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Design of Neural Predictor for Performance Analysis of Mountain Bicycles

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***Abstract*—In recent years, bicycle races, along with the crest of the high technology continues to increase. Because of this increased races, performance of bicycles, in both biological and mechanical terms, is extraordinarily important and efficient. In terms of the ratio of cargo weight a bicycle can carry to total weight, it is also a most efficient means of cargo transportation. In spite of advanced technology, there are still some problems on bicycles during working conditions and road roughness such as on the mountain from tire and mechanical parts. In this investigation, a extraordinary designed with fiber-carbon body and light bicycle is tested on mountain road conditionswith prescribed trajectory on the mountain for different elevation, speed, hearth rate, bike cadence and average temperature. The real time measured parameters are predicted with proposed two types of neural networks for approaching real time neural network predictors. The results of the proposed neural network have shown that neural predictor has superior performance to adopt the real time bicycle performance.**

Keywords— Neural network; Bicycle; performance; systems dynamic; neural predictor.

I. INTRODUCTION

Because of advanced technology, high level bicycle types have been increased to organize competition on ways and mountains. Furthermore, mountain bikes need very strong attention to drive without and problems, due to very random surface of roads. Also, there are plenty of disturbances such as stones, plants and weather conditions.

There are two types of bicycle systems, mountain and road. On a mountain bike the wheel structure is different than road bicycle. The mountain bike involves the delibrate of sound during the race. This sound comes from road rougness surface on the mountain roads. This roughness is accfted the performance of the mountain bike.

Bike races, the demand is increasing every day. This request is of great importance for racers on the bike's performance. Artificial neural networks, to the modeling of such systems can be considered as an alternative. In an alternative system, such as system modelling for performance analysis can be shown to be the best. Bike during the race, to a fault, gives rise to disqualification of a racer. Mountain biking especially the failure rate is high. Because of the mountain road is rugged and rocky as some of the reasons that can be given.

In this study, the performance analysis of the ideal mountain bike racing, professional bike racer, the analysis of different parameters was carried out. Here, the slope of the mountain road, the bike speed racer of variable parameters such as heart rate were analyzed. Testing preferred for the mountain, at an altitude of 3800 m, The position property is a structure with a roughness road.

The aim of this study to perform the analysis of performance in the most difficult road conditions, the bike and the riders, shape modeling with artificial neural networks.

Also, here it is lighter than the bike racers and race to be the rate of successful completion of the appropriate weight increases.

On the other hand, the wheel diameter and the tire air pressure of the bicycle is also important. Furthermore, proper tire air pressure, if so preferred, to the maximum level of accident risk factors increases. In addition, the Athlete's weight and performance in Bicycle racing are of great importance.

In this study, artificial neural networks, trained using back propagation algorithm. The QP algorithm has used and given the best result to perdict real time results of bycycle.

Nowadays, some researchers have been investigated some randomized-control trials These have been improved that lifestyle modification has almost the same effects on aerobic capacity, body composition, and coronary risk factors as planned exercise programs for people who do not conduct daily exercise [1,2]. Other investigation has been done on under the conditions of the same amount of calories being expended daily, repetitive types of moderate exercise such as brisk walking, housework, and yard work are reportedly as effective as performing high intensity exercise [3,4].

On the other study, because of the equivalent inertia moment with respect to the lower wheel of the bicycle was decreased when driven on a sloping road. In this investigation, a novel simple control system has been proposed based on a sensory system for attempting to overcome those issues. By changing biker posture through driving the saddle forward or backward, the stability of the bicycle could be improved greatly [5].

Therefore, for health promotion, people should be encouraged to increase daily physical activity levels including frequency, intensity, duration, and exercise type, irrespective of training plans.

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II. THEORY AND PERFORMANCE OF BICYCLES

A bike driver is being traveling on a bicycle at 16–24 km/h, using only the power required to walk, is the most energy-efficient means of human transport generally available. Air drag disturbances, which increases with the square of speed, requires increasingly higher power outputs relative to speed, power increasing with the cube of speed as power equals force times velocity. A bicycle in which the rider lies in a supine position is referred to as a recumbent bicycle or, if covered in an aerodynamic fairing to achieve very low air drag, as a streamliner.

