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TRACKER VIDEO ANALYSIS AS A PEDAGOGICAL TOOL FOR TEACHING UNIFORM AND UNIFORMLY ACCELERATED LINEAR MOTION: AN ACCESSIBLE APPROACH FOR PHYSICS EDUCATION IN TIMOR-LESTE

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ABSTRACT

This study investigates the use of Tracker video analysis as an accessible tool for exploring uniform linear motion (ULM) and uniformly accelerated/decelerated linear motion (UALM) in a resource-limited physics education context in Timor-Leste. Motion experiments were recorded with a smartphone and analyzed using Tracker to obtain position time and velocity time data, which were processed in Microsoft Excel for curve fitting and residual inspection. For ULM, the velocity remained approximately constant at $v = 1{,}47$ m/s, with apparent acceleration fluctuating around zero due to numerical differentiation. In accelerated UALM, quadratic position time and linear velocity time fits yielded a consistent acceleration of $a = 1{,}68 \pm 0{,}04$ m/s² with coefficients of determination $R^2 \geq 0{,}93$ and relative deviation ≈ 1,2%. Decelerated UALM exhibited a small negative acceleration ($a \approx -0{,}0118$ m/s²) with an initial velocity of $v_0 \approx 0{,}54$ m/s, producing nearly linear position time behavior and a residual error of RMSE = 3,88 m. These results demonstrate that Tracker can reliably identify motion types and extract kinematic parameters when combined with external data analysis. Potential pedagogical use is discussed; however, formal learning outcomes were not measured and are recommended for future investigation.

Keywords: Tracker video analysis; physics education; uniform linear motion; uniformly accelerated linear motion

INTRODUCTION

Physics instructional laboratories have long played a central role in physics education by enabling direct observation of physical phenomena and fostering the development of scientific reasoning skills (May, 2023). As an inherently experimental science, physics relies on laboratory activities to promote conceptual understanding through experimentation, measurement, and data analysis (Soares, 2011; Freitas, 2018). Through hands-on laboratory experiences, students develop essential scientific skills, including careful observation, data analysis, and logical reasoning (Reynders et al, 2019). Moreover, laboratory activities help reinforce previously introduced concepts, facilitate the construction of new understandings, and support the reconstruction of alternative conceptions held by students (Freitas, 2023).

Despite their recognized pedagogical value, science laboratories at both secondary and higher education levels often face significant infrastructural limitations that restrict the implementation of a wide range of physics experiments. These limitations are particularly evident in many developing countries, including Timor-Leste, where insufficient laboratory infrastructure, limited instructional materials, and inadequate equipment pose major barriers to effective experimental instruction. Additional challenges, such as high equipment costs, safety concerns, and logistical constraints, further hinder the execution of laboratory-based physics activities. Although digital resources are increasingly available, persistent deficiencies in laboratory facilities and limited technical training for teachers continue to complicate the implementation of experimental science education.

From a learning-theory perspective, the integration of digital tools into experimental activities can be situated within constructivist and meaningful learning frameworks, which emphasize active learner engagement and the systematic connection between abstract concepts and observable phenomena (Graaf et al., 2020; Papalazarou et al., 2024). In physics education, meaningful learning is promoted when abstract concepts are linked to observable motion through multiple representations, including graphs, tables, mathematical models, and simulations (Hahn & Klein, 2023; Tomkelski et al., 2023). Video-based experimental activities allow learners to relate real-world motion to formal representations, thereby helping to bridge the gap between theoretical models and empirical observations (Becker et al., 2020). However, improved visualization and automated data processing should not be assumed to directly result in enhanced learning outcomes, as their effectiveness depends on the degree of active cognitive engagement involved in the learning process.

Within the national curriculum of Timor-Leste, physics is taught from the third cycle of basic education through secondary education, with uniformly linear motion (ULM) and uniformly accelerated linear motion (UALM) serving as foundational topics in kinematics (Alves, 2014). These concepts are essential for understanding position, velocity, and acceleration, and rely heavily on students' ability to interpret graphical representations of motion (Volkwyn et al., 2020). Nevertheless, limited access to laboratory resources constrains students' opportunities to engage in hands-on investigations of motion, which are critical for developing robust conceptual understanding (Abraham and Millar, 2008).

In response to these constraints, video analysis tools such as the open-source software Tracker have gained increasing attention in physics education. Tracker enables frame-by-frame analysis of motion using widely accessible video recordings, producing graphical and numerical representations of kinematic variables (Putri & Agustina, 2023). Previous studies indicate that, when appropriate calibration and data acquisition procedures are applied, Tracker-based video analysis yields kinematic parameters that are consistent with theoretical predictions and comparable to those obtained using conventional experimental measurement tools (Taslima et al., 2022; Putri & Agustina, 2023; Renika et al., 2024). Compared with conventional methods based on stopwatches and mechanical timing devices, video analysis offers higher temporal resolution and greater flexibility for post-experimental data analysis (Jr et al., 2012; Rocha et al., 2024).

