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Design of a Remote Control Tripod Dolly (iDolly)

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Abstract: **This paper describes the design of a remote control tripod dolly, namely iDolly, a specialized piece of equipment designed to create smooth camera movements and ease equipment transportation. The final tripod dolly is 8 kg and is able to carry a load of 15 kg. IDolly is the first tripod dolly which can be controlled remotely. Existing tripod dolly available in the market are either controlled by pull handle, steering wheel or hand-operated. Mechanical design of iDolly is presented in this paper. The design concept, construction as well as components selection are included in this paper.**

Keywords: **Remote Control; Dolly; Tripod; Automotive; Mobile Robot; Wireless.**

1. INTRODUCTION

Remote control technology has continually evolved and advanced as the complexity of tasks grows rapidly [1]. iDolly is a remote-brainless tripod dolly robot system, in which an operator controls the dolly through a transmitter like a radio-controlled cars. A tripod dolly is also known as camera dolly, is a specialised piece of filmmaking and television production equipment designed to create smooth camera movements. The camera or often tripod stand is mounted to the dolly and the camera operator or camera assistant usually ride on the dolly to operate the camera. Apart from filming equipment, many measuring devices such as 3D Laser Scanners offered by Faro Technologies, Trimble and Leica are also first elevated by a tripod stand, and then transported by a dolly during scanning process.

Fig.1 presents an example of a foldable tripod dolly. There are also dollies operated by a pull handle or simply rolled along collapsible track as shown in Fig.2 and Fig.3.

Figure 1: Foldable Tripod Dolly [2]

Figure 2: Tripod Dolly with Pull Handle [3]

Figure 3: Dolly on Collapsible Track

These tripod dollies presented in Fig. 1, 2 and 3 present a few transportation problems. The foldable tripod dolly in Fig.1 has smaller wheels and it would become unstable when travelling on rough surfaces such as sand and gravel [2].

The tripod dolly operated by pull handle presented in Fig.2 could require a substantial force to move the front wheels and would result in a large turning radius [3]. Also, when heavy equipment is loaded on the dolly, it might be difficult to be moved by a single individual. The collapsible dolly and track [4,5] presented in Fig.3 is heavy and complicated to set up. Besides, high speed filming equipment and scanners typically take less than thirty minutes to complete recording process. Therefore, the time consumed for setting up the track may not justify the cost.

The main objective of iDolly is to increase the flexibility of transporting heavy filming equipment and these measuring devices in a less strenuous but more efficient way than mounting and demounting from tripod and carrying it by hand. iDolly would also allow any non-experienced operators to remotely control the transportation and handle the operation. This would eventually saves times and cost as well. There is no remote control tripod dolly currently available in the market and iDolly would fill a niche not currently filled in today's market.

2. iDOLLY OVERVIEW

iDolly is the first tripod dolly which can be controlled remotely. It is designed to fulfil a set of design criteria which were not fulfilled previously.

1) It must be able to be operated by a minimum of one person or a non-specialist.
2) It should be able to travel in all-weather conditions barring extreme snowfall.
3) It must not vibrate during the scanning process.
4) The platform must be easily detached from wheel assembly for storage.

iDolly has an empty dolly weight of 8 kg and it has a load carrying capacity of 15 kg, which is safe to carry most of the laser scanners available in the market. Fig.4 shows the CAD design of iDolly and Fig.5 shows the transmitter used to operate iDolly.

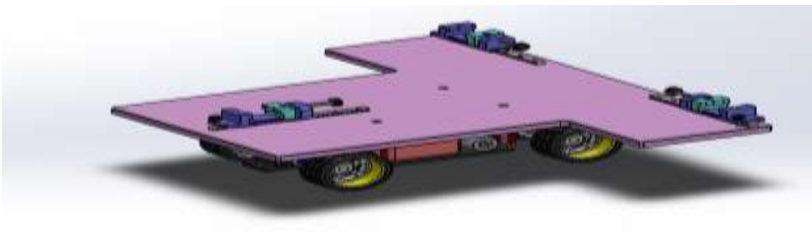

Figure 4: iDolly

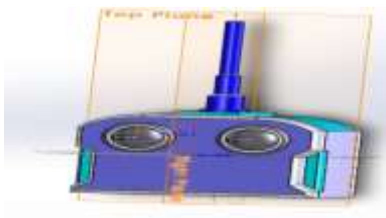

Figure 5: Transmitter

iDolly is made up of several important design components such as receiver for the remote controller, motor drive, battery, suspension systems, and etc. These components are discussed in Section 3 design components.