Nowadays, racing bicycles on the road or mountain are manufactured light in weight, (approximately 6-8 kg) allow for free motion of the legs, keep the rider in a comfortably aerodynamic position, and feature high gear ratios and low rolling resistance.

On firm, flat ground, a 70 kg person requires about 60 watts to walk at 5 km/h That same person on a bicycle, on the same ground, with the same power output, can travel at 15 km/h using an ordinary bicycle, so in these conditions the energy expenditure of cycling is one-third of walking [6, 7].

Active humans can produce between 1.5 W/kg (untrained women for longer periods) and 24 W/kg (top-class male athletes during 5 s). 5 W/kg is about the level reachable by ordinary male athletes for longer periods [7]. Maximum power levels during one hour range from about 250 W ("healthy men") to 500 W (exceptionally athletic men) [8].

On the other energy consumptions can be described The energy input to the human body is in the form of food energy, usually quantified in kilocalories [kcal] This can be related to a certain distance travelled and to body weight, giving units such as kJ/(km kg). The rate of food consumption, it can be described that the amount consumed during a certain period ot time, is the input power. This can be experimentally measured in kcal/day or in J/s = W (1000 kcal/d ~ 48.5 W).

This input power can be determined by measuring oxygen uptake, or in the long term food consumption, assuming no change of weight. This includes the power needed just for living, called the basal metabolic rate BMR or roughly the resting metabolic rate.

The required food for a race biker can also be calculated by dividing the output power by the muscle efficiency. This is 18-26%. From the example above, if a 70 kg person is cycling at 15 km/h by expending 60 W and a muscular efficiency of 20% is assumed, roughly 1 kJ/(km·kg) *extra* food is required. For calculating the *total* food required during the trip, the BMR must first be added to the input power. If the 70 kg person is an old, short woman, her BMR could be 60 W, in all other cases a bit higher viewed this way the efficiency in this example is effectively halved and roughly 2 kJ/(km·kg) *total* food is required [9].

In order to increase in food required for low power cycling, in practice it is hardly noticed, as the extra energy cost of an hour's cycling can be covered with 50 g nuts or chocolate. With long and fast or uphill cycling, the extra food requirement however becomes evident.

On the other hand , it is necessary to complete the efficiency calculation, the type of food consumed determines the overall efficiency. For this the energy needed to produce, distribute and cook the food must be considered.

Furthermore, cycling on the level at a constant speed, a large weight reduction saves only a negligible amount of power and it is on the contrary beneficial to *add* mass in the form of aerodynamic improvements. But climbing steeply, any weight reduction is felt directly. E.g. a reduction of 10% of the total system weight (bicycle, rider, and luggage combined) will save nearly 10% power.

Moreover, a reduced mass is also directly felt when accelerating. For example, the Analytic Cycling calculator gives a time/distance advantage of 0.16 s/188 cm for a sprinter with 500 g lighter wheels. In a criterium race, if a rider has to brake entering each corner, then this is wasted as heat. For a flat criterium at 40 km/h, 1 km circuit, 4 corners per lap, 10 km/h speed loss at each corner, one hour duration, there would be 160 corner "jumps". For 90 kg rider and bike, this adds roughly one third effort compared to the same ride at a steady speed, and a mass reduction of 10% of the total system weight could thus give about a 3% advantage.

The power P_D needed to overcome air drag can be wtitten in the following equation:

$$P_D = \frac{1}{2}\rho v_a^3 C_D A \qquad (1)$$

where ρ is the air density, which is about 1.225 kg/m^3 at sea level and 15 degrees, v_a is the speed relative to the air, and $C_D A$ is a characteristic area times its associated drag coefficient.

The drag coefficient depends on the shape of the object and on the Reynolds number, which itself depends on v_a. However, if A is the cross sectional area, C_D can be taken as 1 for usual cycling speeds of a rider on an upright bicycle.

The power P_R for overcoming the tires' rolling resistances is given by:

$$P_R = v_r mg \cos(\arctan \boldsymbol{s})\, C_{rr} \approx v_r\, mg C_{rr} \quad (2)$$

where g is gravity, nominally 9.8 m/s^2 , and m is mass (kg). The approximation can be used with all normal coefficients of rolling resistance C_{rr}. Usually this is assumed to be independent of v_r (speed of the bicycle on the road) although it is recognized that it increases with speed. Measurements on a roller-mechanism give low-speed coefficients of 0.003 to

0.006 for a variety of tires inflated to their maximum recommended pressures, increasing about 50% at 10 m/s. [10].

