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Original Article

Novel Hybrid Trauma Injury Classification based on Trauma Revise Injury Severity Score (TRISS) and Visum et Repertum (VeR) Features

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Abstract - *Trauma injury classification is crucial for refining diagnostic and increasing the accuracy of Forensic and Medicolegal services. Current approaches are considered challenging in determining the critical features. Insufficient critical features analysis causes inconsistent judgment in analyzing the degree of trauma injury among the medical consultants. The issue becomes more complicated because the dataset consists of incomplete data and outliers class problems that can affect the sampling bias. The objective of this research is to identify the features and terms of trauma injury by combining the Trauma Revise Injury Severity Score (TRISS) with Visum et Repertum (VeR) Data, develop and evaluate the Hybrid Neural Network Model (HNNM) for classifying the degree of trauma injury for an Indonesian use case. The sample data consists of the TRISS features, including physiological and anatomical information. While the VeR data was used to improve the critical features selection. The HNNM is expected to classify the persecution victim as having a minor, moderate, or major injury, as defined by the Indonesian Penal Code. HNNM is proposed based on the case studies at three hospitals in the Indonesian city of Pekanbaru. It comprises three main phases: pre-processing, development, and performance analysis. Pre-processing phases solve the drawbacks of incomplete data by performing data cleansing and normalization. Then, the features' determination is chosen by utilizing the Neural Network (NN) as a classification algorithm and the Genetic Algorithm (GA) as an optimization technique. The selected features are applied during the dataset training stages to increase the HNNM's accuracy and minimize error. GA's goal is to increase the accuracy rate and reduce error in the learning stages of NN. The development phase is accomplished with testing stages by combining the TRISS feature and the VeR dataset. The performance analysis shows the HNNM produced a 98.85% accuracy level and the Root Mean Square Error (RMSE) value at 0.077. In the validation stage, the features of the HNNM are implementable and highly acceptable by the practitioner. For future works, the HNNM needs to increase the accuracy by improving the input features, including lifestyle, habit, and job.*

Keywords - *Trauma Revise Injury Severity Score (TRISS), Visum et Repertum (VeR), Medicolegal Prognostic, Root Mean Square Error (RMSE), Analytical Hierarchical Process (AHP).*

1. Introduction

Trauma injuries are a leading risk factor for disability and mortality, and a critically injured person's life is dependent on receiving expert therapy in a timely way (Saleh et al., 2018). In trauma injuries, estimating the likelihood or probability of survival is critical for an emergency, research, and treatment priorities. (Rau et al., 2019). The probability of survival is affected by various parameters, including the extent of the body injuries, type of the injuries, and host factors such as previous medical condition, age, and gender. It is used to determine various trauma experiences from patients in clinical practices written on Visum et Repertum (VeR) documents. This process is also used as valid evidence to enforce the law and justice during the pretrial hearing in court (Azhari et al., 2012) (Fatriah et al., 2017).

The good quality of Visum et Repertum (VeR) contains the complete patient information written in the doctor's conclusions section. One of the conclusion parts that must be discovered is the level of trauma injury qualifying is known as Visum et Repertum (VeR) (Afandi, 2017). The degree of trauma injury determination highly depends on the background of the doctor's experiences, skills, and participation in continuing medical education, which could lead to inequalities between them.

Trauma and Injury Severity Score (TRISS) is claimed to be a tool for predicting the likelihood of survival by employing consideration of several types of variables, such as Systolic Blood Pressure (SBP), Gender, Age, Type of Injury, Location of Injury, Respiration Rate (RR), Length of treatment, and others (Kang et al., 2019). However, it still has limitations regarding the missing value and less analysis for the determination model (de Jongh et al., 2018).

This research uses machine learning to achieve a better result with various training datasets from the TRISS and VeR features. The feature from the TRISS consists of information from the Revise Trauma Score (RTS) and Injury Severity Score (ISS) from a victim of persecution cases. At the same time, the VeR features are gained from the physical examination of a patient by a doctor or forensic expert. The features will combine and tested to the proposed model based on the hybrid machine learning models.

