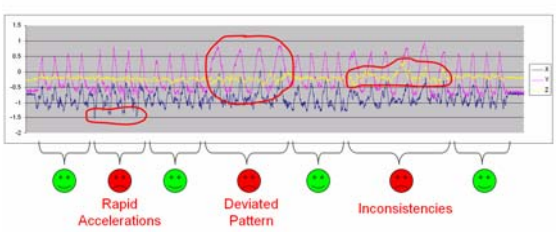
Component architecture

The Not-So-Dumbbells exploit a 3-axis accelerometer package by *SparkFun Electronics*, embedded in the body of a dumbbell that streams the various X, Y and Z acceleration values via Bluetooth to a local computer. During an exercise, computationally viewing the data values collected over time can provide further insight on how to pinpoint improper exercise gestures, such as rapid acceleration, excessive shaking, rhythm inconsistencies and repetition variations. Computational algorithms may then be developed to identify when these improper exercise gestures are present and suggest the necessary procedure for correction.

Movement from dozens of exercises were monitored and accompanied by video in order to recap and pinpoint characteristics where data seemed to reveal important moments.


X Y & Z acceleration values over time

The following data was recorded performing dumbbell biceps curls while continually alternating the form from correct movements to common faulty habits, such as swinging the weights.



Highlighting fragments of poor exercise execution

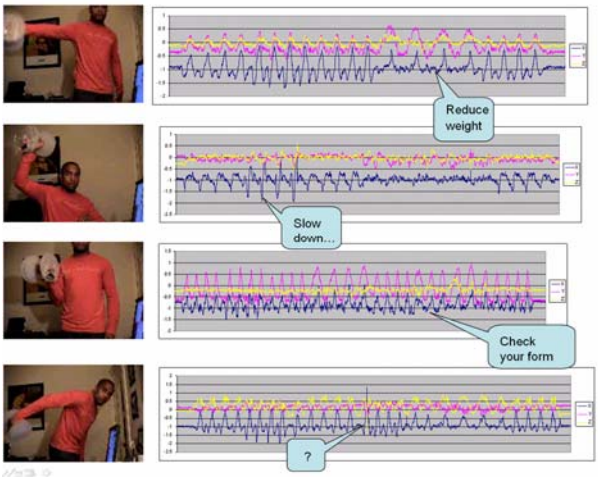
Variations in the waveforms can be observed at specific moments when the exercises were purposely performed incorrectly. This graph (as did the others) proves promising, illustrating that unique characteristics do appear when the movements of an exercise deviate from the normal. Sudden drops in values and inconsistent patterns can be traced to faulty implementation such as unsteady swinging of the weights and irregular movement paths. Further studies must be conducted to understand how robust this information will be and how difficult it will be to withdraw valuable results from more complex exercises that involve full body movements and multiple rotations of the dumbbells.

Conclusion

Implementing a small number of sensors such as an accelerometer can provide enough valuable information to extract certain characteristics pertinent to assessing and facilitating proper exercise execution. The 3-axis accelerometer used was sensitive enough to pick up on many subtleties that result from improper free-weight maneuvers. Although they do not extract as much rich data that can be obtained visually, they do exhibit promise in their ability to relay inconstancies and excessive movements counterproductive to the exercise tasks at hand.

Nevertheless, analyzing and understanding data to evaluate all movements provides an extremely challenging task. Too many variables currently exist, especially using free-weights, considering their unbound range of motion and the multitude of movements that can be performed with them. Therefore, instead of trying to extract the accelerometer information in order to remap it to location based analysis (as we do from visual feedback), it appeared best to scour the streamed data for anomalies, inconsistencies and tempo related cues, which in many situations can be enough to infer what improper movement the user is performing.

Though this system may not extract as much valuable data that a complex system of coordinated sensors (cameras, biometric readers, accelerometers and gyroscopes) or simply a human could, it attempts to observe, learn and teach by means of simple pattern recognition. Many times just reminding or making the user aware at key moments of incorrect execution can be enough to encourage sufficient adjustments towards a properly executed workout. Also, through subtle consistent pattern changes over fixed periods of time (reduced tempo for example), the system may be able to recognize user fatigue, which may represent key moments to introduce audio or visual encouragement.



Possible feedback to complement waveforms

The Not-So-Dumbbells augmented fitness equipment will be the first in a family of many sensor equipped exercise tools that gather information and provide feedback to assist in the proper education of fitness applications. The key is to use simple sensors embedded in various pieces of equipments to extract as much pertinent information as possible yet relay it back to the user in a simple manner to aid them in learning proper performance, achieve attainable results and encourage long term enthusiasm.