The vertical climbing power P_S on slope $\boldsymbol{s}$ is given by [11].

$$P_S = v_r mg \sin(\arctan \boldsymbol{s}) \approx v_r mg\boldsymbol{s} \qquad (3)$$

This approximation approaches the real solution for small, i.e. normal grades. For extremely steep slopes such as 0.35 the approximation gives an overestimation of about 6%.

As this power is used to increase the potential energy of bike and rider, it is returned as motive power when going downhill and none lost unless the rider brakes or travels faster than desired.

The power P_A for accelerating the bike and rider having total mass m with acceleration a and rotationally also the wheels having mass $m_w$is:

$$P_A \approx v_r(m + m_v)a \qquad (4)$$

The approximation is valid if is assumed to be concentrated at the rims and tires and these are not slipping. The mass of such wheels can thus be counted twice for this calculation, independent of the wheels' sizes.

As this power is used to increase the kinetic energy of bike and rider, it is returned when decelerating and not lost unless the rider brakes or travels faster than desired.

The total power can be written as follows;

$$P = (P_D + P_R + P_S + P_A)/\eta \qquad (5)$$

where η is the mechanical efficiency of the drive train described at the beginning of this article.

Mountain biking is the sport of riding bicycles off-road, often over rough terrain, using specially designed mountain bikes. Mountain bikes share similarities with other bikes, but incorporate features designed to enhance durability and performance in rough terrain.

Mountain biking can generally be broken down into multiple categories: cross country, trail riding, all mountain downhill, free ride and dirt jumping. However, the majority of mountain biking falls into the categories of Trail and Cross Country riding styles.

This individual sport requires endurance, core strength and balance, bike handling skills, and self-reliance. Advanced riders pursue both steep technical descents and high incline climbs. In the case of freeriding, down hilling, and dirt jumping, aerial manoeuvres are performed off both natural features and specially constructed jumps and ramps.

Mountain biking can be performed almost anywhere from a back yard to a gravel road, but the majority of mountain bikers ride off-road trails, whether country back roads, fire roads, or single track (narrow trails that wind through forests, mountains, deserts, or fields). There are aspects of mountain biking that are more similar to trail running than regular bicycling. Because riders are often far from civilization, there is a strong ethic of self-reliance in the sport. Riders learn to repair their broken bikes or flat tires to avoid being stranded miles from help. Many riders will carry a backpack, including a water bladder, containing all the essential tools and equipment for trailside repairs, and many riders also carry emergency supplies in the case of injury miles from outside help. Club rides and other forms of group rides are common, especially on longer treks. A combination sport named mountain bike orienteering adds the skill of map navigation to mountain biking.

Mountain bike trials, also known as observed trials, is a discipline of mountain biking in which the rider attempts to pass through an obstacle course without setting foot to ground.

Trials riding is an extreme test of bicycle handling skills, over all kinds of obstacles, both natural and man-made. It now has a strong – though small – following worldwide, though it is still primarily a European sport. Skills taken from trials riding can be used practically on any bicycle for balance, for example controlled braking and track standing, or balancing on the bike without putting a foot down. Competition trial bikes are characterized by powerful brakes, wide handlebars, lightweight parts, single-speed low gearing, low tire pressures with a thick rear tire, distinctive frame geometry, and usually no seat.

III. FEEDFORWARD NEURAL NETWORKS

In feedforward neural networks artificial neurons (also called nodes or processing units) are arranged in a feedforward manner (usually in the form of layers, i.e. each neuron may receive an input from the external environment and/or from other neurons, but no feedback is formed. A standard feedforward neural network consists of simple processing units (without dynamic elements). A feedforward network computes an output pattern in response to some input pattern. Once trained (with fixed connection weights) the output response to a given input pattern will be the same regardless of any previous network activity. This means that the feedforward neural network does not exhibit any real dynamics, and there are no stability problems in such networks. For feedforward networks the dynamics are often simplified to a single instantaneous nonlinear mapping. Some learning algorithm of the ANN can be described in the following [12, 13] ;

