

Chapter 5

Living Safety Testbed Group



Koji Kitamura and Yoshifumi Nishida

Abstract Safety technology for everyday activities is strongly needed for children, the elderly, and persons with disabilities. However, it is difficult to understand problems related to everyday life from injury data, medical data, and so on because such data are distributed over multiple organizations and cannot easily be shared or integrated due to privacy protection concerns. To address this issue, our project is developing technologies for integrating and utilizing multi-organizational distributed big data based on security technology. The authors research school safety based on the developed technologies. In this chapter, the authors describe a trend analysis technology for time series injury data, a cliff analysis technology for extracting serious injury situation, and child behavior prediction technology as the necessary functions for finding and predicting serious injuries and evaluating the effectiveness of an intervention. We also present some analysis examples using the developed function. Furthermore, we describe some social implementation projects for injury prevention for the serious injuries found by analyzing injury data using our developed system.

5.1 Necessity of Living Safety

Community safety is highly desirable for children, the elderly, persons with disabilities, and others with special needs for functional support in daily life. People with variances in the functions of daily life experience insufficiencies in bodily or cognitive function under conditions or environments that had previously been problem-free. Risk arises at certain times, and maintenance of their safety through their own care or the care of people around them is thereafter difficult. It is accordingly important

K. Kitamura (✉)

National Institute of Advanced Industrial Science and Technology, 2-4-7, Aomi, Koto, Tokyo
135-0064, Japan
e-mail: k.kitamura@aist.go.jp

Y. Nishida

Tokyo Institute of Technology, 2-12-1 Ookayama, Meguro-ku, Tokyo 152-8550, Japan
e-mail: nishida.y.af@m.titech.ac.jp

© The Author(s) 2020

A. Miyaji and T. Mimoto (eds.), *Security Infrastructure Technology
for Integrated Utilization of Big Data*,
https://doi.org/10.1007/978-981-15-3654-0_5

to seek out data that will serve as a basis for identification of states of risk and related conditions, implement effective corrective measures, and verify the results.

In the realm of community safety, historical data on the past accidents and therapies commonly exist in a state of dispersion among many different organizations, and it is therefore difficult to determine the total number of accidents that have occurred and gain an overall perspective extending from cause of accident to resulting injury. If relevant data held at many different organizations can be integrated and utilized, this may then lead to problem identification and effective solution based on the data.

In actuality, sharing and integration of data across institutions is difficult because of the need to protect information on individuals, maintain privacy, prevent information leakage, and other needs. So long as non-engagement in active sharing and integration of such data remains blameless, it will tend to discourage advancement of community safety. In this light, we are now engaged in advancing the development of technology for utilization and application of multi-organizational dispersed data using security-based technology, in a Japan Science and Technology Agency (JST) CREST (systemization of the security base technology for expediting/accelerating of/for big data integration and utilization) project. The research group of the authors is working in collaboration with data-holding medical/therapy organizations and with product design and other data-user sites to develop technology for effective utilization of organizationally dispersed data. To date, in collaboration with Fire and Disaster Management Agency, Japan Sport Council, multiple medical institutions, nursery, elementary, and junior high schools, and other entities, we have advanced the development of technology for integration and utilization of dispersed injury-related data.

With school safety as a specific field of application, we are engaged in proof of concept and system by demonstration. So far, we have compiled medical cost and other KPI-bearing big data from accident data dispersed in multiple elementary schools, performed presumed integration without specifying the schools, and conceived and developed a serious injury accident analysis system using the multi-party private set intersection (PSI) protocol privacy-preserving information-sharing technique and severity cliff analysis technology, for analysis of the main accidents causing severe injury, and verified the system effectiveness by applying it to actual data. With this system, the analyst identifies the task to be performed at the school site and presumably has it applied as a preventive measure.

In the present report, we describe the on-site use of the proposed system for task identification focused on temporal changes that becomes necessary and function expansion and application to actual data in intervention results evaluation. We also report on actual utilization of the system and on identified tasks as we engaged in acquisition and analysis of fine data necessary for injury prevention.

5.2 Overview of Test Bed System for Living Safety

For problem identification and solution, a system of privacy preservation is necessary to permit sharing and integration of data held by multiple organizations. It also requires an analytical method of obtaining useful information from the shared and integrated data. One method for this purpose is embodied in the JST CREST (systemization of the security base technology for expediting/accelerating of/for big data integration and utilization) project in which the authors participate, have developed the dataset (PSI: private set intersection) computation technology that preserves privacy, and have proposed a system including the severity cliff analysis technology.

PSI technology enables extraction of intersections in relation to specified data items left uncoded and held by multiple organizations. With its utilization, accident information meeting conditions specified by the user can be provided to the user in an integrated state while leaving concealed the identity of the school where the accident occurred.

The severity cliff analysis technology provides a means of analyzing the cause of severe injury accidents by seeing medical cost as severity. It enables analysis of the severity of accidents occurring in similar circumstances, location of the point of departure between cases of high and low severity, and differences between accidents with severe and slight injury, thus enabling causal analysis of accidents involving severe injury.