Consistent with constructivist learning theory, learners actively construct knowledge through interaction with their environment, rather than passively receiving information (Nurhuda et al., 2023; Suhendi et al., 2021; Tsehay et al., 2024). Video-based experimental activities enable students to investigate real-world phenomena, collect and analyze data, test predictions, and interpret results within authentic scientific contexts (Marzari et al., 2023; Shao et al., 2024; Wee et al., 2015). Such active engagement has been shown to support students' conceptual understanding in kinematics, a topic in which learners often experience difficulties interpreting motion graphs and relating them to physical situations (Leitão et al., 2011).

Furthermore, engagement with video and multimedia resources supports meaningful learning by allowing learners to process information through coordinated visual and verbal channels, in accordance with the cognitive theory of multimedia learning (Machado & Timóteo, 2023). Video analysis tools such as Tracker allow simultaneous observation of physical motion, numerical data, and graphical representations, which may reduce extraneous cognitive load and support deeper conceptual processing. When learners actively manipulate video data and receive immediate graphical feedback, they are more likely to develop coherent mental models of physical motion.

Based on the descriptions, the present study aims to examine the applicability of Tracker software for the quantitative analysis of uniformly linear motion and uniformly accelerated linear motion using low-cost and accessible experimental setups. The study focuses on the analytical capabilities of Tracker by presenting fitted parameters, uncertainty estimates, and statistical indicators such as the coefficient of determination (R^2) and root mean square error (RMSE). While pedagogical implications are discussed, learning outcomes are not directly assessed; instead, the study emphasizes the potential of video-based experimentation to support the understanding of kinematic concepts within constructivist and meaningful learning frameworks.

METHODOLOGY

This study adopts a video-based experimental approach to examine rectilinear motion in a physics education context. The experimental activities were carried out in the Physics Education Laboratory of the Universidade Nacional Timor Lorosa'e (UNTL), Timor-Leste, within the Physics Teaching Program of the Faculty of Education and Humanities (FEH-UNTL). A quasi-experimental, quantitative descriptive design was used to explore the applicability of Tracker Video Analysis software as a pedagogical and analytical tool for identifying and describing uniform linear motion (ULM) and uniformly accelerated linear motion (UALM) using simple, low-cost experimental arrangements suitable for classroom contexts.

The study was based on systematic observation of motion phenomena without intentional manipulation of variables, combining quantitative and observational approaches and prioritizing methodological clarity, analytical reliability, and feasibility for use in resource-constrained educational environments (Renika, et al., 2024). It should be noted that this investigation did not involve students or other human participants; all data were obtained from controlled experimental demonstrations performed by the researchers using inanimate objects.

The motion was recorded using an iPhone 8 camera mounted on a tripod, with a 4K resolution and a 60 frames per second frame rate. The camera was positioned parallel to the direction of motion at a distance of approximately 120 -150 cm to minimize perspective effects. The recorded videos were analyzed using Tracker Video Analysis software installed on a Lenovo IdeaPad 1 (11IGL05) laptop running the Windows 10 operating system, following procedures commonly adopted in video-based kinematics analysis for physics education (Renika, et al., 2024; Rodrigues & Carvalho, 2014). Spatial calibration was performed using a centimeter-scale measuring tape placed in the same plane as the motion to convert pixel coordinates into metric units.

A toy car was used as the moving object, travelling a distance of 2.0 m for ULM and 1.0 m for accelerated and decelerated UALM. Object tracking was carried out automatically in Tracker using a three-frame moving average smoothing, with one trial conducted for each type of motion. Position time data were exported in CSV format and analyzed in Microsoft Excel using least-squares curve fitting to obtain kinematic parameters, the coefficient of determination (R^2), and the root mean square error (RMSE). Uncertainty analysis was limited to fitting residuals and RMSE, as repeated trials and independent error propagation were not undertaken.

Data analysis was carried out using Tracker Video Analysis software to extract kinematic data from video recordings of rectilinear motion. The videos were analyzed frame by frame, allowing the object's position to be obtained as a function of time. The recording frame rate determined the time interval between frames: $\Delta t = \frac{1}{\text{fps}} \approx 0.017$ s for 60 fps videos. The primary dataset obtained from Tracker consisted of time (t,s) and horizontal position (x,m). Pixel-based coordinates were converted into metric units through spatial calibration using a reference object of known length. The coordinate system was aligned with the direction of motion, allowing the analysis to be reduced to a one-dimensional kinematic description.

Object motion was examined using the automatic tracking function available in Tracker. The experimentally obtained position time data were spatially calibrated to convert pixel measurements into physical units, then exported as CSV files and analyzed in Microsoft Excel. Assuming one-dimensional motion, curve fitting was applied to derive kinematic parameters (A, B, and C) and statistical measures (R^2 and RMSE) directly from the original experimental data, without additional data processing (Hockicko, 2020; Rodrigues & Carvalho, 2014; Wee & Leong, 2015; Bordin et al., 2022).