A. Quickpropagation (QP) learning algorithm

QP is another training method based on the following assumptions, *E(w)* for each weight can be approximated by a parabola that opens upward and the change in slope *E(w)* fort his weight is not affected by other weights that change at the same time. The weight update rule is;

$$\Delta w(t) = \frac{S(t)}{S(t-1)-S(t)} \Delta w(t-1) - \eta\, S(t) \qquad (6)$$

Where $S(t-1) - S(t)$ The numerator is the derivative of the error with respect to the weight and is a finite difference approximation of the second derivative. Together these approximate Newton's method for minimizing a one-dimensional function . To avoid an infinite backward step, or a backward uphill step, a maximum growth factor parameter μ is introduced. No weight change is allowed to be larger than μ times the previous weight change. Furthermore, QP has a fixed learning parameters, η ,that needs to *e(t)* chosed to suit the problem.

B. Delta–Bar-Delta (DBD) learning algorithm

An adaptive learning rate method in which every weight has its own learning rate. The learning rates are updated based on the sign of the gradient does not change signs on successive iterations then the step size is increased linearly. If the gradient changes signs, the learning rate is decreased exponentially. In some cases this method seems to learn much faster than non-adaptive methods. Learning rates (t), are updated as follows;

$$\Delta_{ij} \begin{cases} \kappa & if\ \ \delta'(t-1)\,\delta(t) > 0 \\ -\phi\boldsymbol{\eta}(\mathbf{t}) & if\ \delta'(t-1)\,\delta(t) < 0 \\ 0 & else \end{cases} \qquad (7)$$

Where δ(t)= $\frac{\delta E}{\delta w}$ at time t and δ is the exponential average of past values of δ. δ'(t)=(1-θ) δ(t)+ θ δ'(t-1)

IV. EXPERIMENTAL AND SIMULATION RESULTS

This section is presented two approaches that are experimental and simulation approaches. For experimental measurement real time values for performance of the mountain bike, **Garmin** type instrument was used to measure real time parameters of the bike and bike driver. The schematic representation of the mountain bike is outlined in Figure 1. The figure shows the angular and distance parameters of the bike such as rake, wheelbase, head angle and trial. These measured with a Garmin 520 Bundle, variable parameters were bike speed, candance, hearth breath elevation of the bike during the travelling on the mountain which has highness of approximately 4000 meters. However, the proposed prediction model of the bicycle performance on the roughness road on the mountain with a prescribed trajectory. The mountain bicke with driver is shown in Figure 2. Ac can bee seen on the figure, the bike and driver are also suit on the bike conditions with a light weight. On the other hand wheel of the bicycle is analyzed with the weight of driver by using ANSYS software. However, the stress variation on the wheel can be shown in Figures 3(a) and (b) for both wheels rear and front.

In this experimental study, a very good quality bike was analyzed and tested with defined trajectory on the Erciyes mountain which has highness of 3900 meters.

Experimental work has been carried on high quality bicycle with a trained bike driver and prescribed trajectory. As can be seen from the table, the weather condition and road surface is changing suddenly within 10 minutes. Four parameters were measured with Garmin 520 bundle which measures all parameters in accurately. These parameters were elevation of road, speed of bicycle, hearth rate of driver, bike cadence and average temperature.

The measured parameters of the bike and biker were used to predict by the proposed neural networks represented in Figures 4-5. In this simulations study, two types of neural network were employed to predict real time bicycle performance during the travelling on the mountain. However, figure 6 shows that elevation DBT with two approaches. As can be seen from figure, neural predictors exactly follow the results of experimental measurement. QP neural network type was also employed for comparison (see Figure 7). The variations of the bike driver heart rate were measured from the bike during travelling on the prescribed trajectory, the measured results were predicted by using two types of neural predictors. (See Figures 8-9). Finally, the performance of the bike is analysed by measuring the speed on the same prescribed trajectory.

V. CONCLUSIONS AND DISCUSSIONS

This paper has presented neural network based performance analysis of mountain race bike with professional driver with prescribed trajectory. Due to unpredicted road profile, it is very necessary to predict all parameters of the bike.

In this study, especially the mountain bike both wheels of the load distribution were analyzed using ANSYS. The load used here is approximately equal to the weight of the bike driver. As can be seen from the figure, the load distribution seems to be a uniform distribution. In addition, when the bike is moving, the roughness of the mountain road due to this distribution will show a random behavior.