2. Related Works

2.1. Determination of the Likelihood of Trauma Survival

Mohammad Saleh et al. (Saleh et al., 2017) proposed that 'Patients with trauma injuries can use fuzzy logic to predict their chance of survival which utilizes fuzzy logic for the survival for trauma diagnosis. An anatomical and physiological scoring system is used for relative accuracy and popularity. Collection of Trauma Audit and Research Network (TARN), which has thousands of trauma injury cases, is used. The method operation of the approach is shown in (Fig. 1).

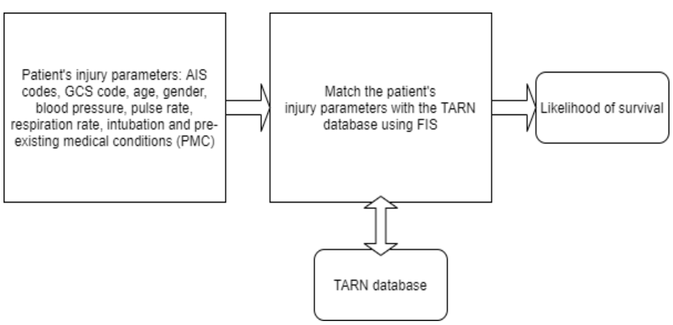

Fig. 1 Fuzzy logic method to determine the likelihood of survival

Fig. 1 shows the trauma injury data for a certain patient is evaluated to other injury cases in the TARN database and matched closely to the injury conditions handled by the Fuzzy Inference System (FIS) (Saleh et al., 2017). The model was developed as a prototype that tested the patient with two injuries related to chest and head injury. The FIS system categories injuries into maximum, critical, severe, serious, moderate, and minor levels of severity. This approach's result can be more accurate by including other factors such as injury in multiple regions, physiological parameters, age, and gender (Saleh et al., 2017).

2.2. Trauma Patient Prediction Using Machine learning

The studies from (Rau et al., 2019) proposed the prediction of survival in trauma patients by utilizing the machine learning approach. (Fig. 2) shown the method of machine learning prediction for survival patients.

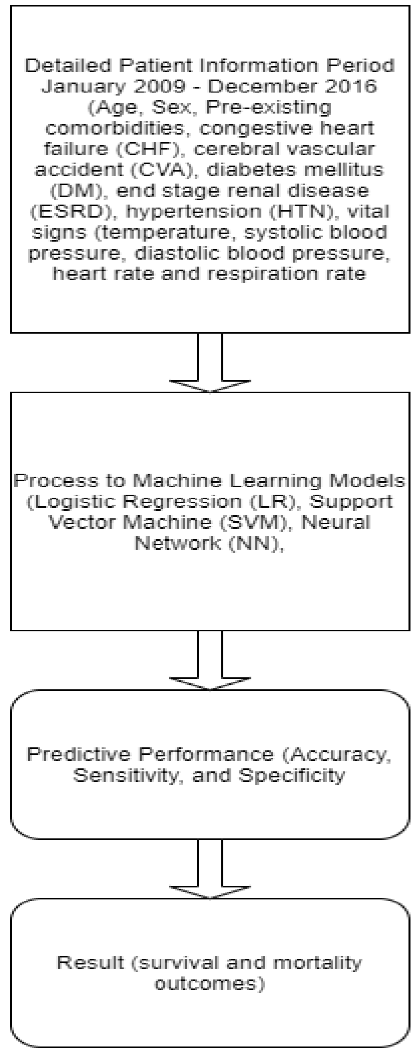

Fig. 2 Machine learning approach to predict survival in the trauma patient

In 1990, the American College of Surgeons' Major Trauma Outcome Study (MTOS) (Rau et al., 2019) used TRISS to review trauma patients' results concisely. Several variables such as Injury Severity Score (ISS), Revise Trauma Score (RTS), and another coefficient for penetrating and blunt injuries is utilized as an input for the model. For more than 30 years, the TRISS model has been the best model for survival prediction and attempts to replace it have failed (Rau et al., 2019). The TRISS model generates various results dramatically on trauma patient records (De Jongh et al., 2010). So, it is questionable whether their models can analyze complex biological systems since the TRISS still has limitations in terms of overfitting and multicollinearity from the regression analysis to many explanatory variables (Rau et al., 2019).

