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Geographical Positional and Predictive Accuracy of a Shovel Bucket

Arko Banerjee
arkokkr@gmail.com
Techanalogy, Mumbai, Maharashtra

Sahil Yadav
sahil.techanalogy@gmail.com
Techanalogy, Mumbai, Maharashtra

ABSTRACT

Excavators are increasingly being equipped with guiding and automation systems on modern building sites. Recent research has focused on comparing the bucket tip estimation results with the motion measuring method of the boom, stick, and bucket, as well as sensor selection. The method of measuring the cylinder length of the boom, stick, and bucket, as well as the method of measuring the cylinder length of the boom, stick, and bucket, were chosen for this study. The methods of measuring the cylinder length of the boom, stick, and bucket, as well as the method of directly measuring the boom, arm, and bucket, were chosen for this study. These methods are commonly used in guidance and automation systems. To apply the aforesaid methods to a commercial excavator, a low-cost sensor that can be mounted and detached in a modular manner was used. KS best fit predictive test has been conducted for predictive positioning .A default data sheet has been acquired. The entire model was prototyped and designed over a CAD model presented in Solid works.

Keywords- *Industrial Excavator, Shovel Positioning, Inertial Measurement Unit, Wire Drawn Sensor,Ks Best Fit Test, Solid Works, Path Projection*

1. INTRODUCTION

Excavators with machine control, guidance, and/or extra systems for expressing the environment have recently increased the efficiency of construction/Mining sites. The most important aspect of the aforementioned procedures is the precise estimation of the excavator's end-point using the suitable sensing equipment. However, due to inherent characteristics such as engine vibration, significant gravitational force, or unanticipated disruption, predicting the excavator's end-point exactly through the sensor system is challenging. As a result, estimation performance is dependent on the sensor devices used to measure kinematic parameters, and it should be assessed as part of the character. Methods for calculating the position of an excavator's end-point are categorised as follows: (1) measuring the length of cylinders; (2) performing a link motion to indirectly estimate angle displacements; (3) knowing the angle displacements directly; and (4) considering the hydraulic system. The displacements of the cylinder can be measured using an linear encoder or stroke sensors(Stroke sensors are wire pull-out type length meters that are used for construction vehicles and industrial machinery.) in the case of the cylinder length.

Fig1. (top) Machine guidance using measured cylinder length, which is developed by KOMATSU; (bottom) Machine guidance using measured links motion, which is developed by EZDig.

The end-point can then be determined by substituting sensor output data for parameters in the developed mathematical equation. In the case of the link motion, inertia measurement unit (IMU), tilt, and/or accelerometer sensors are used and attached to each link for measuring the joint angle indirectly through the rotation of the boom, stick, and bucket links. Through derived kinematic modelling, these measured data are also used to estimate the excavator's end-point. The flow rate sensors are inserted into the pipeline, and then devices measure the flow rate so that the angular displacement of each joint that is used for estimating the end-point of the excavator can be estimated.

2. EXCAVATOR MATHEMATICAL MODELLING

Forward Kinematics: Revolute Joint

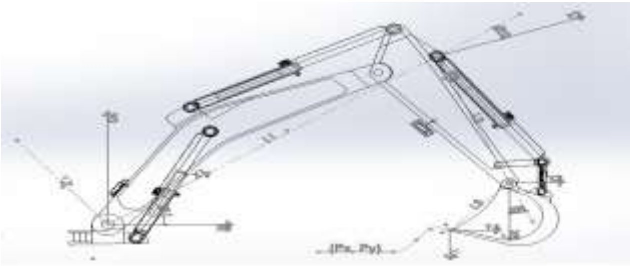


Fig. 2: Axis and Frame Description

Therefore following DH convention
ai= Link Length
αi = Link Twist
di= Link Offset
θi = Joint Axis

DH Convention Table as-

Cθi	-SθiCαi	SθiSαi	aiCθi
Sθi	CθiCαi	-CθiSαi	aiSθi
0	sαi	Cαi	di
0	0	0	0

C= cos , S= sin

DH table for excavator=

LINK	αi	ai(CM)	di	Øi
1	0	0	0	Ø1(36.62)
2	0	L1(240)	0	Ø2(15)
3	0	L2 (113.6)	0	Ø3(21.56)
4	0	L3 (52.8)	0	Ø4(0)

T4= DH1 X DH2 X DH3 X DH4

0.495	0	1.02	26.15
0.465	0	0.35	24.58
0	0	1	0
0	0	0	0

The excavator's end-point position(T4) can be described as x and y values in relation to the defined base frame in above Figure, and the forward kinematics results are as follows:

$P_x = L_1c_1 + L_2c_{12} + L_3c_{123}$ (1)

