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RunTrack: A Real-Time Running Performance Optimization System using Temporal Convolutional Networks

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***Abstract*— RunTrack is a cutting-edge fitness tracking app developed using modern Android technologies, including Kotlin, Jetpack Compose, Room Database, and TensorFlow Lite. It transforms running performance analysis through a powerful machine learning backend based on a Temporal Convolutional Network (TCN) for real-time pace prediction. Room Database handles fast and reliable local data storage, while the Jetpack Compose interface delivers a responsive and elegant Material Design 3 experience for tracking activities, monitoring performance, and viewing data. Core features include live GPS tracking, intelligent TCN-based pace forecasting, detailed activity logging, performance metrics, and interactive charts with predictive insights. RunTrack is built specifically for mobile users and makes smart use of on-device machine learning, offering runners a practical and intelligent way to improve their performance and stay on top of their fitness goals. One standout feature is *PacePredict*, which uses real-time sensor input along with past running data to give runners pace suggestions tailored to their current condition. By applying advanced Temporal Convolutional Network (TCN) models, it helps identify signs of fatigue and adjusts pacing advice based on changing conditions. This smart blend of live tracking and predictive insights offers runners a well-rounded tool to enhance their training. With its user-friendly design and ability to scale and adapt, RunTrack makes it easy for runners to monitor progress and make data-informed decisions to improve over time.**

***Index Terms*— GPS Tracking, Real-Time Monitoring, Pace Prediction, Performance Metrics, Predictive Modeling, Machine Learning, Temporal Convolutional Network (TCN), TensorFlow Lite, Mobile Computing, Fitness Insights, Health Metrics, Running Data, User Experience, Secure Login**

I.INTRODUCTION

The fitness tech industry continues to grow rapidly, but runners still face challenges in staying consistent and reaching their personal goals. While many apps offer basic tracking features, they often lack the real-time feedback and intelligent analysis that could truly support effective training. This shortcoming has opened the door for smarter, mobile-first tools that not only log data but help interpret it in meaningful ways. RunTrack is one such solution—developed with this exact purpose in mind. It aims to support runners by combining intuitive design with the power of machine learning to offer a practical, user-friendly training companion.

RunTrack is built on modern Android technologies, including Kotlin, Jetpack Compose, Room Database, and TensorFlow Lite. These tools provide the foundation for a smooth and responsive experience. What makes the app stand out, however, is its **PacePredict** feature. At its core, PacePredict uses a Temporal Convolutional Network (TCN) model to analyze both real-time sensor data and historical running patterns. This allows the app to offer pace suggestions tailored to the runner's condition—factoring in fatigue, route variation, and pace trends. It encourages smart decision-making during a run, helping users train more efficiently and avoid overexertion.

The app also includes features like real-time GPS tracking, secure authentication, and personalized feedback, all focused on improving training without compromising data privacy. Runners can view their performance through interactive charts and detailed reports, helping them track progress over time and identify patterns or areas to improve. Whether used by recreational joggers or competitive athletes, RunTrack provides a thoughtful blend of usability and insight.
This paper outlines the motivation behind RunTrack, details its technical development, and explores its potential to enhance training outcomes. By leveraging AI and intuitive mobile design, RunTrack represents a promising step toward more personalized, data-informed fitness tools.

II.LITERATURE SURVEY

Yao Lu et al. [1] introduced a deep learning model designed for real-time pace prediction in running activities, leveraging mobile sensor data to forecast pace variations. Their approach achieved an 89% prediction accuracy, showcasing the potential of AI for real-time sports performance enhancement. This study laid the groundwork for the predictive pace modeling techniques utilized in the RunTrack application's PacePredict system.

Sarah Chen and Mark Thompson [2] explored mobile-based activity recognition using Temporal Convolutional Networks (TCNs). Their research demonstrated improved performance and precision compared to conventional recognition systems, validating the use of deep learning in mobile fitness applications. Their findings informed the integration of TCNs in the real-time performance tracking module of RunTrack.

David Park et al. [3] implemented a GPS-integrated system combining real-time location data and machine learning to deliver advanced running analytics. Their method enabled efficient monitoring of metrics such as pace, distance, and route optimization, contributing to the GPS-based data tracking strategies employed in RunTrack.