2.3. Coefficient Analysis of Trauma and Injury Severity Score

Trauma and Injury Severity Score (TRISS) estimates the survival rate post-trauma (Kang et al., 2019). Many studies have been conducted in different countries to gain the characteristic of variables, the TRISS model's validity, and categorization (Kang et al., 2019). A study in Korea mentioned that the TRISS model was never studied. Meanwhile, TRISS is incompatible with Korea's consequent injury mechanism and mortality (Kang et al., 2019). **(Figure 3)** shown the process of inclusion and exclusion criteria based on proposed work.

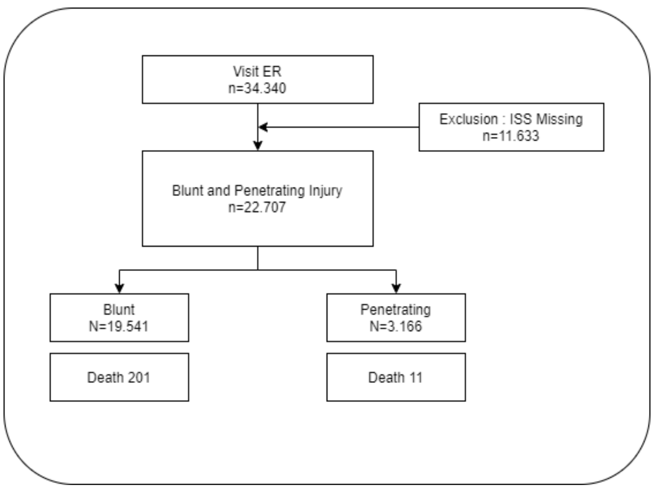

Fig. 3 Inclusion and exclusion criteria process

The study examined how the existing TRISS coefficient was created and developed for trauma patients in the department of emergency in a Korean hospital. An analytical method has been selected for a sum of 34.340 trauma patients admitted to emergency rooms between January 2012 and December 2014, spinning three years of analysis. The result stated that TRISS coefficients were transformed by building a logistic regression analysis model using variables such as RTS, ISS, and age depending on survival with TRISS (Kang et al., 2019).

2.4. Decision Analysis of Multi-Criteria Using Analytical Hierarchy Process (AHP)

Decision analysis is a method purposed to provide decision-making to help the user generate a decision once the data collection and analysis has been done. The study emphasized the importance of diagnosing the most serious injuries. One contribution to this study is a concept for a structured decision analysis technique that uses expert-based rules for picking several criteria (Salah et al., 2017).

Analytical Hierarchy Process (AHP) is a decision-making process that will analyses and structures complicated multi-factor or multi-criteria problem into mathematical hierarchies (Salah et al., 2017) (Keren and Hadad, 2016). The target is at the top of the values hierarchy, followed by the sub-criteria, level factor, down to the bottom. A complicated problem may be divided into groups of groups, which can be structured into a hierarchy that appears more systematic and structured using a hierarchy.

2.5. Severity Prediction Using Genetic Algorithm (GA)

Theoretical computers were associated with the vast tasks assigned as the complexity that usually test relevant computing sources such as space of completion and time. The development of algorithmic may help to assist in increasing efficiency (Ayon, 2019). It will turn complicated tasks into clear classes with specified time and limited space. The real challenge happens when it is related to a strong mathematical analysis of a large data set that becomes so complex while the optimal solution is not defined. The heuristic algorithm's purpose is associated with quality problems where all examples of problems look for the best solution to finding the feature selection (Zeng et al., 2012).

GA has been used in many kinds of applications in various industries (Saleh, 2018). Implementation of GA can be adapted in injury caused by the accident prediction to define the severity of the injury. The disadvantages of NN can be overcome by using the genetic algorithm to identify and optimize the multi-objective features and tune the feature parameter selection (Hashmienejad and Hasheminejad, 2017).

2.6. Discussion on Analysis of Techniques in Determining Degree of Injury

Choosing an alternative solution for determining injury degree is difficult and complex in terms of making the decision. Practitioners must define the difference between each parameter and the features used. Therefore, the Degree of Injury Determination could be a combinatorial problem. When considering decision-making factors, it should be realized that in all persecution cases, the expert is the decision maker of the medical record. Analysis of recent technique was concluded based on the outlier, incomplete data, irrelevant features attribute, and selection for the critical feature. The gap between the current approach can be seen in Table 1.