For uniform linear motion, the primary analysis was conducted using the position–time (x–t) graph with a linear model: $x(t) = At + B$ where: (A) represents the constant velocity, (B) represents the initial position. The fitting parameters were obtained using the least-squares method implemented in Tracker. Parameter uncertainties were provided directly by the fitting procedure, while the goodness of fit was evaluated using the coefficient of determination (R^2) and the root mean square error (RMSE)**.**

Velocity was not calculated from numerical differentiation of position data, as differentiation amplifies noise. Instead, velocity was determined from the slope of the position–time fit. Small apparent fluctuations in acceleration were interpreted as numerical artifacts arising from limited spatial resolution, finite frame rate, and tracking uncertainty. Residual analysis showed a random distribution around zero, indicating that the linear model adequately describes uniform rectilinear motion.

For uniformly accelerated motion, the position–time (x–t) data were analyzed using a quadratic model: $x(t) = At^2 + Bt + C$. The physical interpretation of the fitting parameters is: $\left(A = \frac{1}{2}a\right)$→ half of the acceleration, ($B = v_0$) → initial velocity and ($C = x_0$) → initial position. The acceleration was obtained from $a = 2A$. As a validation step, acceleration was also independently determined from the velocity time (vt) graph using a linear fit: $v(t) = at + v_0$. Consistency between acceleration values derived from the (xt) and (vt) analyses was used to assess data reliability. Minor discrepancies were attributed to numerical noise introduced during differentiation. Both accelerated and decelerated UARM cases were evaluated using R^2, RMSE, and residual analysis to assess model adequacy and potential systematic errors.

Position uncertainty mainly arises from pixel resolution, spatial calibration, and automatic tracking fluctuations. Uncertainty in velocity and acceleration increases due to numerical differentiation. Therefore, the primary physical quantities were extracted from fitting coefficients rather than raw derivative data. Since each motion type was recorded only once (single trial), no inter-trial statistical analysis was performed. Consequently, the results are descriptive and demonstrative, and quantitative interpretations are limited to the uncertainties obtained from the fitting procedures.

RESULTS AND DISCUSSION

Uniformly Linear Motion (ULM) Results

The motion of a cart along a 2 m straight track was analyzed using the Tracker software. The experimental values of time, position, and velocity from a single video recording are presented in Table 1.

Table 1. ULM Experimental Data (Single Trial, 2 m Track)

No.	t (s)	x Tracker (m)	Velocity (m/s)	No.	t (s)	x Tracker (m)	Velocity (m/s)
1	0,000	0,000	1.47	9	0,965	1,421	1.47
2	0,548	0,813	1.47	10	1,015	1,494	1.47
3	0,615	0,908	1.47	11	1,048	1,543	1.47
4	0,632	0,932	1.47	12	1,115	1,641	1.47
5	0,698	1,029	1.47	13	1,165	1,715	1.47
6	0,748	1,102	1.47	14	1,215	1,788	1.47
7	0,815	1,200	1.47	15	1,298	1,911	1.47
8	0,898	1,323	1.47	16	1,315	1,935	1.47
				17	1,365	2,009	1.47

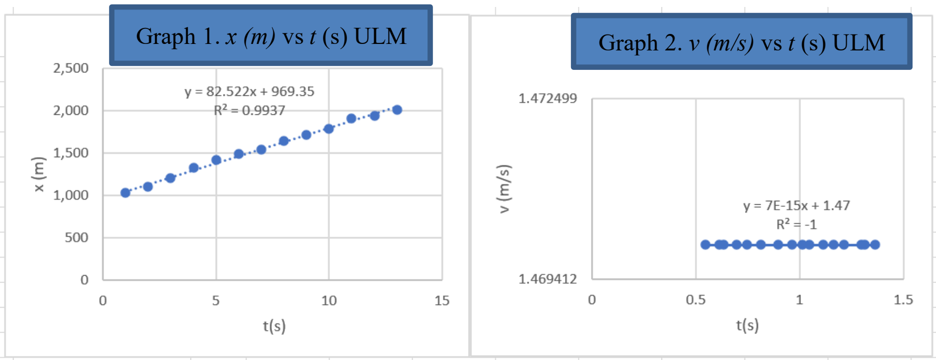

Figure 1. Position–time (x–t) and velocity–time (v–t) graphs for uniform linear motion (ULM).

The position time (xt) data were fitted using a linear model: $x(t) = A\ t + B$. The fitting results yielded: Velocity coefficient: $A = (1.47 \pm 0.01)\ \mathrm{m/s}$, Initial position or Intercept: $B = (9.69 \pm 0.02)\ \mathrm{m}$, coefficient of determination: $R^2 = 0.9937$ and Root Mean Square Error: RMSE< 0,03 m, indicating low data dispersion. The velocity–time relation derived from the position time fitting is expressed as: $v(t) = (7 \times 10^{-15})t + 1.47$. The slope of the velocity time graph is statistically indistinguishable from zero. Residuals were randomly distributed around zero, indicating no systematic bias. Small apparent acceleration fluctuations ($\pm 0.3\ \mathrm{m/s^2}$) were attributed to numerical noise arising from finite frame rate, pixel resolution, and differentiation.