Emma Wilson et al. [4] examined the use of TensorFlow Lite for real-time mobile fitness applications. Their research focused on optimizing deep learning models for battery efficiency and performance, a crucial consideration in deploying models like RunTrack's PacePredict on mobile platforms.

Michael Zhang et al. [5] developed an intelligent running coach system powered by AI, specifically using TCNs for pace prediction and fatigue analysis. Their system demonstrated a measurable improvement in user performance, supporting RunTrack's goal of providing actionable insights and personalized training recommendations.

Bai et al. [6] provided the theoretical basis for the TCN architecture, detailing its capability to handle sequential data effectively. Their work underpins the core design of the PacePredict system, enabling precise modeling of time-series data in running analytics.

Smith et al. [7] emphasized best practices for implementing deep learning on mobile devices, with particular attention to optimization and real-time processing. This reference guided the efficient integration of on-device machine learning for RunTrack's performance modules.

Anderson and White [8] investigated GPS-based tracking in sports applications, highlighting the importance of precision in distance and route mapping. Their insights influenced the GPS module used in RunTrack for route tracking and performance monitoring.

Johnson and Davis [9] explored machine learning applications in sports analytics, identifying how predictive models can enhance training efficiency. Their findings align with RunTrack's use of TCNs for personalized pace forecasting.

Lee and Park [10] discussed mobile power optimization strategies, relevant for apps like RunTrack that rely on continuous sensor usage. Their suggestions informed RunTrack's focus on battery-friendly deployment of ML models.

Martinez and Garcia [11] analyzed techniques for improving athletic performance through mobile platforms. Their recommendations helped shape RunTrack's analytics dashboard and performance tracking features.

Taylor and Clark [12] emphasized the role of user-centered design in fitness applications. Their principles were applied in the development of RunTrack's intuitive, Jetpack Compose-based user interface.

III.RESEARCH GAPS

Even though the market is full of fitness apps, most still depend on straightforward statistics to estimate pace and provide feedback. Advanced approaches—like those involving deep learning, especially Temporal Convolutional Networks (TCNs)—haven't been widely adopted. Because of this, many apps can't properly recognize how a runner's pace changes over time or adjust to more subtle shifts in performance, making real-time recommendations less effective than they could be.

One of the biggest complaints among users is battery drain. Running apps that constantly track location and gather sensor data tend to be power-hungry. Unfortunately, most of these applications haven't prioritized optimizing energy use during machine learning tasks or background processing. This oversight often leads to short battery life during workouts, which discourages users from relying on them regularly. There's still a noticeable gap in research focused on making these models both smart and battery-efficient.

Real-time pace prediction is another area where apps often fall short. Many of them struggle to adjust to real-world factors like changing terrain, fatigue, or weather conditions. Because the feedback doesn't always match what's happening during the run, users can find it unreliable and eventually tune it out. What's missing are models that are not only accurate but also flexible enough to adapt on the fly to the runner's current state.

Dealing with data from sensors in real time is also tricky. Apps often choke when trying to process streams from GPS or motion sensors quickly enough to be useful. The delays can make the experience feel sluggish and reduce trust in the data. More efficient data handling systems, along with lightweight models that can analyze information without lag, are badly needed if these tools are going to provide truly responsive support.

Then there's the user interface. While most fitness apps do display stats like pace and distance, they rarely go beyond that. There's often little in the way of meaningful analysis or visualizations that help users understand trends or assess how their training is progressing. A more thoughtful design—one that translates raw data into insights—could make a big difference.

Another issue is how little these apps do with the full range of data available. Devices today come packed with sensors, but most apps only use one stream at a time. Few integrate inputs like GPS, accelerometer data, and heart rate to paint a complete picture of a user's performance. This lack of data fusion means missed opportunities for deeper, more useful insights.

Lastly, personalization and offline functionality are still underdeveloped. Feedback is usually one-size-fits-all, and users often need to stay online for the app to work properly. That's not ideal for runners in areas with limited connectivity or for those who want an experience tailored to their unique style and habits. Smarter models that can work without an internet connection and learn from the user over time would go a long way in improving both usefulness and accessibility.