Table 1. Existing approaches to determine the degree of injury

*	Technique / Model(s) / Tool(s)	Contribution	Advantage(s)	Disadvantage(s)	Result(s)
1	Trauma and Injury Severity Score Coefficient Model (Kang et al., 2019)	Finding the new coefficients related to the trauma outcome from the patients in Korea using the analytical method	TRISS seems to have the potential to understand the importance of survival rate by deriving coefficients data from Korean Patients	The indicator of the injury severity needs to be developed based on the dynamic understanding of the post-treatment data and quality management of the pre	New coefficients derived from the patients can be used as the input for formulation to calculate the Korean Trauma Patient
2	Machine Learning Models of Survival Prediction in Trauma Patients, (Rau et al., 2019)	Four models of machine learning to revise the TRISS performance	For LR models like TRISS, more predictive factors may increase the validity of performance	The examination of several explanatory variables may be hampered by overfitting and multicollinearity in regression analysis	TRISS and Neural Network presented the highest score for the balanced accuracy
3	Comparing ANNs and logistic regression for predicting trauma survival. (Hassanipour et al., 2019)	ANN and Logistic can use to predict the injury.	Easy to control the prediction variable and output.	Need to add another variable (age) Add variable (sex) Compare the result with the data mining technique.	ANN and Logistic can use to predict the injury.
4	International Classification Injury Severity Score (ICISS), (Allen et al., 2016)	Indexed mortality risk improvement	All the scoring systems showed strong predictive with the high level of the area under the receiver-operator curve (AUROC) values	The trauma treatment method and the system cannot rescue all types of injured patients, and death does not represent the effects on quality of life. and damage to disability	ICISS was lower than the current injury scoring tools at predicting mortality
5	Severity prediction using a novel multi-objective genetic algorithm (Hashmienejad and Hasheminejad, 2017).	Optimization severity prediction	The flexibility of prediction using user's preferences instead of the conventional technique	The fundamental problem of SVMs and ANNs for humans is their lack of interpretation, while the main drawback of conventional DTs like CART, ID3, and C4.5 is very low accuracy	According to all Comprehensibility, Confidence, and Support metrics, it outperforms other rule-based classification algorithms such as CART, ID3, and C4.5 in the rule detection process

3. Preliminaries Methods

3.1. Proposed Design 1: Weighted Critical Feature of Injury Determination Model (WCFI)

3.1.1. Understanding the process, identifying the problem

A case study is conducted in three hospitals in Pekanbaru, Indonesia, involving private and public hospitals. The private hospital is a specialist hospital that includes the forensic discipline to examine life-or-death patients from persecution cases. The general hospital also serves the patient by using a specialist expert there. The case study explored the flow of business procedures, processes, problems, and applications developed in the organization.

3.1.2. Analyze missing values and data

In this phase, related information is carried out to understand the research field and its requirement to solve the limitations. It leads to the study of the outcome that fulfills these requirements. The analysis begins by examining the definition of Injury Types, Cause of Injury, the concept of Injury Classifications, characteristics of injury, differentiation, advantages, and disadvantages. AI technique has opted for this study. The preliminary study's outcome illustrated the determination model's promising success, which offers many advantages.

3.1.3. Critical feature development

This step is used to selection of the justification technique on how to select the suitable component or features for enhancement Degree of Injury Determination model. The component will be assigned consist of critical features selection and classification algorithm. The first will be analyzed the technique for feature selection using decision theory and classification. The feature of injury degree was developed in this research for the data pre-processing using AHP and Regression techniques. To produce a better result, AHP Model recommended the weight and ranking for each feature used by the next model phase. The Regression technique is also used to discover the value of consistency based on the result of the AHP Model.

3.1.4. Analytical Hierarchy Process (AHP)

Decision theory was proposed in this research. Analytical Hierarchy Process (AHP) was chosen because it has become a beneficial tool for controlling decisions; the analysis focuses on deciding and aims to provide insight into the decision-making process. AHP assists in the analysis of the decision-making context, the organization of the process, enhancing coherence also on objectives and conclusion, and decision-maker cooperation, resulting in improved mutual understanding. The procedure is shown in **(**Fig. 4**)**.