3. DESIGN COMPONENTS

This section outlines the important major components used in the final iDolly design.

3.1 Platform:

Flat platform is an important part of dolly construction. It not only provides a stable support, it also contributes to the dolly personality and appeal [6]. To increase the portability, the platform is detachable from the wheel assembly for easy storage; therefore, it does not hold any design components as this is the only way to disassemble the platform without touching the wires in the receiver.

The thin platform has a thickness of 20 mm and it is secured onto the chassis by four Allen Bolt M8X25mm. Fig.6 shows the detachable platform and its dimensions.

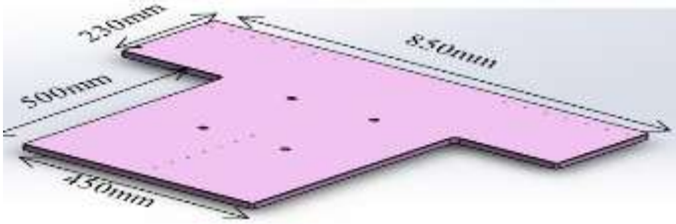

Figure 6: Detachable T-shaped Platform Dimensions

3.2 Adjustable Clamps:

To accommodate any conventional tripod stands, three adjustable clamps are added onto the platform as shown in Fig.7. The construction of these adjustable clamps involves several part components such as adjustable link, slider block, clamp rest, and a locking bar. The adjustable clamp has a few advantages:

1) It fits any conventional tripod stand which has a 60cm (24-inch) to 70cm (28-inch) base spread.
2) It allows the tripod legs to open to several different angles by providing up to 100 mm stroke, hence allowing shots for low positions.
3) It holds and secures the legs of tripod stand, reducing vibration and stabilizing the image captured.

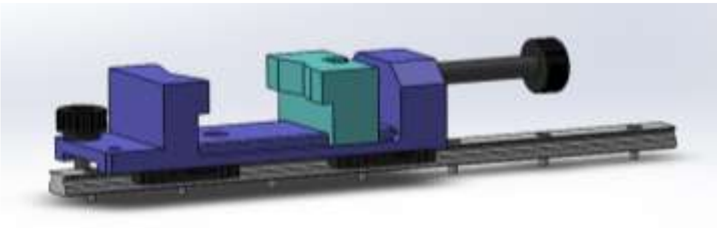

Figure 7: Adjustable Clamp

3.3 Remote Control System:

The remote control system used in iDolly is wireless instead of wired. With a wired remote control system, the operator uses a control box connected to the robot via a long wire or cable. However, the range is limited and the cable itself can get in the way during operation. Wireless, on the other hand, allows a much greater range for the operator, and there is no control cable to get in the way [7]. A wireless system is built out of a transmitter, receiver and servo [8]. Transmitter sends radio signals to the receiver, which will then convert these radio signals into electrical signals which the servos understand. A servo uses these signals to turn the motors attached to wheels [9,10].

3.4 Motorized Wheel:

iDolly uses four 4” ball bearing hard rubber motorized wheels. The required load capacity per wheel, T can be defined in Eq (1), where E is the empty dolly weight, Z is the dolly load capacity, N is the number of wheels, and S is the safety factor [11,12].

T= (E+Z)/N x S (1)

The required load capacity per wheel, T is 11.5 kg, hence I selected 4” ball bearing hard rubber wheel as shown in Fig. 8. The 4” ball bearing hard rubber wheel has a load capacity of 14 kg according to Blickle [12].

Figure 8: 4” Ball Bearing Hard Rubber Wheel.

To determine the correct motor to be attached to the wheels, required horsepower of the motor is calculated using the designed criteria listed in Table 1 and Eq (2)-(8). All equations used in this section are taken from the work of [13].

TABLE 1: IDOLLY DESIGN CRITERIA

Total Dolly Weight (Maximum Empty Dolly Weight + Maximum Load Capacity) (TDW)	23kg (50.7 Ib)
Desired Max Speed (V_{max})	0.45m/s (1.5ft/s)
Desired Acceleration Time (TA)	1sec
Radius of Wheel (R_w)	50.8mm (2 inches)
Maximum Inclined Angle (α)	3º
Coefficient of Surface Friction, C_{rr} of the Worst Working Surface	firm grass (0.055)

To choose motors capable of producing enough operating torque to propel iDolly, it is necessary to determine the total tractive effort (TTE) requirement for this dolly [14] .