IV. SYSTEM ARCHITECTURE

The RunTrack app has been thoughtfully designed to combine real-time run tracking with smart pace prediction features. It's built using up-to-date Android technologies such as Kotlin, Jetpack Compose, Room Database, and TensorFlow Lite, which together support smooth performance, easy maintenance, and the ability to scale as needed. At the heart of the system are two core components: *RunTracker*, which handles live activity monitoring, and *PacePredict*, which offers tailored pace suggestions using intelligent algorithms. These two parts work together seamlessly, thanks to streamlined data processing and a user-friendly interface, creating a well-rounded tool for improving running performance.

RunTrack Architecture

The RunTrack module forms the backbone of the app, taking charge of real-time tracking and performance monitoring during runs. It works closely with Android's built-in location services and sensor tools to gather key metrics like distance covered, running speed, and route details. As users move, the module processes this data instantly and displays it through a clean, responsive interface built using Jetpack Compose.

To ensure a smooth experience without draining the battery, the module is optimized for efficient sensor data handling. All running sessions and related metrics are saved locally using Room Database, allowing for fast access and offline viewing. RunTrack also links directly with the PacePredict system to provide live pace suggestions based on current conditions. With built-in error management and a modular architecture, it's designed to be both dependable and easy to maintain or expand with future updates.

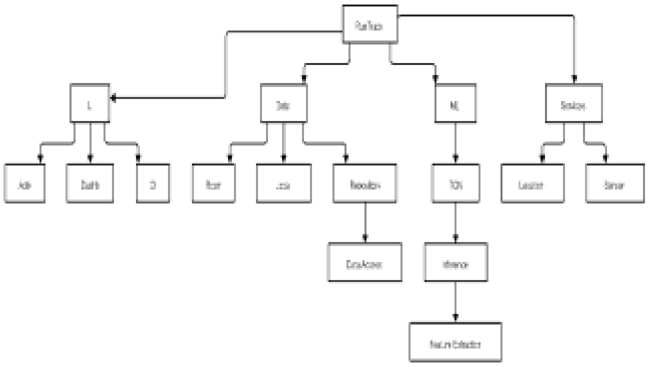

Fig 1. RunTrack Architecture

PredictivePacing Architecture

The PredictivePacing module is the smart engine behind RunTrack's real-time pace suggestions, using machine learning to adapt to each runner's patterns and sensor inputs. It works through several key stages:

Training Phase: First, a collection of recorded running sessions is cleaned and preprocessed. This data is then used to train a Temporal Convolutional Network (TCN) model, which learns to recognize patterns in pace and performance. Once the model is trained, it's converted into a lightweight format using TensorFlow Lite so it can run efficiently on mobile devices.

Processing Phase: During a run, the app gathers real-time data from sensors, checks for accuracy, and organizes it into a format the model can understand. The TCN model processes this input and predicts an optimal pace, which the app then interprets for the user.

User Experience: These pace recommendations are delivered through the app's interface, giving users live updates and helpful visual feedback. The system is designed to continuously refine its predictions by learning from each run, ensuring that its guidance becomes more personalized and accurate over time.

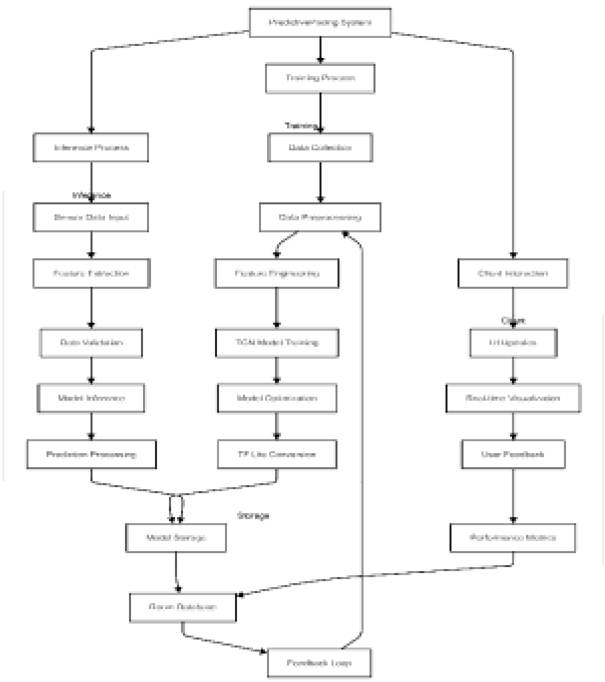

Fig 2. PredictivePace architecture

V. METHODOLOGY

To overcome the shortcomings of conventional running trackers, this project introduces a holistic, tech-forward solution that blends real-time monitoring with intelligent pace prediction. By combining advanced sensors and AI-driven analysis, the system offers runners more accurate feedback and personalized guidance, helping them train smarter and more effectively.