The aim of the work experimental different path here in the profile of the bike, performance behavior by testing against different destructive factors that will occur to develop designs. On the other hand, adaptive and robust in design to be used as a model structure of neural networks provides convenience. That is used type of neural network, feed-forward and consists of three layers.

As can be seen from the results, quick prapagation (QP) algorithm gives the best results between three types algorithms. The results of artificial neural networks as a result of this type of models real-time modeling can be used. Here the main objective of the study is robust due to the structure of artificial neural networks in real-time, applications. Despite technological advancements, still there is the fundamental problem in the system and run on the road bike to test.

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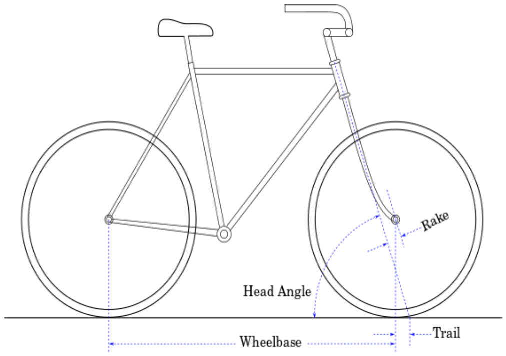

Fig. 1. Schematic view of the bicycle

Fig. 2. During the testing bicycle system

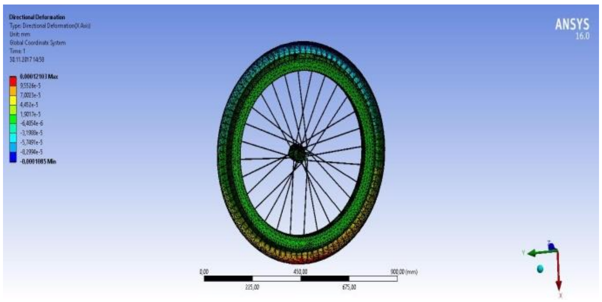

Fig. 3(a). Directional deformational variations on the wheel

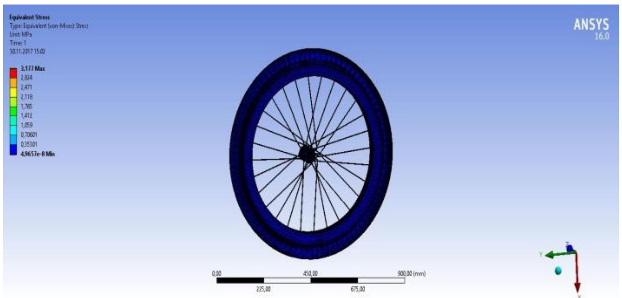

Fig. 3 (b) Equivalent Stress variations on the wheel

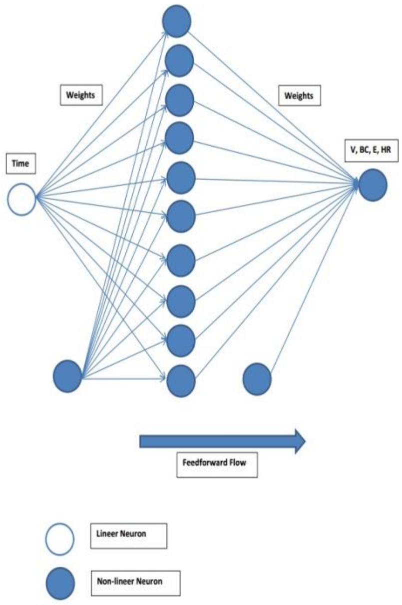

Fig. 4. Schematic representation the proposed network type

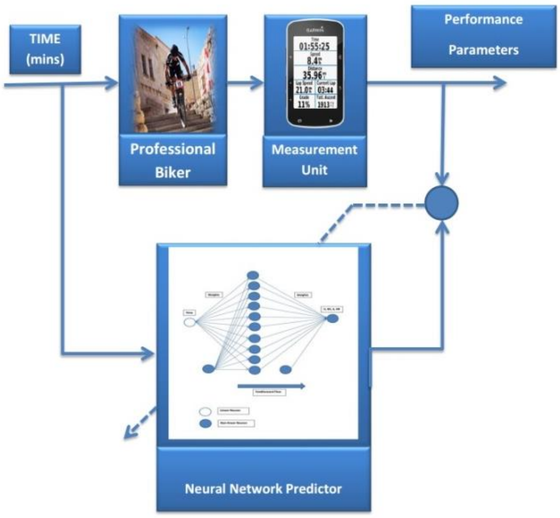

Fig. 5. The proposed prediction model of the system with feedforward NN

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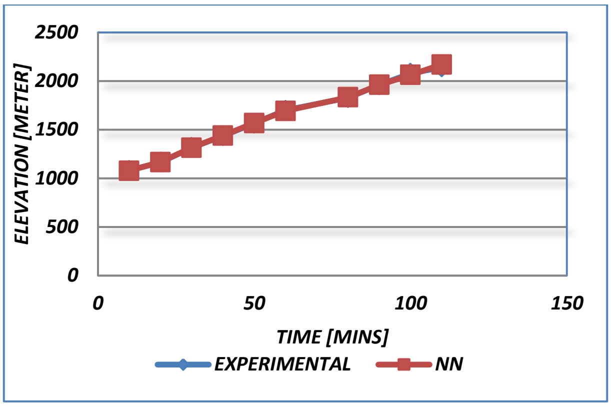

Fig. 6. Elevation variation by using DBD-NN type

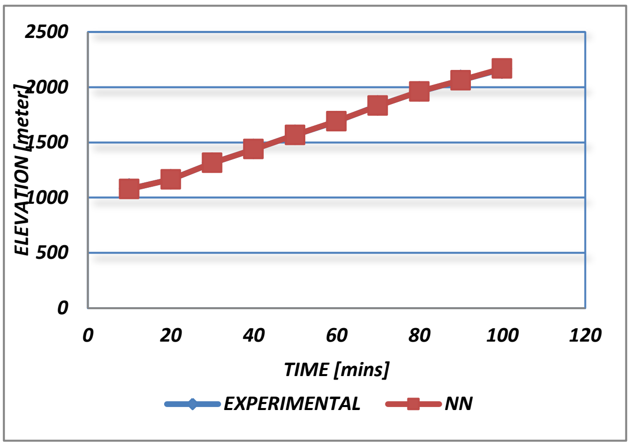

Fig. 7. Elevation variation by using QP-NN type

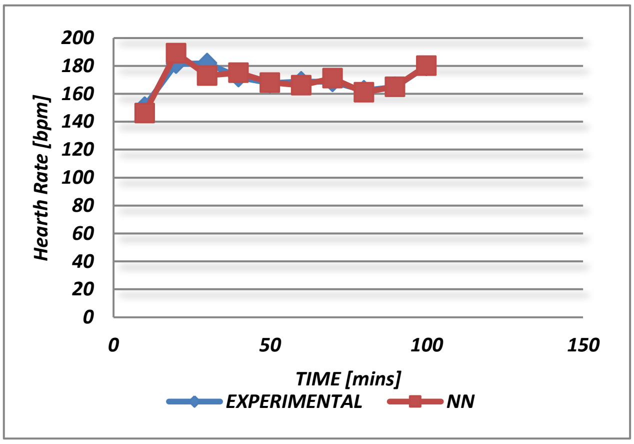

Fig. 8. Hearth Rate variation prediction using DBD-NN

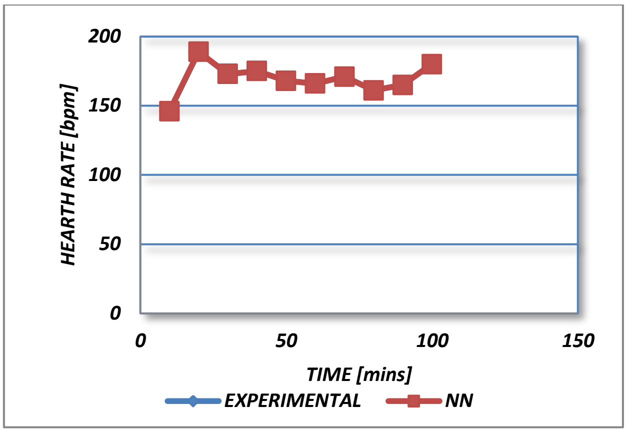

Fig. 9. Hearth Rate variation prediction using QP-NN

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