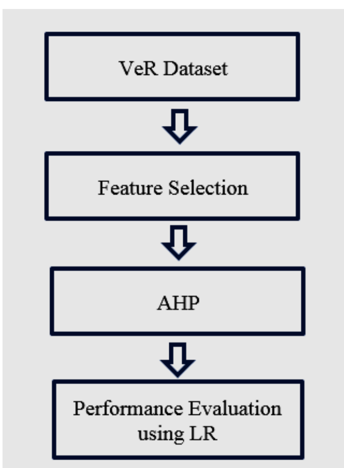

Fig. 4 The critical feature selection procedure

Based on Figure 4, decision-making is broken down into the following steps, utilizing the priorities generated from the items at one level to balance the priority of the factors at the next level. The advantage of applying the concept of AHP is to gain weight from the different sides of thinking based on the experts' perspectives. AHP utilized the experts' opinions since each feature has so many opinions. The value of features relies on the range of the defined values.

Develop ranking of critical features, understanding process, identify the problem

Developed ranking of the critical feature will be visualized representation where most of the measurements critical features. Questionnaires and interviews will do it to all subject matter experts in the private, public hospital, and industrial workers. The importance of accurate data for classification modelling using the critical features is recognized.

Weight consistency body region, analyze missing value and data

The characteristic of the component will be done with the AHP method. These characteristics can be presented via the pairwise comparison of the body region. According to the research, numerous bodily regions exist, including the neck, head, abdomen, chest, external extremities, and face. The first aspect of implementing the AHP technique to determine the weight of the criteria for assessing the degree of damage is to compare the factors on a scale of 1 to 9.

Weight consistency is another feature critical feature of the development

The kind of injury was divided into two categories: Blunt (BL) injury and Penetrating (PE) injury, and the source of damage was also divided into many categories. Chop Wound (CW), Incised Wound (IW), and Penetrating Incised Wound (PIW) are all examples of Types of Penetrating injury (TPW). Bleeding (B), Fracture (F), Contusion (CO), and Abrasion (AB) are examples of Types of Blunt (TBW). In addition, the AHP evaluates several criteria and indicators, which are Respiration Rate (RR), Systolic Blood Pressure (SBP), Glasgow Coma Scale (GCS), Age (A), and Sex (S). All these features will be calculated using AHP through a scoring system based on the critical level.

The goodness of fit test (chi-square)

Statistical goodness-of-fit tests were used to validate the fit to the hypothesized primary distributions. Several statistical tools can assist in determining whether a distribution model is a proper choice from a statistical perspective, which are often based on the type of criteria and data points. The test consists of $\chi 2$ (chi-square); it is also significant to ensure that the time axis chosen is relevant to the problem; otherwise, misleading results can be generated.
There are three main tasks to be completed in this phase. Identifying the degree of injury characteristics and terms, designing a method for proposing combination critical feature selection, and proposing a method to develop an optimized degree of trauma injury classification model.

3.2. Proposed Design 2: Intelligent Injury Determination model (IID)

This section discusses the classification algorithm used to classify injury degrees and can apply the critical features from the previous model as the input. The classification algorithm will analyze for the best performance and RMSE when determining the injury classification based on the critical features as an input. The suitable classification algorithm will produce the Intelligent Injury Determination model (IID), which has dominant accuracy compared to all classification algorithms. The procedure will compare the performance of classification algorithms that selected 5 (five) algorithms such as Artificial Neural Network, Decision Tree, K-Nearest Neighbor, Naïve Bayes, and Random Forest. **(Figure 5)** shown the procedure of IID.

