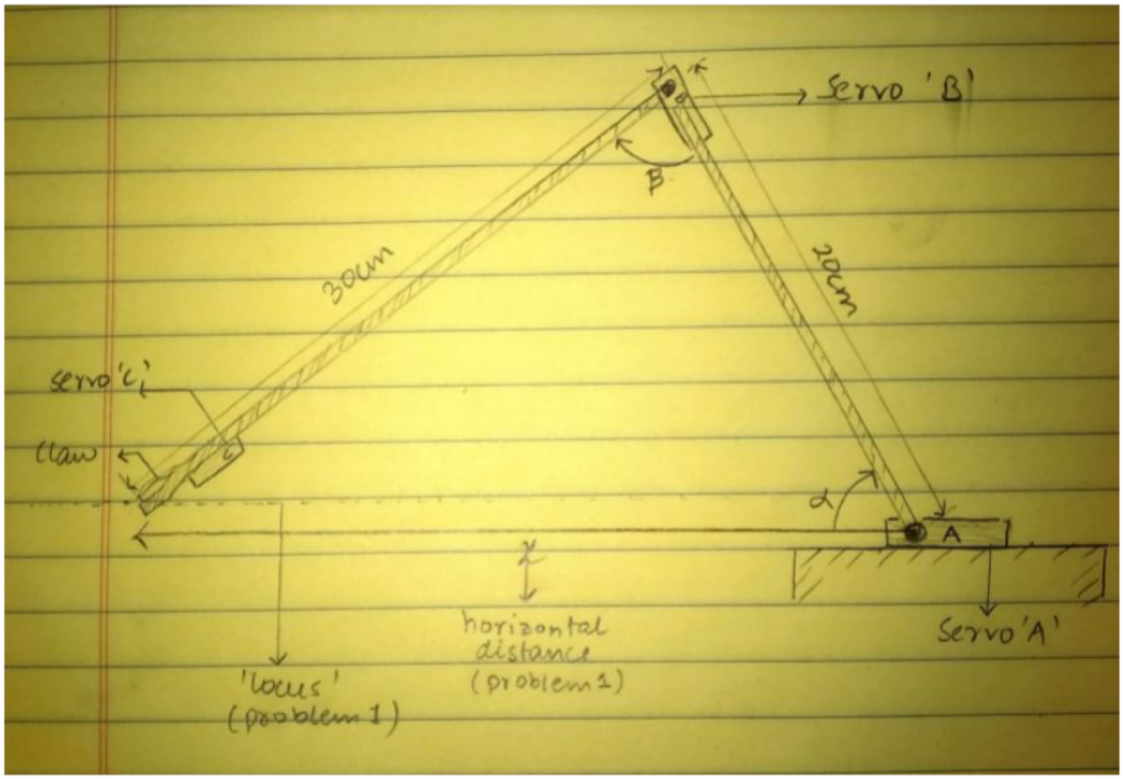
Solutions

Assignment 2: Mini Project

The problem of calculating joint angles is known as **inverse kinematics**, and it comes up all the time in robotics. The question we gave you is one of the most basic of such problems - but don't worry if you found it hard, we'll be teaching this topic in the following weeks.



Problem 1

To solve this question really doesn't need any knowledge of inverse kinematics, rather, all you need is trigonometry. First, to constrain the claw to a horizontal line, the following constraint equation should be satisfied (try deriving it yourself, it's just trigonometry):

$$L_1 sin\alpha = L_2 sin(\alpha + \beta)$$

Where is the length of the upper arm and L_2 is the length of the forearm/lower arm. The question states that $L_1 = 20cm$ and $L_2 = 30cm$. From this, we can get an equation to calculate β from α, which is:

$$\beta = \pi - arcsin(\frac{L_1}{L_2}sin\alpha) - \alpha = \pi - arcsin(\frac{2}{3}sin\alpha) - \alpha$$

Next, we find the relationship between x, the horizontal distance, and the angles. This turns out to be:

$$x = 20cos(\alpha) - 30cos(\alpha + \beta)$$

One could calculate α (and hence β) from x using the *cosine law*,;then use x as a variable parameter, of which the angles are a function.

Another way, as I have done in the solution, is to the keep α as the variable parameter; x and β are functions of it, and its value is directly mapped from the analog value of the potentiometer. So, in the loop function, I have the following expressions:

```
int potValue = analogRead(potPin);
alpha = potValue * PI / 1024;
beta = PI - asin(0.66 * sin(alpha)) - alpha;
x = 20 * cos(alpha) - 30 * cos(alpha + beta);
```

Note:

- All the angle values are in radians, convert it to degrees when using `Servo.write()`.
- Inverse trigonometric functions (such as `asin()`, the inverse sine function) reference can be found here.

The entire circuit can be found here.

Problem 2

The way our solutions works is:

1. Go to position A, i.e where $x = 20cm$.
2. Pick up the object by setting the servo C to 180deg.
3. Go to position B ($x = 40cm$), along the horizontal line (as described by the constraint equation in problem 1).
4. Drop the object by setting servo C to 0deg.
5. Go to step 1 and repeat indefinitely.

The circuit can be found here.

Note, that in the question, you were told to keep the claw above the ground. Technically, by following the above steps, this condition is satisfied. But, for more reliability, you might want to first elevate the claw before moving from position A to B (and vice versa). This isn't hard to implement, try it yourself!