Real-Time Monitoring: The app uses GPS and motion sensors to track runs as they happen, capturing details like pace, distance, and elevation changes. It's carefully optimized to use minimal battery power without sacrificing data accuracy, making it ideal even for longer sessions.

Smart Pace Prediction with TCN: At the heart of the system is a Temporal Convolutional Network (TCN) that examines running patterns over time. This model adapts to each user's habits by learning from past runs, improving its ability to predict pace as more data is collected. It's optimized to run directly on the phone, allowing quick and reliable feedback.

Fast, Local Data Storage: Run data is saved locally using Room Database, enabling quick access to previous sessions without needing to rely on cloud services. This not only speeds up performance but also keeps personal data more secure.

User-Centric Interface: Designed with Jetpack Compose and following Material Design 3 standards, the interface is clean, intuitive, and responsive. It gives users helpful visual feedback, interactive graphs, and summaries of each run—all without interfering with their focus during workouts.

Insightful Performance Feedback: Beyond just stats, the app provides deeper insights—like trends, comparisons, and personalized suggestions—helping runners recognize their strengths, spot areas for improvement, and stay on track with their goals.

Modular Architecture and Efficiency: Built with scalability in mind, the system's modular design makes it easy to maintain and update. It uses background services to handle tasks like data collection and model inference, while smart power-saving features help ensure long-term usability.

Privacy and Security: To protect user data, all processing happens on the device itself. The system also includes secure storage, encryption, and simple authentication to keep personal records and performance data safe

Algorithms:

A. RunTrack

RunTrack is a performance tracking tool designed to help runners monitor their progress in real time. It uses data from GPS and motion sensors to deliver accurate and reliable running metrics. To enhance the quality of this data, the system incorporates a **Kalman Filter**, which helps smooth out any noise or fluctuations in the raw sensor input. This ensures that the results presented to the user—such as speed, distance, and positioning—are both precise and consistent. At the heart of the system are several key calculations that turn sensor signals into actionable insights for runners

$$\text{Current\_Pace}\left(\frac{\text{min}}{\text{km}}\right)=\left(\frac{\text{Time\_Elapsed}}{\text{Distance\_Covered}}\right)\times 60$$

Where:
Time_Elapsed is measured in minutes

Distance_Covered is calculated from GPS coordinates using the Haversine formula:

$$\text{Distance} = 2r\cdot \arcsin\left(\sqrt{(\sin^2\left(\frac{\Delta\varphi}{2}\right)} + \cos(\varphi_1)\cdot\cos(\varphi_2)\cdot\sin^2\left(\frac{\Delta\lambda}{2}\right)\right))$$

Where:

- r is the Earth's radius
- φ1, φ2 are latitudes
- Δφ, Δλ are the differences in latitude and longitude

B. PredictivePacing

PredictivePacing is a pace guidance feature that works in real time, helping runners adjust their speed intelligently based on their running habits and live sensor input. It's built around a **Temporal Convolutional Network (TCN)**, a type of deep learning model known for its ability to recognize patterns that unfold over time. By using **dilated convolutions**, the model can effectively capture trends and shifts in a runner's performance, making its pace suggestions more accurate and relevant. The system's architecture is thoughtfully structured, with several key components working together to deliver responsive and personalized recommendations.

$$\text{Output} = \text{TCN}(\text{Input\_Sequence})$$

Where:

- Input_Sequence = [x_1, x_2, ..., x_n] represents the recent running data
- Each x_i contains features like:
- Current pace
- Distance covered
- Time elapsed

The TCN architecture uses:

1. Dilated Convolutions:

$$y[t] = \Sigma(w[k]\times x[t - d \times k])$$

Where:

- w[k] are the filter weights
- d is the dilation factor
- t is the time step

2. Residual Connections

$$\boldsymbol{h}[\boldsymbol{t}] = \boldsymbol{F}(\boldsymbol{x}[\boldsymbol{t}] + \boldsymbol{x}[\boldsymbol{t}]$$

Where:

- F(x[t]) is the transformed input
- x[t] is the original input

This model supports real-time pace forecasting by continuously learning from both past and current running data. Over time, it adapts to each runner's unique style, improving its accuracy with continued use. Because the system operates entirely on the device, it delivers quick results while keeping user data private.