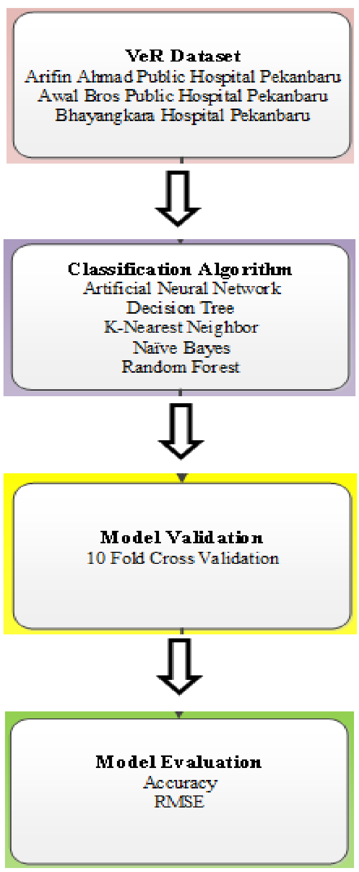

Fig. 5 Intelligent Injury Determination model (IID) procedure

The classification model is made by validating the training data with testing data from 3 different hospitals in Pekanbaru. The classification algorithm has been compared to discover the best accuracy in different datasets to choose the suitable critical features. The classification algorithm used NN, DT, K-NN, NB, and Random Forest. The data type was set to Boolean, integer, binomial, and polynomial for two or three outputs. Missing data were removed by applying missing data analysis and removing noisy data. Below will describe the process of model establishment.

3.2.1. Establish IID

Classification algorithms in machine learning can be used to diagnose disease. It is expected to enhance the WCFI model Classification algorithm and may improve the quality of the system in healthcare (Bolón-Canedo et al., 2013). To compare the suitable classification algorithm, accuracy is one of the components to be considered. The classification technique used in this research is K-Nearest Neighbor, Support Vector Machine, Naïve Bayes, and Neural Network Decision Tree. The validating process will be splitting data into train and test. Then 10-fold cross-validation was employed on the same datasets for the selected algorithm.

3.2.2. Establish parameter

An open-source data mining tool analyzes and models Degree of Injury Determination. SPSS is a statistical tool with various functions to enhance data analysis and statistical needs. The parameters were adjusted in Table 2 below to achieve the persistent accuracy of the classification model.

Table 2. Parameter Setup

Section	Method	Item	Detail
Classifier	K-NN	K	5
		Measure Type	Mixed Measure
		Mixed Measure	Mixed Euclidean Distance
	NB	Laplace Correction	
	SVM	Kernel	dot
		C	0
		Cache	200
		Epsilon	0.001
	Backprop (NN)	Training cycles	800
		Learning rate	0.2
		Momentum	0.4
		Hidden layer	1
		Epoch	1.00E-04
	Decision Tree	Maximal depth	10
		Confidence	0.1
		Minimal gain	0.01
		Minimal leaf size	2
		Minimal size for split	4

Table II shows the data will be split into two parts: training and testing. The total sample from three hospitals is 289 data. The training and testing process will utilize the data from the total sample used randomly for training data in the development phase. At the same time, the rest will be employed for testing data randomly. This scheme is mentioned as 10 folds cross-validation, a common classification method (Sanz et al., 2017). 10-times cross-validation divides the dataset into ten equal-sized folds, or VeR is divided into ten groups.

3.3. Proposed Design 3: Optimize the Injury Determination model (OID)

Artificial Intelligence (AI) is a powerful tool by many researchers, especially when combined with optimization techniques to cope with such problems. Indeed, there has been comprehensive attention to the applications of AI in healthcare, as experienced by many areas of study. This research uses the Genetic Algorithm technique to gain optimal performance. AI and Optimization techniques depend on case studies to get better accuracy and minimum error.

3.3.1. Optimized – Genetic Algorithm (GA)

GA is most applicable in many optimization problems as this method tackles problems in nature. In addition, this algorithm is the potential to well adapted and find a replacement to the problem using numerical to find the optimum accuracy. GA is used to improve the feature selection weight criteria. The weight from the NN algorithm is successfully created and still needs improvement. GA significantly can result in better performance compared with another classification technique.

3.3.2. Determine optimum accuracy

The determination degree of injury model reveals that the prediction is not flat. It is around optimal and increases quickly just on the side. In all instances, the ideal interval should be observed. If the value of a variable required in the analysis is uncertain, the overall accuracy for different values of the uncertain characteristic may impact the solution.

The curve can show the overall cost around the optimal value and the value of t. The objective is to create a model that correlates with prediction accuracy. The method by which models were created to determine the best accuracy gain from the suggested AI technique.

