

Deadpool: A how-to-build-guide

1. Introduction

This is a brief how-to-build write-up for *Deadpool*, an adaptable, low-cost, semi-adjustable field cart platform suitable for proximal sensing and imaging in a wide range of agricultural and environmental settings. This system utilizes readily available products for the frame, sensor arm bars, and wheels. The design can be modified to accommodate different crops, field designs, and proximal sensing arrays. The *Deadpool* design is a modified version of the White and Conley (2013) proximal sensing cart. In this *Deadpool* version, we added custom wheel mounts to improve cart stability on rough terrain, and swivel wheels to improve the cart turning radius.

2. Materials

All of the components needed for the *Deadpool* assembly are listed in Table 1. These standardized components are easy to obtain and relatively inexpensive, which enables replication and customization, based on program goals and available resources. Components for the original cart design can be found as a supplementary file in White and Conley (2013)

<https://dl.sciencesocieties.org/publications/cs/supplements/53/1646-supplement.pdf>.

3. Methods

The cart is comprised of a square tube frame, a fixed front and rear swivel wheel assembly using bicycle wheels and tires, and proximal sensor suspension arms. The two adjustable sensor arms clamp to the front of the cart frame, while a data acquisition system (i.e. laptop or data logger) is rear mounted (Figure 1). Sensors and recording apparatus are modularized and largely independent of a specific cart platform. Sensor brackets are mounted to sensor arms and can be mechanically reconfigured.

Design file name	File type	Cart component
File 1	PDF	Cart frame
File 2	PDF	Swivel wheels
File 3	PDF	Front wheels
File 4	PDF	Sensor arm bars
File 5	PDF	Arm bracket

Nomenclature key:

Height = h; Width = w; Length = l; Thickness = t; Inner diameter = id; Outer diameter = od.

3.1 Cart Frame

3.1.1 Dimensions and Structure

The *Deadpool* cart frame is welded from 0.16 × 3.18 × 3.18 cm (t × w × h) A36 steel square tubing. The cart frame can be broken into three different sub sections. An upper box shape, a mid-frame, and side

supports. The upper box portion of the frame consists of six 45.72 cm (l) square tubing members and two 200.03 cm (l) square tubing members. Each side has three 45.72 cm (l) pieces of the tubing welded together at 90 degree angles. The two side pieces are welded so that the cut ends of the middle piece form the width of the rectangular box. Each of these side pieces are welded so that one side lines up with the front bar of the mid-frame and the other side with the middle bar on the mid-frame. The two 200.03 cm (l) horizontal members are welded between the corners to complete the rectangular box. The mid-frame is built from five square tubes. Two 114.30 cm (l) tubes are set on each side, and two more 200.03 cm (l) horizontal members span between them to form a rectangle. A third piece of square tubing at 200.03 cm (l) is welded 45.72 cm from the front. The side supports are each made from one piece of 91.44 cm (l) and two pieces of 48.90 cm (l) square tubing. The longer span forms the bottom most portion of the frame and both ends are miter cut at 45 degrees. The two shorter pieces have one end cut at 90 degrees and the other at 45 degrees. These three pieces are welded together using the 45 degree cuts on each piece to form a right angle. Two additional supports are added to the corners of the side support by welding in a 20.32 cm (l) piece of square tubing with 45 degree cuts on each end. The side supports are then welded to the bottom of the mid-frame so that one of the 48.90 sections is flush with the front of the cart. This leaves 22.86 cm between the side support and the back of the mid-frame (File 1).

3.2 Wheel Assembly

3.2.1 Swivel Wheels

The wheels for the swivel wheel assembly are standard 66.04 × 4.45 cm (26 × 1.75 in) front mountain bicycle wheels including a 10 cm hub. The swivel wheel mount is modeled after a bicycle front wheel fork assembly where an outer tube is fixed to the frame, and an inner nested tube is attached through headset bearings. This allows a standard 2.86 cm Venzo threadless mountain bike sealed headset to be used for the swivel wheel assembly bearings. The assembly is created by welding the header tube, 3.4 × 0.64 × 15.24 cm (id × t × l), inside a 0.64 × 2.54 × 5.08 × 12.70 cm (t × w × h × l) U-channel. The rotating portion of the swivel wheel assembly is built with a 2.86 × 0.64 × 27.94 cm (od × t × l) steer tube welded inside a 2.86 cm hole, drilled in the center of a larger rectangular 0.62 × 10.16 × 5.08 × 17.15 cm tube (t × w × h × l). This steer tube is connected to the header tube via the bearing headset. Additional 0.64 × 7.62 × 10.16 cm (t × w × l) bars are welded to the sides of the rectangular tube for support. These support arms are built from 0.48 × 2.54 × 5.08 × 41.28 cm (t × w × h × l) rectangular tubes with an angled cut at the top. The top of the arms are welded to the bottom of the large rectangular tube so that the arms are angled 26.57 degrees away from vertical. The arms are welded into a spacing of 10.16 cm. A

0.64 × 5.08 × 15.24 cm (t × w × l) steel rectangle bar is also welded across the two arms with one side flush to the larger rectangular tube. The wheel is attached by drilling a 1 cm diameter hole, 2.54 cm from the end and sides of the arm. A notch is cut out of the end of the arm to allow the wheel to slide into place where the hole is drilled. The outer of the two holes in the rectangular tubing is enlarged to 2.86 cm diameter, to allow a socket bit access to the wheel nut (File 2).

