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PATENT CLAIM

Electronic Chin Up Station

1. Introduction

- 1.1 A complete chin-up exercise encompasses two distinct motions. First is the mount up position (herein called M1) where the user hanged with his palm gripped on the bar and arms fully extended (straighten) and his leg not touching the floor as shown in Figure 1.
- 1.2 Second is the upward motion (herein called M2) where he pulled his body upward until his chin went above the bar level as shown in Figure 2.

2. Detection Algorithm – General Description

- 2.1 A full chin-up cycle encompasses the complete action of M1 through M2. To detect both $M1_n$ and $M2_n$ motions, a matrix of optic sensors are arranged by the side of the chin up bar as shown in Figure 3. The number of sensors depends on the desired resolution. (i.e the higher the number of sensors, the higher the resolution it is and hence better precision).
- 2.2 At motion zero (i.e M_0), as shown in Figure 3, the algorithm automatically collects 2 profiles (a) number of sensor activated and (b) the level activation. Motion M_0 is explicitly defined as the starting position taken at rest prior to his initial attempt, at this position his arm is fully extended (straighten) and leg fully cleared from floor level.
- 2.3 Following motion M_0 , as shown in Fig 4 (i.e . $M1_{n+1}$ and $M2_{n+1}$), the algorithm captures the n^{th} profiles of subsequent motions and set as $PM1_{nth}$, and $PM2_{nth}$.
- 2.4 Collectively the algorithm computes the prevailing reference profiles (PR) of each motion (i.e PR_{M1} and PR_{M2}). That means the values of PR up to the preceding motion (M_{n-1}) are used to set the threshold to count or validate whether the subsequent chin-up cycle ($PM1_n + PM2_n$) is successful¹

¹A successful chin-up cycle is defined as that both arms must be straighten (fully extended) at $M1_n$. And consecutively at $M2_n$ the chin level must be lifted above the bar.

3. M1 Detection Algorithm

- 3.1 For illustration purpose, say we laid out a matrix of 5 by 8 optic sensors by the side of the chin-up bar identified from C1R1 (*column1, roll1*) to C5R8 (*column5, roll8*) as depicted in Fig 5. If each sensor is spaced 10 cm apart and has a detection zone of 100 cm², then the said matrix should cover an overall area of 4000 cm².
- 3.2 Different head's size will activate different number of sensors. At the same time different chin-up height will activate different level. The M1 detection algorithm simply collects (a) the number of activated sensors (converted to area) and (b) the level of sensor activated at M1₀ position. It takes into account that at M1₀, his arms must be fully extended (straighten) as shown in Figure 4.
- 3.3 For example, at M1₀ detection as show in Figure 6, the number of sensors activated may comprise of C1R6, C1R7, C1R8, C2R7 and C2R8. (5 sensors activated in total = 500 cm²). In addition the head level activation is at level 7. Level 1 has a known physical distant value measured from the 0 reference (say 30 cm). Therefore L7 will give a value of 30+(6*10) = 90 cm.
- 3.4 It is important to note that reference profile RP_{M1} has 2 elements – the level (L) and the area of NON-activation (N). Hence RP_{M1} for this particular M1 motion () is set to (a) $LRP_{M1} = 90$ and (b) $NRP_{M1} = 3500$. The value of 3500 is derived from Total Area *minus* Activated Area (4000 – 500).
- 3.5 *Strictly speaking*, any subsequent n^{th} profile of M1 ($PLM1_{n+1}$ and $PNM1_{n+1}$) that matches or greater than the value of LRP_{M1} and NRP_{M1} respectively, should be validated as 'successful'.
- i.e: $TRUE_{M1n} \equiv PLM1_n \geq LRP_{M1} \text{ AND } PNM1_n \geq NRP_{M1} = 1$
- 3.6 However the algorithm must also take into account that the head may tilt backward during his subsequent M1 motion(s) as shown in Figure 7 - resulted in more sensors activated despite the arms remained straightened. That means the algorithm must still validate that particular M1_{n+1} as a successful one.

- 3.7 Having considered the above 3.6 scenario, a constant value (lets call this value, discount factor dF) should be applied to LRP_{M1} and NRP_{M1} . This value can be useful to set the stringent level (i.e Hard, Medium or Easy). Therefore the simple Count formulae for M1 can be defined as follow:

$$TRUE_{M1n} \equiv PLM1_n \geq (LRP_{M1} - LdF_{M1}) \text{ AND } PNM1_n \geq (NRP_{M1} - NdF_{M1}) = 1$$

where $TRUE_{M1n}$ is set to 1 if $PM1_n$ is successfully validated

where $PM1_n$ = the profile values of M1 motion at $M1_{nth}$

where RP_{M1} = the reference profile value at $M1_0$

where dF_{M1} = discount factor set as $(CT/100) \times RP_{M1}$

where CT is the constant value set between 1 to 10 (typical)

- 3.8 In view of the dynamism of head movement during executing of M1 motion, it is necessary to allow dynamic adjustment of dF_{M1} . A dynamic correction factor (dCF) is derived by capture the prevailing average value ($PM1_{pAVG}$) up to the last preceding $M1_{n-1}$ motion. For example, at the fifth motion of M1 where $n^{th}=5$ (i.e $M1_5$), the value of $PM1_{pAVG}$ will be set to the Sum of ($PM1_0$ to $PM1_5$) divide by 6.