TTE =RR+ GR+ FA (2)

Where:

RR=force necessary to overcome rolling resistance [Ib]

GR=force required to move iDolly up an incline [Ib]

FA= force necessary to accelerate from a stop to maximum speed in a desired time [Ib]

The components of this equation will be determined in the following equation (3)-(5).

RR [Ib]=TDW [Ib] x Crr (3)

GR [Ib]=TDW [Ib] x sin (α) (4)

$$FA\ [Ib \frac{TDW[Ib] x\ Vmax\ [\frac{ft}{s}]}{32.2\ [\frac{ft}{s^2}] x\ TA[s]} \quad (5)$$

The Total Tractive Effort (TTE) is calculated to be 7.8025Ib and the desired operating torque, To is 17.633 Ib-in as indicated by Eq (6).

To [Ib-in]=TTE[Ib] x Rw[in] x RF (6)

Where, RF is the “resistance factor” which accounts for the frictional losses between the wheels and their axles and the drag on the motor bearings [15]. Typical values range between 1.1 and 1.15 (or 10 to 15%) [16]. In this case, a value of 1.13 is used in the calculation.

Since iDolly has a max speed of 0.45m/s, the speed of the wheel in revolutions per minute (RPM) is calculated to be 84.59 rpm as defined by Eq (7). The amount of horsepower required for the motor is given in Eq (8).

RPM=(Vmax [in/min])/(2π Rw[in]) (7)

$$HP=\frac{2\pi\ x To[ft-Ib]\ x\ RPM}{330000[\frac{ft-Ib}{min}]} \quad (8)$$

The horsepower required to propel iDolly is 0.0283 hp, therefore, a permanent magnet DC electric motor which has an output power of 0.03 hp is selected.

3.5 Suspension System:

Four suspension systems are included in iDolly to optimize the vehicle's handling and stabilize the movement of idolly, especially for operation in all-terrain situations. The suspension system used in iDolly is a simple spring-damper shock absorber. It consists of a shock absorber with a coil spring encircling it. Hence, the methods used in analysis of the suspension system are a single mass-spring-damper model as shown in Fig.9, and also the use of ordinary second order differential equations, Eq (9)-(10) to design the suspension system.

Fig.9 can be represented by Eq (9) where m is the iDolly Empty Weight + Maximum Load Capacity, b is the damping coefficient of the shock absorber, k is the spring rate of the coil spring, and x is the measure of the spring displacement, and its associated velocity and acceleration derivatives. This equation allows for overdamped, critically damped, and under damped situations. iDolly aims to achieve a critically damped system to allow the suspension to recover as quickly as possible. The critically damped solution to Eq (9) is defined in Eq (10) where r is the roots of the equation as stated in [17,18].

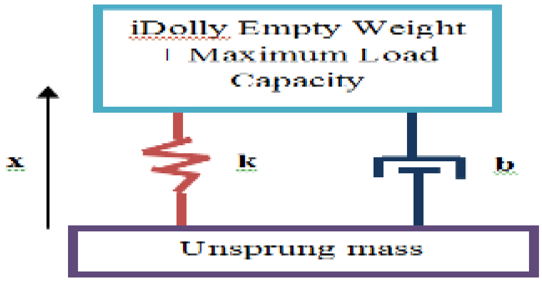

Figure 9: Mass-Spring-Damper System Model

$$m\ddot{x}=b\dot{x}+kx \quad (9)$$

$$x(t)= C_1e^{rt}+ t\, C_2\, e^{rt} \quad (10)$$

In order to achieve critical damping, it is necessary to relate spring rate and the damping coefficient. Namely, in solving for the roots of the differential equation, the radical in the quadratic equation must be zero (Eqs 11, 12).

$$r= \frac{-b\pm\sqrt{b^2-4mk}}{2m} \quad (11)$$

$$b= 2\sqrt{km} \quad (12)$$

Where k is the spring constant 2452.5 N/m calculated based on Hooke's Law. The damping coefficient calculated from Eq (12) is 350.17 kg/s. Fig.10 shows the CAD drawing of the suspension system. The four suspensions are secured to the dolly chassis by four Allen Bolts (M8X25mm).