In developing a determination model, this research uses medicolegal forensics as a case of determination injury degree. The description of model development and the nature of the dataset are shown in Table 3.

Table 3. Element of model development

Element	Information
Input	Visum et Repertum (VeR) dataset
Method	A Hybrid Neural Network Model to determine the degree of injury using AHP+NN+GA (HNNM)
Output	The enhanced degree of injury determination model
Dataset Name	VeR (Private Data)
Source	Private and Public Hospital
Data type	Real dataset from a forensic lab and hospital report (name and location of the hospital are classified)
Number of Original Attributes	16 attributes
Variable's type	Numerical and categorical
Data collection method	The General Doctors and Forensic experts generated the VeR report. Ranking analyses were collected through surveys and interviews among the practitioners

The proposed model is expected to improve the medicolegal forensic operation, which is continuously done by practitioners that consist of General doctors and Forensic experts. These subjects work to generate the report, which can be used as legal evidence in court if a criminal case happens. The output will be the examination status of the victims or the patient from the criminal case.

3.4. Performance Evaluation

The system's performance is evaluated using the performance parameter, which includes accuracy, classification error, and AUC. Classification accuracy measures performance results with the formula:

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN} \tag{1}$$

4. Result and Discussion

The development process of the proposed model was explained. This section explains the assessment of the proposed model, namely, the Hybrid Neural Network Model (HNNM). The evaluation was conducted on an experimental approach compared to another performance technique. This purpose ensures the proposed model provides accurate results on all Visum et Repertum (VeR) data sources from three hospitals. This research proposes comparing the proposed technique with various classification methods for the degree of injury determination. The benchmark was created using the NN algorithm and compared with another technique, as shown in Table 4.

Table 4. Performance comparison among classification techniques

Algorithm	Accuracy	Classification Error	Kappa	Absolute Error	Root Mean Square Error
NN	90.77%	9.23%	0.568	0.100	0.275
DT	86.54%	13.46%	0.503	0.145	0.345
KNN	85.77%	14.23%	0.314	0.158	0.344
Random Forest	89.62%	10.38%	0.493	0.157	0.272
Proposed Model	**98.85%**	**1.15%**	**0.957**	**0.022**	**0.077**
DT+GA	93.46%	6.54%	0.759	0.087	0.233
KNN+GA	94.62%	5.38%	0.791	0.083	0.227
RF+GA	91.92%	8.08%	0.654	0.152	0.284

Table 4 showed that the NN produced an accuracy of 90.77%, followed by random forest, Decision Tree + Genetic Algorithm (DT+GA), and K-Nearest Neighbor + Genetic Algorithm (KNN+GA). To enhance the performance of NN, the proposed model successfully improves the accuracy rate and minimizes the classification error by employing the proposed design (WCFI, IID, OID), known as the Hybrid Neural Network Model (HNNM). As for the missing data analysis, missing data were removed from the VeR dataset. Other than the missing data analysis, HNNM also removes noisy data. Unnecessary space characters or other misspellings were also cleaned in the dataset. The classification algorithms were selected from the state-of-the-art research on predicting trauma survival or probability of survival which can be related to the determined degree of injury.

5. Conclusion

These new proposed features consist of Systolic Blood Pressure, Respiration rate, Sex, Age, Shot Injury, Contusion injury in the head, face, abdomen, and extremities, abrasion injury in the head, face, abdomen, extremities, and external, laceration injury in the head, face, and penetrating incised wound in external which fulfill the combination of the definition of injury based on Indonesian Penal Code, degree of injury based on the expert's opinion that has been ranked. Based on the result, it is proven that the users, particularly general practitioners and forensic experts, need further information by referring to more features to assist them in identifying and defining the real practice. The conventional determination problem of injury degree does not yet explicitly include the capacity to evaluate the performance of predefined goals. It is difficult to adapt due to a lack of study, especially on a large injury scale.

The WCFI Model can analyze problems more precisely with improved techniques in the intelligent injury determination model (IID) and Optimize Injury Model (OID). This will improve the accuracy and reduce the error rate when identifying the degree of injury consistency determination process. HNNM had exceeded the handle of finding the characteristics, terms, missing values, removing noisy class, and irrelevant attributes.

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