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Position Sensing Problem

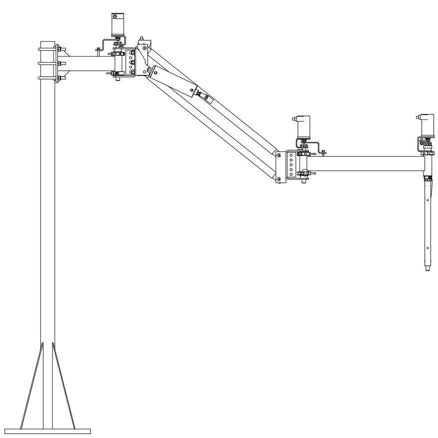
1 INTRODUCTION

The objective is to measure the 3D position of a hand held device in a defined work space, relative to a fixed datum.

- Work space: $\Delta X = 2m$, $\Delta Y = 0.75m$, $\Delta Z = 0.75m$
- Required positional accuracy: ±0.5 inches

2 PRIOR SOLUTION

Existing systems utilize an articulated arm with rigid members and encoders for joint angle measurement. Simple geometry is used to calculate end position relative to the arm base.



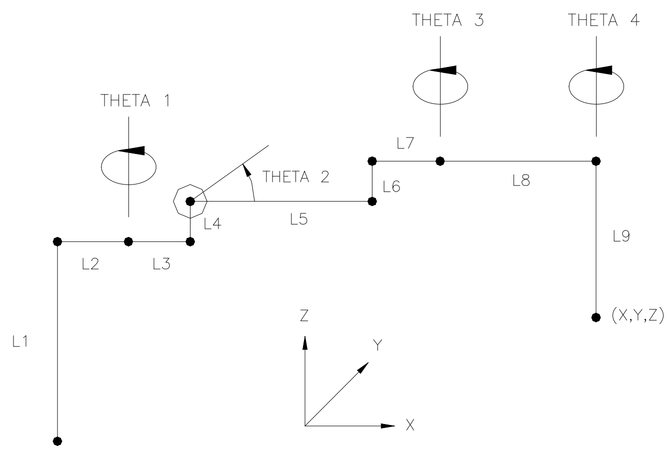


Figure 1. Measurement arm

2.1 Pros

Relatively simple design and relatively low cost. Repeatable position measurements.

2.2 Cons

Cumbersome and designed specific to work space due to physical limitations of arm joints and number of degrees of freedom. Limited accuracy due to flexing in mechanical components. Difficult to accurately calibrate.

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3 PROPOSED SOLUTION

3.1 Concept

Utilize a series of small articulated mechanical elements connected together to form a freely moving “cable” to connect from a fixed reference point to a movable object. Each element has known dimensions. Encoders are used to measure relative angle between elements. Based on known dimensions and measured relative angles, it is conceivable to use geometry to calculate the end position. In 2D, this can be pictured as a bicycle chain; see **Figure 2**. In 3D, universal joints with 2 degrees of freedom could be used; each degree of freedom requires an encoder. **Figure 3** shows one style of universal joint.

Other element styles exist that have linear and rotational degrees of freedom about their central axis. The solution could be a combination of different styles and different dimensions from one element to the next.

To allow flexibility / mobility of the end device, at least one rotational joint may be required.

3.2 Pros

Conceptually appears feasible. May be possible to find an alternative to encoders to measure angles.

3.3 Cons

Small encoders may not exist with required resolution, potentially high cost due to many encoders, electrically connecting all encoder wires to processor may be cumbersome, may be difficult to calibrate.

3.4 Comments

If the system is relatively easy to calibrate, incremental encoders would be preferable to absolute encoders due to their smaller size (for a given resolution) and lower cost. Refer to the appendix on encoders.