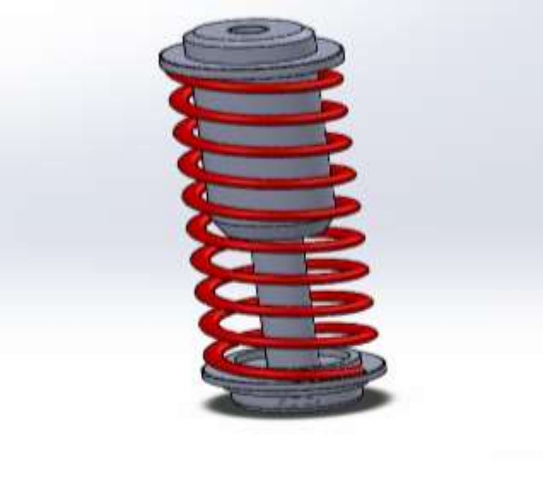

Figure 10: Suspension System

4. CONSTRUCTION

In order to make iDolly easier to travel with, the platform must be easily detached from wheel assembly for storage. Major design components are mounted on the chassis instead of the platform as this is the only way to disassemble the platform without touching the wires in the receiver. The construction of the chassis is shown in Fig.11 and the specification of iDolly is given in Table 2.

Figure 11: iDolly Chassis and its Components

Two miniature shock absorbers are attached to front suspension mount and the other two are attached to the rear suspension mount to further reduce shock and vibration on the dolly.

TABLE 2: SPECIFICATION OF IDOLLY

Dolly Section	Empty Dolly Weight, E	8 kg
	Max Load Carrying Capacity, Z	15 kg
	Dolly Height (from Ground Level)	200 mm
	Safety Factor, S	3
Platform	Vertical Platform Height	2 mm
	Platform Material	Aluminium
Remote Control System		Wireless
Wheel Section	Type	4” ball bearing hard rubber wheel
	Number of wheels, N	4
Motor	Type	Permanent Magnet DC Electric Motor
	Operating Torque	17.633 Ib-in
	Horsepower	0.03 hp
Battery		2x 6-volt rechargeable Nickel Metal Hydride (NiMH) batteries
Suspension System	Type	Spring-mass-damper shock absorber
	Height	138mm
	Spring Constant, k	2452.5 N/m
	damping coefficient, b	350.17 g/s

4.1 Wheel Assembly:

The detail view of the wheel assembly is shown in Fig.12. The four wheels are attached to their respective wheel hub and wheel hub mounting. The wheels are then connected in parallel pairs, through their center, by a drive shaft. A driven gear and gear housing are located in the middle of the drive shaft. This driven gear is also called differential [19]. The differential allows the wheels to rotate at different speeds so that when the dolly turns, the wheel that is travelling around the outside of the turning curve can roll farther and faster than the other [20]. According to Suzuki [20], this is necessary in order to avoid difficulty and unpredictable handling, damage to tires and roads, and strain on or possible failure of the entire wheel assembly. The lower arm attached to each wheel keeps the wheels in alignment.

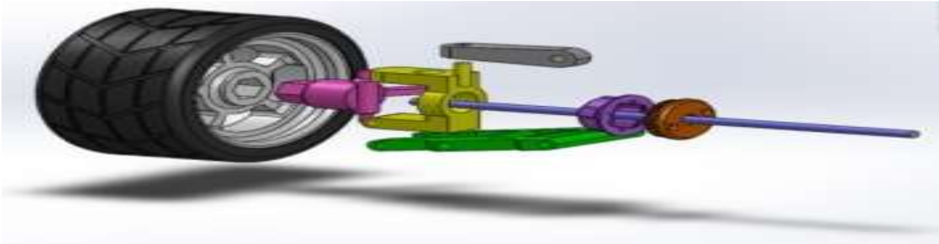

Figure 12: Detail View of Wheel Assembly.

5. CONCLUSION

The main purpose of iDolly is to ease filming and scanning operations by allowing a non-experienced operator to remotely operate and transport filming or scanning equipment with a push of a button. The mechanical design and its philosophy are also presented in this paper. This paper provides the base for future research on tripod dolly usefulness and remote control systems development in mobile robot applications. More research could be conducted to exploit the remote control technology and its application for other robotic projects.

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