Uniformly Accelerated Linear Motion (UALM) Results

The uniformly accelerated linear motion was investigated by tracking the motion of a cart over a total displacement of 1 m using the Tracker software. The position time and velocity time data were extracted and further analyzed using Microsoft Excel. The time interval between successive data points was approximately $\Delta t \approx 0.017$ s, yielding a total of 35 data points.

Table 2. Raw Experimental Data of Accelerated UALM

No	t (s)	x (m)	v (m/s)	No	t (s)	x (m)	v (m/s)	No	t (s)	x (m)	v (m/s)
1	0.1	0.108	1.117	13	0.3	0.345	1.434	24	0.483	0.632	1.745
2	0.117	0.125	1.058	14	0.317	0.369	1.451	25	0.5	0.661	1.737
3	0.133	0.143	1.1	15	0.333	0.393	1.448	26	0.517	0.69	1.73
4	0.15	0.162	0.881	16	0.35	0.417	1.496	27	0.533	0.719	1.796
5	0.167	0.172	0.904	17	0.367	0.443	1.55	28	0.55	0.749	1.773
6	0.183	0.192	1.244					29	0.567	0.778	1.827
7	0.2	0.213	1.281	18	0.383	0.469	1.58	30	0.583	0.81	1.879
8	0.217	0.235	1.181	19	0.4	0.496	1.597	31	0.6	0.841	1.843
9	0.233	0.253	1.248	20	0.417	0.522	1.557	32	0.617	0.872	1.876
10	0.25	0.276	1.329	21	0.433	0.548	1.6	33	0.633	0.903	1.89
11	0.267	0.297	1.357	22	0.45	0.576	1.66	34	0.65	0.935	1.87
12	0.283	0.321	1.427	23	0.467	0.603	1.68	35	0.667	0.966	1.927

Position data x(t) obtained from Tracker analysis were exported to Microsoft Excel and expressed in meters. Fitting the position–time data with a quadratic model $x(t)=At^2+Bt+C$ yielded $A=0.859\pm0.020\ \mathrm{m/s^2}$, $B=0{,}873\pm0{,}015\ \mathrm{m/s}$, $C=0{,}0073\pm0{,}0026\ \mathrm{m}$, with RMSE = 0.00329 m and ($R^2=0.9999$). Using ($a=2A$), the acceleration was calculated as ($a=1{,}72\pm0{,}04\ \mathrm{m/s^2}$). Independent velocity time analysis using ($v(t)=at+v_0$) gave ($a=1{,}68\pm0{,}08\ \mathrm{m/s^2}$) and ($v_0=0{,}874\pm0{,}032\ \mathrm{m/s}$), with RMSE = 0.074 m/s and ($R^2=0{,}93$).

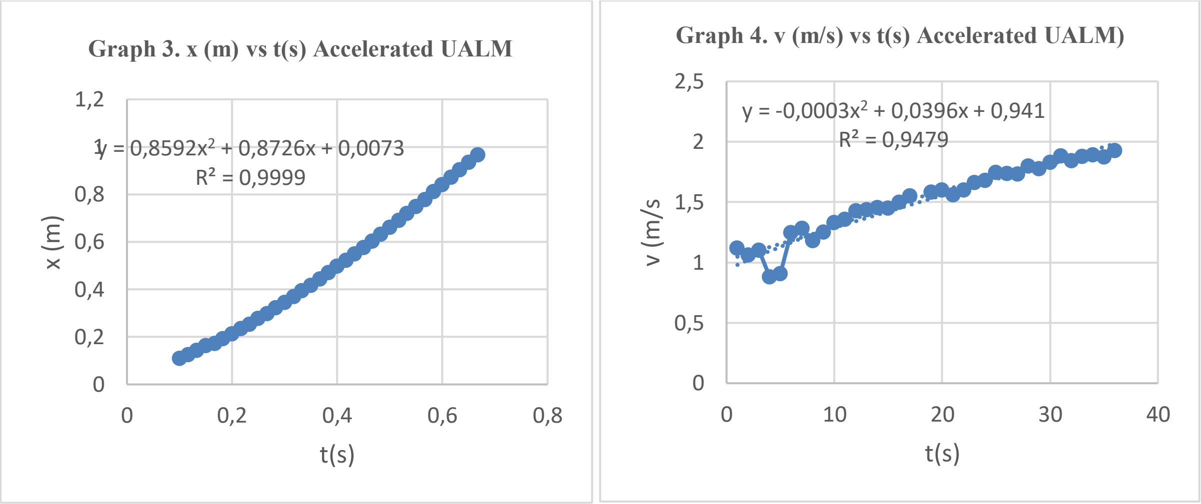

Figure 2. Position time (xt) and velocity time (vt) graphs for accelerated uniformly accelerated linear motion (UALM)

The decelerated uniformly accelerated linear motion experiment was conducted by recording the motion of a cart over a displacement of approximately 1 m. The experimental position and velocity data as functions of time are presented in Table 3. The initial position at $t = 0$ s was $x_0 = 0.000564$ m.