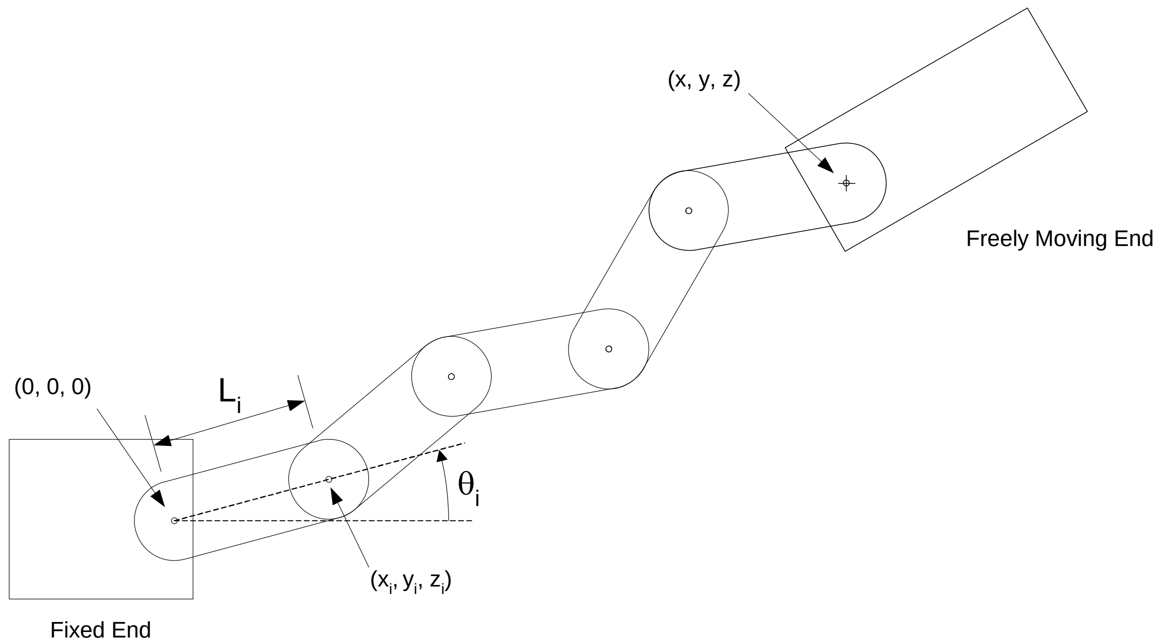

Figure 2. Chain (2D elements)

Figure 3. Universal joints (3D elements)

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4 PROBLEM STATEMENT

4.1 Primary Problems

1. How to determine the optimum combination and quantity of elements / element styles / dimensions / encoder resolution to:
    - achieve the desired positional accuracy
    - allow “sufficient” mobility of the end device
        - Unobtrusive and not cumbersome to the user (i.e. sufficient degrees of freedom of the end device)
2. How to calibrate the articulated cable?
    - Possible to self calibrate by simply moving the free end over some range of motion? (similar to robot manipulator)

4.2 Secondary Problems

3. How sensitive is the system to dimensional variations of the elements (due to manufacturing tolerances)
4. Can this system be scaled up or down to a larger or smaller work space?

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5 APPENDIX – ENCODER BASICS

There are two mechanical types of encoders:

- Rotary
- Linear

Rotary encoders provide direct angular measurement on a joint. Linear encoders provide position measurement along a single axis.

There are two types of encoder output signals:

- Incremental (quadrature)
- Absolute (binary or Gray-scale)

Incremental encoders provide position relative to a specified reference. Absolute encoders provide direct position information and do not require a reference.

With incremental encoders, at system power-up the control system must be provided with the starting position of the encoder. If power is switched off or the signal drops out momentarily, it becomes necessary for the operator to move the encoder to a known reference point and signal the controller to re-sync the position signal. With absolute encoders, the starting position of the encoder is immediately known. If signal drop out occurs momentarily, the system is without position information only during the time of drop out.

Incremental encoders provide a quadrature output signal, requiring a quadrature input module to decode the signal and provide it to the control system in a usable form. Absolute encoders provide direct digital output in either binary or Gray-scale, allowing direct interface to a standard digital input module. Similar to binary, Gray-scale counts up and down, but only one bit changes on each up or down count. When using long connection cable runs and high frequency, Gray-scale is preferred as it minimizes errors due to cross-wire noise.

Absolute encoders can also be equipped with industrial bus interfaces, requiring less electrical connection wires.

Encoder resolution is specified in number of counts per revolution. A 10-bit encoder provides 1024 counts per revolution. For a given resolution, incremental encoders are more cost effective and can be manufactured physically smaller than absolute encoders, and incremental encoders are more readily available at much higher resolution than absolute encoders.