$P_y = L_1s_1 + L_2s_{12} + L_3s_{123}$ (2)

Forward Kinematics : Cylinder Length

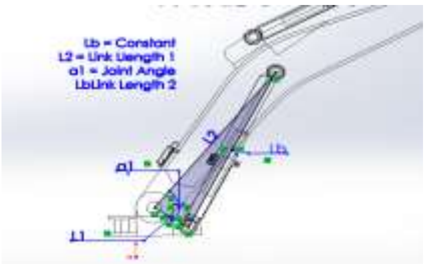


Fig. 3: Boom Cylinders

$\alpha_{boom}= \cos^{-1}(l_1^2+l_2^2-l_b^2/2l_1l_2) = 87.76$ degrees

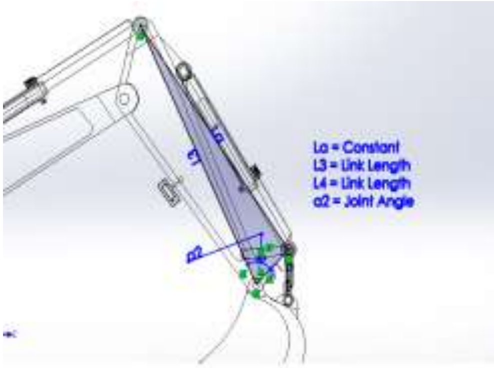


Fig 4.Arm Cylinders

$\alpha_{arm}= \cos^{-1}(l_3^2+l_4^2-l_a^2/2l_3l_4) = 74.92$ degrees

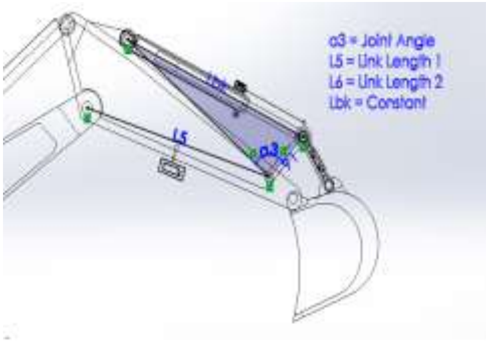


Fig 5. Bucket Cylinders

$\alpha_{bucket}=\cos^{-1}(l_5^2+l_6^2-l_{bk}^2/2l_5l_6) = 85$ degrees

Limiting Factor

$K=\sqrt{l_6^2+l_5^2-2l_5l_6\cos(\alpha_{bucket})} = 104.0024$deg

3. PREDICTIVE POSITIONING

The analysis of the goodness-of-fit (best-fit) approximation for TBF datasets is the next stage in this research. The Kolmogorov-Smirnov (K-S) method was used to do the best fit analysis. The idea here is to see how far the chosen distribution deviates from the real dataset, or how closely the chosen distribution represents the observed distribution

Itteriation	Average Bucket Deviation IN deg
ITN1	78.20
ITN2	80.77
ITN3	83.21
ITN4	80.00
ITN5	85.76

A default data

Evaluating Value of Ks

D+=$\max\{i/N - R\}$

D-= $max\{R-(i-1/N)\}$

Itteriation	i	R	D+	D-
ITN1	1	78.20	NA	78.20
ITN4	2	80.00	NA	79.80
ITN2	3	80.77	NA	80.37
ITN3	4	83.21	NA	82.61
ITN5	5	85.76	NA	84.96

Itteriation	Avg Bucket Dvn	Rank	Exponential	Weibull 1	Estimates η=100 β=1(expo) β=2(Wei)	Bestfit
ITN1	78.20	1	0.45	0.54	η=100 β=1(expo) β=2(Wei	Exponential
ITN2	80.77	2	0.44	0.52	η=100 β=1(expo) β=2(Wei	Exponential
ITN3	83.21	3	0.43	0.50	η=100 β=1(expo) β=2(Wei	Exponential
ITN4	80.00	4	0.44	0.52	η=100 β=1(expo) β=2(Wei	Exponential
ITN5	85.76	5	0.42	0.47	η=100 β=1(expo) β=2(Wei	Exponential
ITNAVG	81.588	6	0.44	0.51	η=100 β=1(expo) β=2(Wei	Exponential