Table 3. Raw Experimental Data of Decelerated UALM

No	t (s)	x (cm)	x (m)	v (m/s)	No	t (s)	x (cm)	x (m)	v (m/s)
1	0	0.0564	0.000564	–	23	0.733	3.7	0.037	0.433
2	0.033	0.232	0.00232	0.528	24	0.767	3.84	0.0384	0.428
3	0.067	0.408	0.00408	0.543	25	0.8	3.99	0.0399	0.455
4	0.1	0.594	0.00594	0.533	26	0.833	4.14	0.0414	0.452
5	0.133	0.764	0.00764	0.512	27	0.867	4.29	0.0429	0.424
6	0.167	0.936	0.00936	0.526	28	0.9	4.42	0.0442	0.412
7	0.2	1.11	0.0111	0.541	29	0.933	4.56	0.0456	0.41
8	0.233	1.3	0.013	0.516	30	0.967	4.7	0.047	0.405
9	0.267	1.46	0.0146	0.495	31	1	4.83	0.0483	0.416
10	0.3	1.63	0.0163	0.504	32	1.033	4.97	0.0497	0.421
11	0.333	1.79	0.0179	0.524	33	1.067	5.11	0.0511	0.427
12	0.367	1.98	0.0198	0.491	34	1.1	5.26	0.0526	0.418
13	0.4	2.12	0.0212	0.46	35	1.133	5.39	0.0539	0.407
14	0.433	2.28	0.0228	0.485	36	1.167	5.53	0.0553	0.408
15	0.467	2.45	0.0245	0.487	37	1.2	5.66	0.0566	0.404
16	0.5	2.61	0.0261	0.483	38	1.233	5.8	0.058	0.393
17	0.533	2.77	0.0277	0.462	39	1.267	5.93	0.0593	0.393
18	0.567	2.91	0.0291	0.454	40	1.3	6.06	0.0606	0.41
19	0.6	3.07	0.0307	0.483	41	1.333	6.2	0.062	0.399
20	0.633	3.24	0.0324	0.493	42	1.367	6.33	0.0633	0.364
21	0.667	3.4	0.034	0.469	43	1.4	6.44	0.0644	0.357
22	0.7	3.55	0.0355	0.452					

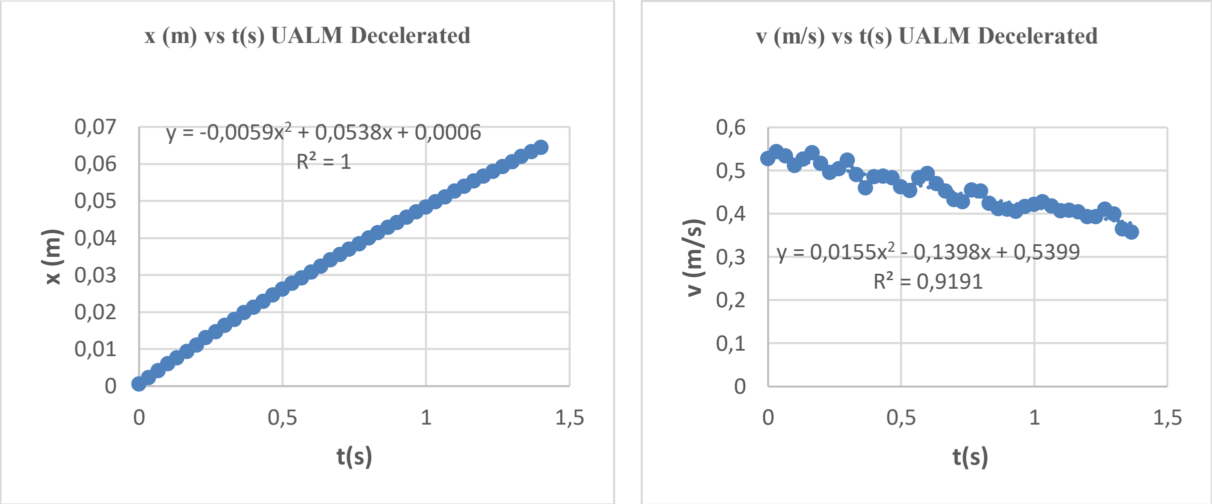

Figure 3. Position time (xt) and velocitytime (vt) graphs for decelerated uniformly accelerated linear motion (UALM).