- 3.9 The computed dCF_5 value is used to dynamically correct the dF constant and revise the threshold for validating $PM1_{5+1}$. Hence the formula for dCF_{M1} is defined as follow:-

$$dCFL_{M1} = \frac{(dFL_{M1} \times PLM1_{pAVG})}{LRP_{M1}}$$

And

$$dCFN_{M1} = \frac{(dFN_{M1} \times PNM1_{pAVG})}{NRP_{M1}}$$

Where $PM1_{pAVG}$ = the prevailing average value of PM up to the last preceding M1 motion ($M1_{n-1}$).

- 3.10 Taking into account of the above dCF, the simple Count formulae is now revised as follow:-

$$\text{TRUE}_{M1n} \equiv \text{PLM1}_n \geq (\text{LRP}_{M1} - \text{dCFL}_{M1}) \text{ AND } \text{PNM1}_n \geq (\text{NRP}_{M1} - \text{dCFN}_{M1}) = 1$$

Therefore the final COUNT formula for M1 detection is:-

$$\text{TRUE}_{M1n} \equiv \text{PM1}_n \geq \left[\text{RP}_{M1} - \frac{(\text{dF}_{M1} \times \text{PM1}_{\text{dAVG}})}{\text{RP}_{M1}} \right]$$

4. M2 Detection Algorithm

- 4.1 Prior to the initial motion of M2 (i.e at $M2_0$), a default value is set as a starting threshold for RP_{M2} . The default value of RP_{M2} is the arithmetic mean value of PM2 (M2_{MEAN}). This mean-value can be derived from a sizeable historical population data. For illustration purpose, say M2_{MEAN} for $L=50$ and $N=2300$, then the actual default value of RP_{M2} at $M2_0$ is set to 'L50, N2300'
- 4.2 At $M2_{n+1}$, as the body lifting upwards, the number of non-activated sensors will progressively decrease to a minimum value (M2_{Min}) - at the point where the arm fully collapsed and his chin's level went above the bar as shown in Figure 4.
- 4.3 For example if at M2_{Min} , the level activation is at level 2 and the number of sensors activated comprises of 16 sensors. Hence the value of PM2_{n+1} will be set to 'L50, N2400' because $L2 = (300+25+25)$ and $N = [4000-(16 \times 100)]$.
- 4.4 *Strictly speaking*, any value of PM2_{n+1} that matches or is lesser than the value of RP_{M2} , the so attempted M2 motion should be validated as 'successful'¹. i.e

$$\text{TRUE}_{M2n} \equiv \text{PLM2}_n \leq \text{LRP}_{M2} \text{ AND } \text{PNM2}_n \leq \text{NRP}_{M2} = 1$$

where TRUE_{M2n} is set to 1 if PM2_n is successfully validated

where PM2_n = the profile value of M2 motion at $M2_{nth}$

where RP_{M2} = the default reference profile value at $M2_0$

- 4.5 Similarly as in M1, a constant value of discount factor dF is introduced for user to set the stringent level (i.e Hard, Medium or Easy). Therefore the simple M2 Count formulae can be revised as follow:

$$\text{TRUE}_{M2n} \equiv [PM2_n \leq (RP_{M2} + dF_{M2})]$$

where dF_{M2} = discount factor set as $(CT_{M2}/100) \times RP_{M2}$

where CT_{M2} is the constant value set between 1 to 10 (typical)

- 4.6 In view of the dynamism of head movement during executing of M2, it is necessary to allow dynamic adjustment of dF_{M2} . A dynamic correction factor (dCF) is derived by capture the prevailing average value ($M2_{pAVG}$) up to the last preceding motion of $M2_{n-1}$.
- 4.7 For example, at the fifth motion of M2, where $n^{th} = 5$ (i.e $M2_5$), the $M2_{pAVG}$ is set to the Sum of ($M2_0$ to $M2_5$) divide by 6. The updated dCF value is used dynamically to correct the dF constant and set the revised threshold for validating $PM2_{5+1}$.

- 4.8 Hence the formula of dCF_{M2} is as follow:-

$$dCF_{M2} = \frac{dF_{M2} \times RP_{M2}}{M2_{pAVG}}$$

Where $M2_{pAVG}$ = value of the prevailing average up to the last preceding $M2_{n-1}$ motion.

- 4.9 Taking into account of the above dCF , the resultant Count formulae for M2 is revised as follow:-

$$\text{TRUE}_{M2n} \equiv [PLM2_n \leq (LRP_{M2} + dCFL_{M2})] \text{ AND } [PLM2_n \leq (LRP_{M2} + dCFL_{M2})] = 1$$

4.10 Correspondingly, the final Count formula for M2 is as follow:

$$LTRUE_{M2n} \equiv PLM2_n \leq [LRP_{M2} + \frac{(dFL_{M2} \times LRP_{M2})}{LM2_{pAVG}}]$$

AND

$$NTRUE_{M2n} \equiv PNM2_n \leq [NRP_{M2} + \frac{(dFN_{M2} \times NRP_{M2})}{NM2_{pAVG}}]$$

4.11 **EXAMPLE:** To successfully validate and count the 6th chin-up cycle the following VALIDATION must be true: -

$$TRUE_{M1(6)} \equiv PM1_6 \geq [RP_{M1} - \frac{(dF_{M1} \times M1_{pAVG})}{RP_{M1}}]$$

AND

$$TRUE_{M2(6)} \equiv PM2_6 \leq [RP_{M2} + \frac{(dF_{M2} \times RP_{M2})}{M2_{pAVG}}]$$

$$COUNT_{ChinUp} \equiv TRUE_{M1(6)} + TRUE_{M2(6)} = 1$$