$$R+F=1$$

R=reliability
F=unreliability

$$F(t)= 1-e^{-(t/\eta)^{\beta}}$$

$$R(t)= e^{-(t/\eta)^{\beta}}$$

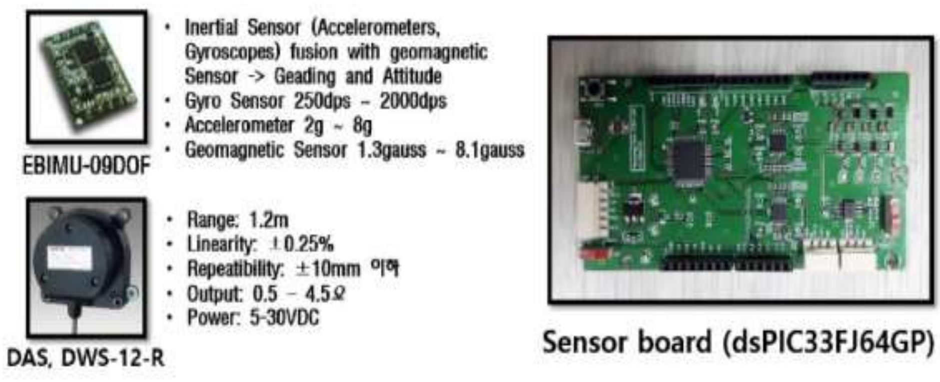
Where η is life//β is shape parameter

In our default case we set life as 100 deg

And shape parameters as 1 and 2 respectively

4. SENSOR SYSTEM

The sensor system was split into two parts, one for cylinder length and the other for link motion, To begin, a low-cost draw-wire sensor of the linear potentiometer type that could be quickly attached to the link was chosen to estimate the excavator's end-point through measurements of each cylinder length.



The Specifications of the draw-wire and IMU sensors.

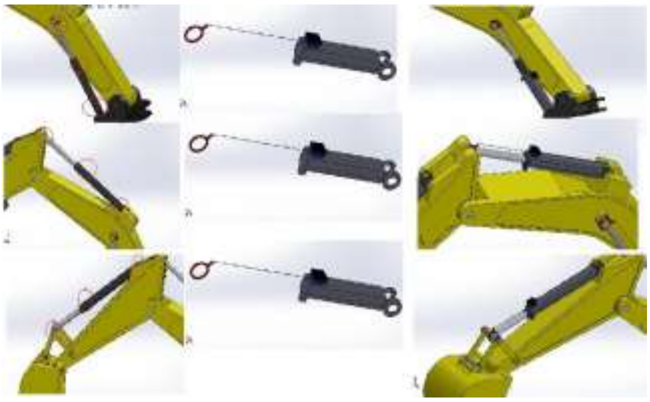
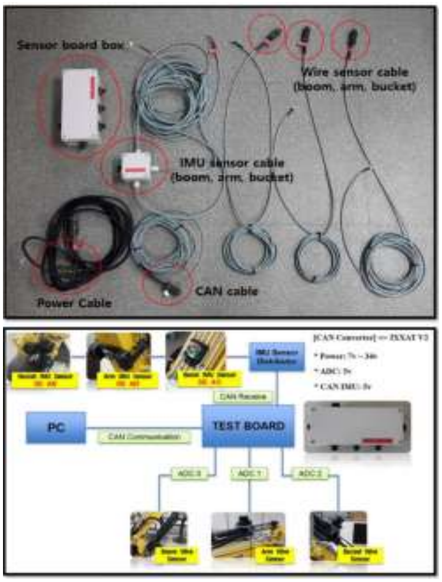
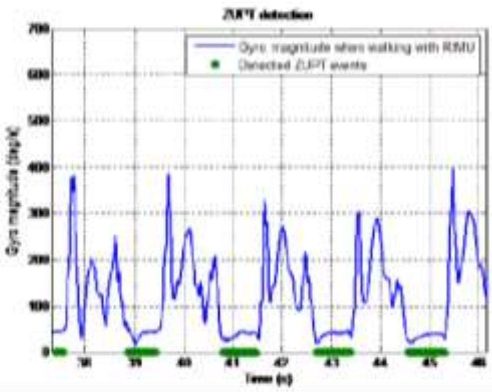


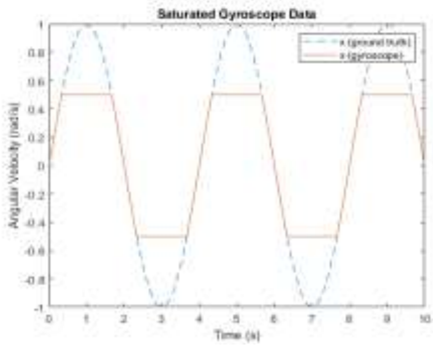
Fig6. column 1(from left) (from top wire sensor install location for boom,arm and bucket respectively)
Column 2(from left)(Wire Sensor Design for boom,arm and bucket from top respectively)
Column 3(from left)(Installed wire sensor for boom,arm and bucket from top respectively)