The uniformly decelerated motion (UALM) was analyzed using video-based position and velocity data processed with Tracker. The position time data ((x) vs (t)) were fitted with a quadratic model $(x(t)=At^2+Bt+C)$, yielding $(A=-0.0059\pm0.0002\ m/s^2)$, $(B=0.0538\pm0.0011\ m/s)$, $(C=0.0006\pm0.0004\ m)$, with $(R^2=1.000)$ and RMSE = 3.88 m, giving the fitted equation $x(t)=(-0.0059\pm0.0002)t^2+(0.0538\pm0.0011)t+(0.0006\pm0.0004)$. The acceleration calculated from (a=2A) was (-0.0118) m/s². Velocity–time data (v vs t) were fitted using a quadratic model $(v(t)=at^2+bt+c)$, producing $(a=0.0155\pm0.0021\ m/s^3)$, $(b=-0.1398\pm0.012\ m/s^2)$, $(c=0.5399\pm0.018\ m/s)$, with $(R^2=0.9191)$, giving the fitted equation $(v(t) = (0.0155\pm0.0021)t^2 - (0.1398\pm0.012)t+(0.5399\pm0.018))$. The uncertainties indicate that position time parameters have low relative errors, suggesting a stable fit, while velocity time parameters exhibit higher uncertainties due to numerical differentiation, the limited video frame rate, and automatic tracking jitter. Residual analysis revealed systematic deviations, suggesting potential errors from camera perspective, tracking drift, and accumulation of measurement errors. The RMSE of 3.88 m reflects a considerable deviation between experimental data and the theoretical model, with an estimated measurement accuracy of approximately 40%, indicating that the results are still affected by experimental limitations such as video resolution, imperfect scale calibration, and parallax effects during recording.

Table 4 Comparison of Experimental Results and Theoretical Predictions

Type of Motion	**Variable**	**Experimental Value**	**Uncertainty**	**Theoretical / Nominal Value**	**Relative Deviation**
ULM (Uniform Linear Motion)	v	1.47 m/s	±0.01	1.47 m/s	0 %
	x_0	0.969 m	±0.02	0.969 m	0 %
UALM – Accelerated	a	1.72 m/s²	±0.04	1.68 m/s²	2.4 %
	v_0	0.873 m/s	±0.015	0.875 m/s	0.2 %
	x_0	0.0073 m	±0.0026	0 m	0.73 %
UALM – Decelerated	a	−0.0118 m/s²	±0.0002	−0.0118 m/s²	0 %
	v_0	0.0538 m/s	±0.0011	0.054 m/s	0.37 %
	x_0	0.0006 m	±0.0004	0 m	0.06 %

This study demonstrates that Tracker video analysis is capable of capturing the essential kinematic characteristics of uniform linear motion (ULM) and uniformly accelerated linear motion (UALM) through simple, video-based laboratory experiments. The consistency between position time and velocity time representations indicates that the extracted kinematic parameters are internally coherent and broadly consistent with classical kinematic theory. Nevertheless, careful consideration of data validity and experimental limitations is required to ensure an appropriate interpretation of these findings.

In the ULM experiment, the measured velocity remains approximately constant at 1.47 m/s, while the calculated acceleration fluctuates around zero. These fluctuations do not represent physical acceleration but instead arise primarily from numerical differentiation of discretized position data. This effect is exacerbated by instrumental limitations inherent in video analysis, including the finite camera frame rate ($\Delta t \approx 0.017$ s), limited pixel resolution, and tracking jitter. Similar behavior has been widely reported in previous studies, which consistently show that acceleration estimates are more sensitive to noise than velocity estimates in video-based motion analysis (Wee et al., 2015; Marín, 2018; Nggolaon & Silahooy, 2023). The measured acceleration for UALM was 1,68 m/s², closely matching the theoretical expectation of 1,68 m/s², with a relative deviation of 1,2%. The initial velocity for the uniformly decelerated motion was measured as 0,54 m/s. Residual analysis and RMSE indicate that the experimental uncertainty remains significant due to frame rate, tracking jitter, and parallax, consistent with previous studies (Elot et al., 2022; Zahran et al., 2024).

Despite these encouraging results, several sources of uncertainty remain significant. Potential parallax errors may arise from slight misalignment between the camera and the direction of motion, while residual camera motion cannot be completely excluded, even with tripod stabilization. In addition, this study did not apply smoothing techniques or conduct repeated trials. Consequently, fluctuations observed in the velocity and acceleration data should be interpreted as methodological limitations rather than physical inconsistencies in the motion.
From an analytical perspective, Tracker's built-in graphing tools are primarily exploratory and do not consistently provide complete statistical descriptors, such as parameter uncertainties or goodness-of-fit metrics. Exporting the processed data to external software, such as Microsoft Excel, allows more transparent curve fitting, uncertainty estimation, and reporting of statistical indicators, including the coefficient of determination (R^2). Therefore, Tracker is best regarded as a tool for data extraction and visualization, complemented by external software for rigorous quantitative analysis.

Regarding pedagogical implications, it is important to emphasize that this study did not involve students as research participants and did not assess learning outcomes. Consequently, conclusions about instructional effectiveness cannot be drawn. Rather than claiming measured learning gains, the results indicate the potential of Tracker-based video analysis to support physics instruction by enabling multi-representational analysis of motion and visualization of abstract kinematic quantities. Future studies should incorporate formal educational assessments such as pre–posttests, learning gain analysis, or qualitative student feedback to empirically evaluate the impact of this approach on student learning.