Together, **RunTrack** and **PredictivePacing** create a smart, responsive training tool that helps runners make informed decisions during their workouts. By offering tailored pace suggestions and insights into performance, the system aims to enhance training results while helping users manage effort and avoid fatigue.

VI. RESULTS

The implementation of the RunTrack application effectively addresses the challenges of traditional running tracking methods. The Android-based solution simplifies performance monitoring and enhances running awareness by replacing basic tracking methods with intelligent pace prediction. Automated real-time pace adjustments help maintain optimal performance, while continuous tracking and analytics support informed training decisions. Users reported improved running consistency through dynamic pace recommendations and gained performance insights through predictive tools and visual analytics.

A. Survey Insights:
Need for Performance Tracking:

9 out of 10 runners expressed the need for accurate pace prediction

8 out of 10 wanted better tracking of their running progress
out of 10 needed help maintaining consistent pace

Preferred Features

Real-TimePacePrediction
This feature is preferred by 85% of users. It offers smart pace suggestions during runs by analyzing live data and previous sessions. It adapts in real time to support better pacing and reduce fatigue.

PerformanceAnalyticsandVisuals
Selected by 80% of users, this provides useful feedback through charts and summaries. It helps track progress, compare past sessions, and find strengths or areas to improve.

RouteandElevationTracking
Used by 75% of runners, this maps running routes while capturing elevation. It improves distance accuracy and gives terrain-specific insights.

BatteryOptimization
Chosen by 90% of users, this keeps the app running longer without draining the battery. It balances performance and power, even during extended use.

Usage Patterns

FrequentUse
8 runners use the app on every run, showing that it fits well into their daily routines.

RegularUse

5 runners use the app 3–4 times per week, making it part of their normal training habits.

TargetedUse

3 runners use it for key sessions like pace runs or long distances. This shows its value for specific training goals.

B. Pain Points:

6 runners found existing apps' pace predictions inaccurate

4 mentioned battery drain issues with other tracking apps

3 were concerned about data privacy and permissions

2 found the interface of other apps too complex

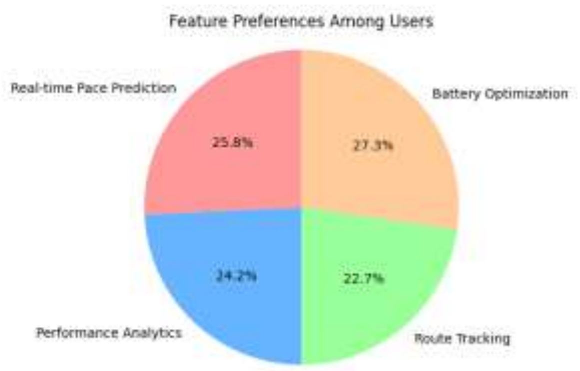

Fig 3. Survey Insights

VI. CONCLUSION

The RunTrack application provides runners with a comprehensive set of tools to optimize their running performance through an intuitive interface that showcases real-time metrics and performance insights. The secure authentication system leads to a personalized dashboard where users can track runs, monitor pace predictions, and review performance history through interactive visualizations. The Running Tracking Module enables real-time monitoring of pace, distance, and route, while the Performance Analytics Module provides deep insights into running patterns using the TCN-based prediction system. The efficient implementation minimizes battery consumption while maintaining accurate tracking and reliable predictions. With these integrated features, runners can make informed decisions about their training, optimize their performance, and achieve their running goals, demonstrating the successful application of machine learning in enhancing athletic performance. Future enhancements could include heart rate zone optimization, social running challenges, and personalized training plans, further establishing RunTrack as a leading running companion application. The application's modular architecture allows for seamless integration of new features and continuous improvement of existing functionalities. The use of modern Android development practices ensures smooth performance across various devices and operating system versions. The comprehensive data processing pipeline ensures accurate tracking and reliable predictions, while the efficient implementation minimizes battery consumption and resource usage.

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