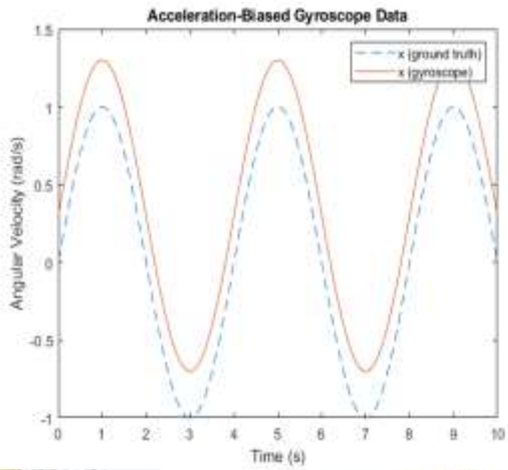
Since in a wire sensor, the output length delivered by the motor can be fixed/changed, the length of the wire for boom, arm or bucket can be changed accordingly. Since it's a piezometric type sensor, the output in the dashboard will b seen as a potential difference



Second, a low-cost IMU sensor device named EBIMU-09DOF was chosen to estimate the end-point by measuring each joint angle displacement indirectly by measuring the rotation of links motion







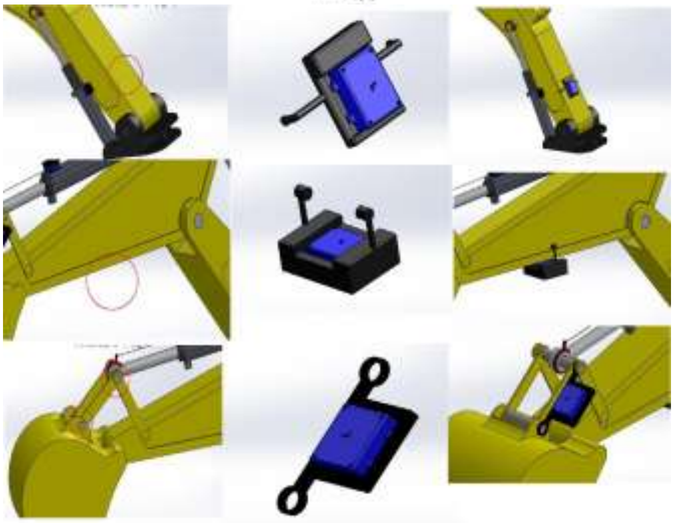


Fig7. column 1(from left) (from top IMU sensor install location for boom,arm and bucket respectively)
Column 2(from left)(IMU Sensor Design for boom,arm and bucket from top respectively)
Column 3(from left)(Installed IMU sensor for boom,arm and bucket from top respectively)

5. UNDERSTANDING THE DATA

The embedded system has a CAN (Controller Area Network) connection mechanism for logging the output data of both draw-wire and IMU devices at the same time for estimating the end-point, these output values were fed into the generated equations.

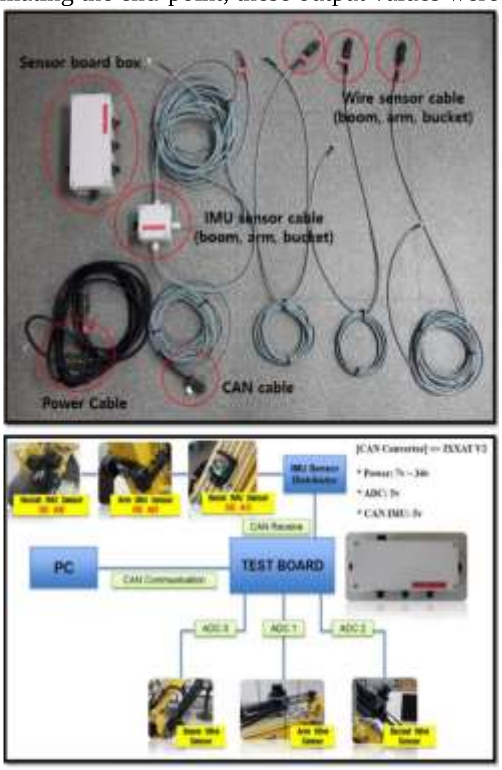


FIG8. Circuit connection Diagram

6. CONCLUSION

In the excavator guiding and automation, we investigated the characteristics of position recognition of the bucket tip based on motion measurement of the excavator boom, stick, and bucket. Ks method was used to test the Best FitThe measurement methods were classified into two categories: cylinder length measurements and boom, stick, and bucket link rotation measurements. The wire sensor was chosen for measuring the cylinder length, and the IMU sensor was chosen for measuring the rotation of the boom, stick, and bucket link, according to the features of each approach.We also plotted the enclosed area of activity.

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