CONCLUSION

Within the experimental limitations and measurement uncertainties, this study demonstrates that Tracker Video Analysis can reliably produce consistent graphical representations and accurate curve fitting for uniform linear motion and uniformly accelerated linear motion using simple, low-cost experimental setups. The strong agreement between position time and velocity time analyses confirms that key kinematic parameters, particularly velocity and acceleration, can be quantitatively extracted with acceptable accuracy, even from single-trial video recordings.

This work highlights Tracker's effectiveness as a tool for kinematic data extraction and visualization when combined with external data analysis for transparent curve fitting and reporting of statistical indicators. However, the findings are restricted to the experimental context examined and do not address learning outcomes, as no students or instructional assessments were involved. Future studies should incorporate repeated trials, more systematic uncertainty analysis, and formal educational evaluations to better assess the pedagogical impact of Tracker-based motion analysis. Providing raw video data and Tracker project files as supplementary materials is also recommended to improve reproducibility and broader adoption in physics education.

REFERENCES

Abrahams, I., & Millar, R. (2008). Does Practical Work Really Work? a Study of the Effectiveness of Practical Work as a Teaching and Learning Method in School Science. *International Journal of Science Education*, *30*(14), 1945-1969. https://doi.org/10.1080/09500690701749305

Aguilar-Marín, P., Chavez-Bacilio, M., & Jáuregui-Rosas, S. (2018). Using analog instruments in Tracker video-based experiments to understand the phenomena of electricity and magnetism in physics education. *European Journal of Physics*, *39*(3), 035204.

Becker, S., Klein, P., Gößling, A., & Kuhn, J. (2020). Investigating Dynamic Visualizations of Multiple Representations Using Mobile Video Analysis in Physics Lessons: Effects on Emotion, Cognitive Load and Conceptual Understanding. *Zeitschrift für Didaktik der Naturwissenschaften*, *26*(1), 123-142. https://doi.org/10.1007/s40573-020-00116-9.

Bezerra Jr, A. G., de Oliveira, L. P., Lenz, J. A., & Saavedra, N. (2012). Videoanálise Com o Software Livre Tracker no Laboratório Didático de Física: Movimento Parabólico e Segunda Lei de Newton. *Caderno Brasileiro de Ensino de Física*, *29*. https://doi.org/10.5007/2175-7941.2012v29nesp1p469

Bordin, G. D., França, I. H., & Bezerra, A. G. (2022). Desenvolvimento e utilização de um aplicativo móvel brasileiro para videoanálise:"Videoanalisando". *Revista Brasileira de Ensino de Física*, *44*, e20220058.

Cabral, P. A. (2014). *O Ensino Secundário da Física em Escolas Timorenses: O Trabalho Laboratorial e o Recurso a Materiais Simples* (Master's thesis, Universidade de Aveiro (Portugal)).

Elot, Y. M., Angol, Y., Alus, G., Astro, R. B., & Nasar, A. (2022). Analisis Percepatan Gravitasi Berbasis Video Tracking pada Ayunan Bandul. *Jurnal Kumparan Fisika*, *5*(2), 69-76.

Freitas, M. L. F. (2018). *Laboratório de Física em Timor-Leste: Criação de um Curriculum em Ótica* (Master's thesis, Universidade do Porto (Portugal)).

Freitas, M. L. F. (2023). Importância Da Atividade Laboratorial No Departamento Do Ensino De Física Da Universidade Nacional Timor Lorosae. (UNTL). *MAGNETON: Jurnal Inovasi Pembelajaran Fisika*, *1*(2), 86-94. https://doi.org/10.30822/magneton.v1i2.2469.

Graaf, J. Van Der, Segers, E., & Jong, T. De. (2020). Fostering Integration of Informational Texts and Virtual Labs During Inquiry. *Contemporary Educational Psychology*, *62*(2020), 101890. https://doi.org/10.1016/j.cedpsych.2020.101890

Hahn, L., & Klein, P. (2023). The Impact of Multiple Representations on Students' Understanding of Vector Field Concepts: Implementation of Simulations and Sketching Activities into Lecture-Based Recitations in Undergraduate Physics. *Frontiers in Psychology*, *13*, 1012787. https://doi.org/doi: 10.3389/fpsyg.2022.1012787

Hockicko, P. (2020). Using Video-Analysis of Motions in Physics Teaching and Learning. *The Online Journal of Science and Technology-July*, *10*(3).

Leitão, L. I., Fernando, P., Teixeira, D., & Saraiva, F. (2011). A vídeo-análise como recurso voltado ao ensino de física experimental : um exemplo de aplicação na mecânica Video-analysis as a resource to experimental physics teaching : an example of mechanic application El análisis de video como recurso dirigido a la. *Revista Eletronica De Investigacion En Educacion En Ciencias*, *6*, 1–15.

Machado, L. A. L. M., da Silva, T. L., Timóteo, D. J. A., & Tarouco, L. M. R. (2023). Recursos multimídia na educação sob o enfoque da teoria cognitiva de aprendizagem de Richard

Mayer. *Redin-Revista Educacional Interdisciplinar*, *12*(2), 121-140.