3.2.2 Front Wheels

The front wheels are the same standard 66.04 × 4.45 cm (26 × 1.75 in) front mountain bicycle wheels with 10 cm hubs, as those used for the swivel wheel assembly. Each side of the front wheel mount is built from three pieces of 0.16 × 3.18 × 3.18 cm (t × w × h) square tubing. The front piece, 38.10 cm (l), has a 90 degree cut on one end and 45 degree cut on the other and is welded to a 10.80 cm (l) piece that also has a 45 degree cut on one end to make the two pieces form a 90 degree angle. The other end of the 10.80 cm piece is cut with a 67.5 degree angle and is welded to the 53.88 cm (l) back piece of square tubing with a 67.5 degree cut, and an additional 45 degree cut on its other end that when mated, creates a 45 degree angle with the vertical. These three pieces welded together form one side of the wheel mount. Two pieces of 0.64 × 5.08 × 15.24 cm (t × w × l) steel rectangle bars are used to weld each side together with a spacing of 10.16 cm between them. The front piece is welded to the 90 degree cut on the front tube, and the back is welded to the 45 degree cut of the back bar. An additional piece of 0.64 × 2.54 × 5.08 × 3.81 cm (t × w × h × l) U-channel is welded on the bottom of each of the 10.80 cm (l) pieces of square tubing 2.54 cm from the front. A 1 cm hole was drilled 2.54 cm from the side and then a notch was cut out allowing the wheel axle to slide in (File 3).

3.3 Proximal Sensing Arms

3.3.1 Dimensions and Structure

The sensor arms are also welded from the same 0.16 × 3.18 × 3.18 cm (t × w × h) A36 steel square tubing. The design is such that it allows for a large range of height adjustability and consists of two sliding sections. The first sliding section is fabricated from four pieces, two long and two short, all with 45 degree cuts on the ends to form a long rectangle. The long pieces are 0.16 × 3.18 × 3.18 × 110 cm (t × w × h × l) and the short are 0.16 × 3.18 × 3.18 × 12.0 cm (t × w × h × l) and form the rectangular section. The second section is constructed from two 0.16 × 3.18 × 3.18 × 70.0 cm (t × w × h × l) pieces of square tubing with a 45 degree cut on one end. The 45 degree cuts are welded together to form a right angle between the two pieces. An additional piece of 0.16 × 3.18 × 3.18 × 40.0 cm (t × w × h × l) square tubing with 45 degree cuts on both ends is welded to add support to the two 70 cm pieces, forming the right angle section. The right angle section is connected to the rectangular section via six 0.64 × 5.08 × 8.89

cm ($t \times h \times w$) steel rectangular bars. The rectangle bars are welded to the sides of one of the 70 cm pieces of the right angle sections in three pairs. The top pair is 3.18 cm from the top, and the next one is 28.28 cm from the top, and the last one is 2.54 cm from the bottom. A 0.95 cm hole was drilled in the center of the rectangular bars, 1.27 cm from the end. This allows for a bolt to clamp the L shaped arm to the rectangular section. For maximum adjustment, one of the three clamps can be moved off the rectangular arm leaving the other two for support. This works for both the highest, 250 cm (Figure 2) and lowest, 106 cm (Figure 3) adjustment points and allows for there to always be at least two clamp supports. The long rectangular section is bolted to the main frame using two $0.64 \times 7.62 \times 7.62$ cm ($t \times w \times l$) flat plates with four drill holes so that they fit around the square tubing. The plates are used to clamp the rectangular section of the arm to the front frame of the cart (File 4).

3.3.2 *Optional Clamping System*

An easier to use version of the clamping system described above consists of a $0.64 \times 7.62 \times 7.62$ cm ($t \times w \times l$) flat plate that is welded to each side of two additional $0.64 \times 5.08 \times 5.72$ cm ($t \times w \times l$) pieces of flat steel bars. The two side pieces are welded with a spacing of 3.18 cm to fit across the square tubing at right angles to each other. Drill holes in the end of each plate allow one side to clamp to the frame and the other to clamp the long rectangular section of the sensor arms. One side of the clamp can be used for height adjustment and the other side for horizontal placement of the sensor arm (File 5).

Discussion

Light weight, steel framed, push carts are inexpensive, and provide a stable mobile platform effective in agricultural phenotyping, and expanded environmental sensing. The carts can be designed to accommodate different crop row spacing and height needs with relative ease. Limited skills are required to build and operate proximal sensing carts like *Deadpool*, which enables scientists to allocate more resources into sensing and computation rather than fundamental platform systems.

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References

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