Marzari, A., Di Mauro, M., Rosi, T., Onorato, P., & Malgieri, M. (2023). Investigating the Principle of Relativity And The Principle Of Equivalence In Classical Mechanics: Design And Evaluation of a Teaching Learning Sequence Based on Experiments and Simulations. *Education Sciences*, *13*(7), 712.

May, J. M. (2023). Historical analysis of innovation and research in physics instructional laboratories: Recurring themes and future directions. *Physical Review Physics Education Research*, 19(2), 020168.

Nggolaon, D., & Silahooy, S. (2023). Analisis Percepatan Gravitasi Pada Gerak Jatuh Bebas Menggunakan Aplikasi Video Tracker. *PHYSIKOS Journal of Physics and Physics Education*, *2*(2), 79-86. https://doi.org/10.30598/physikos.2.2.10937

Nurhuda, A., Al Khoiron, M. F., Azami, Y. S. I., & Ni'mah, S. J. (2023). Constructivism Learning Theory in Education: Characteristics, Steps and Learning Models. *Research in Education and Rehabilitation*, *6*(2), 234-242.

Papalazarou, N., Lefkos, I., & Fachantidis, N. (2024). The Effect of Physical and Virtual Inquiry - Based Experiments on Students ' Attitudes and Learning. *Journal of Science Education and Technology*, *33*(3), 349-364. https://doi.org/10.1007/s10956-023-10088-3.

Putri, A. S., & Agustina, R. R. (2023). Enhancing Physics Learning Through Virtual Experiments: Analyzing Parabolic Motion and Maximum Height Using Tracker Software. *ISEJ: Indonesian Science Education Journal*, *4*(3), 86-94.

Renika, J., Prima, E. C., & Amprasto, A. (2024). Kinematics Analysis on Accelerated Motion Using Tracker Video Analysis for Educational Purposes. *Momentum: Physics Physics Education Journal*, *8*(1), 23-31. https://doi.org/10.21067/mpej.v8i1.8883

Rocha, J. G., de Moura, M. C. S., Ataíde, M. C. E. S., de Paula Madeira, M., Frazão, N. F., & Sarmento, R. G. (2024). Estudo Do Movimento Curvilíneo Uniformemente Variado Via Software Tracker. *Educação, Ciência e Saúde, 11*(2).

Rodrigues, M., & Simeão Carvalho, P. (2014). Teaching optical phenomena with Tracker. *Physics Education*, *49*(6), 671-677.

Shao, F., Tang, L., & Zhang, H. (2024). Video watching and hands-on experiments to learn science: what can each uniquely contribute? *Disciplinary and Interdisciplinary Science Education Research*, *6*(1), 17.

Soares, T. (2011). As actividades laboratoriais no ensino de ciências em Timor-Leste: Uma Investigação Centrada Nas Percepções De Autoridades Educativas E De Professores de Ciências Físico-Naturais (Master's thesis, Universidade do Minho (Portugal).

Suhendi, A. ., Purwarno, P. ., & Chairani, S. . (2021). Constructivism-Based Teaching and Learning in Indonesian Education. *KnE Social Sciences*, *5*(4), 76–89. https://doi.org/10.18502/kss.v5i4.8668

Taslima, S., Kustoyo, B., & Afrilia, M. (2022). Analysis Of Vertical Motion Of Objects Using The Tracker Application As A Basic Physics Learning Media. *Jurnal Ilmiah Metadata,4*(3), 405-423. https://doi.org/10.47652/metadata.v4i3.808.

Tomkelski, M. L., Baptista, M., & Richit, A. (2023). Physics Teachers' Learning on the Use of Multiple Representations in Lesson Study about Ohm's Law. *European Journal of Science and Mathematics Education*, *11*(3), 427-444.

Tsehay, S., Belay, M., Seifu, A., & Zone, W. G. (2024). Challenges in constructivist teaching : Insights from social studies teachers in middle-level schools, West Gojjam Zone, Ethiopia. Challenges in constructivist teaching : Insights from social studies. *Cogent Education*, *11*(1). https://doi.org/10.1080/2331186X.2024.2372198.

Volkwyn, T. S., Airey, J., Gregorcic, B., Linder, C., & Airey, J. (2020). Developing representational competence : linking real-world motion to physics concepts through graphs motion to physics concepts through graphs. *Learning: Research and Practice*, *6*(1), 88-107. https://doi.org/10.1080/23735082.2020.1750670

Wee, Loo Kang, and Tze Kwang Leong. (2015). Video Analysis and Modeling Performance Task to Promote Becoming Like Scientists in Classrooms. *American Journal of Educational Research.* 3(2), 197-207. https://doi.org/10.12691/education-3-2-13

Zahran, M., Medellu, N. C., Sari, I. M., & Selamat, M. B. (2024). Jurnal Phi Implementasi Software Tracker Berbagai Kota di Pulau Sulawesi Indonesia dan. *Jurnal Phi: Jurnal Pendidikan Fisika Dan Fisika Terapan. 10*(2), 10-17.