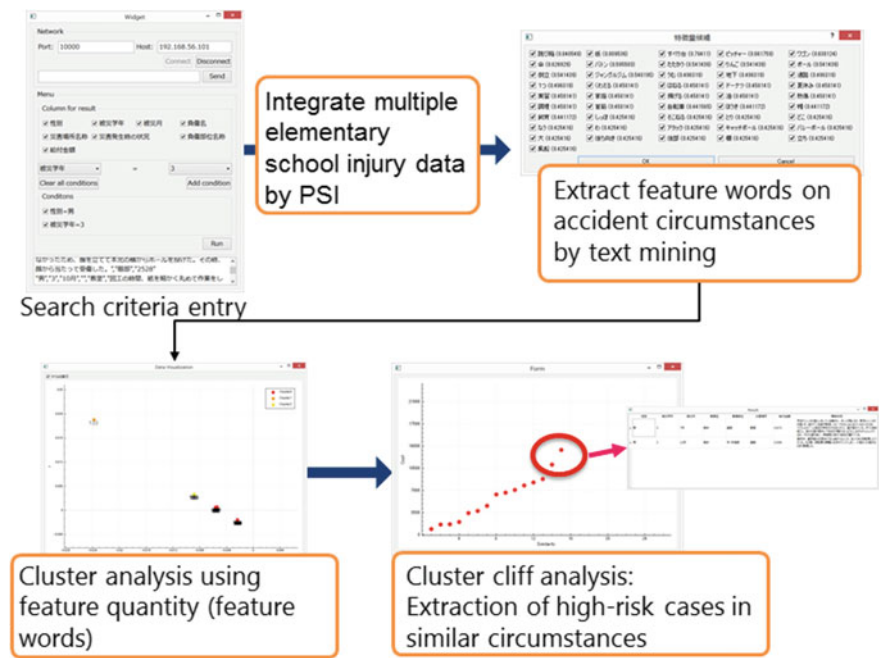


Fig. 5.1 System for sharing and analyzing life-safety-related data with secure function

In combination, these two technologies can be used to integrate information on accidents in multiple school environments while preserving privacy, identify severe injury accidents from the integrated accident data, and analyze their causes. More specifically, we have conceived and developed a system as shown in Fig. 5.1. Accident-related information (e.g., grade, sex, and accident and injury categories) desired by the user is entered and criteria-meeting injury data from multiple schools are acquired and integrated. Severity cliff analysis is then applied to the accident circumstances described by textual data accompanying the acquired injury data, thus enabling determination of the severe injury accidents for the specified accident circumstances and analysis of the cause.

5.3 Severity Cliff Analysis of School Injury

5.3.1 Development of Severity Cliff Analysis System

5.3.1.1 System Overview

As shown schematically in Fig. 5.2, the developed severity cliff analysis system comprises four functions: accident circumstance registration, similar accident circumstance search, severe injury accident search, and severity cliff analysis. These functions are described in detail in the following corresponding subsections.

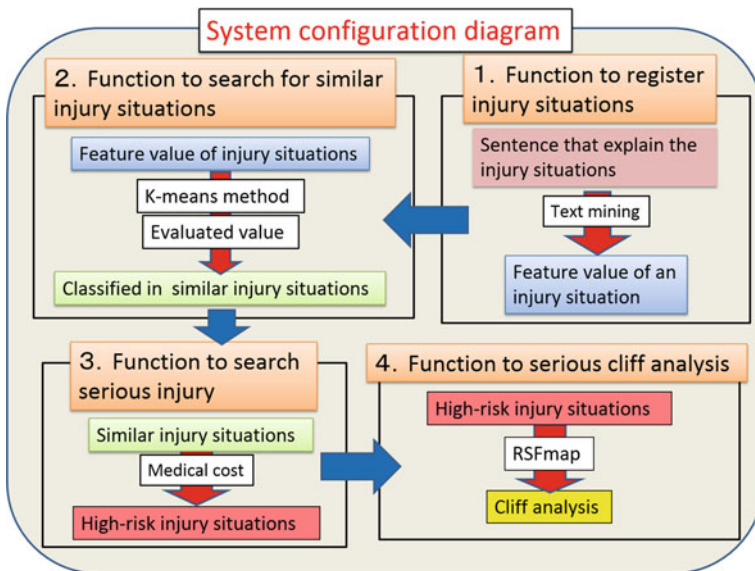


Fig. 5.2 System configuration for cliff analysis

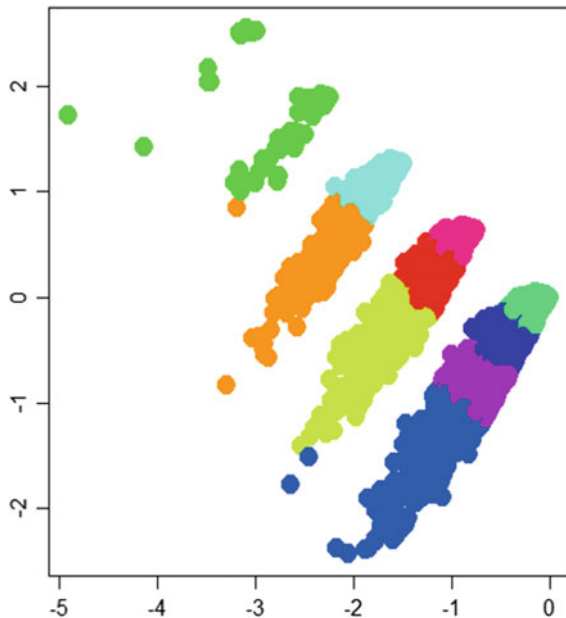
5.3.1.2 Accident Circumstance Registration

The accident circumstance registration function assigns the accident circumstance feature values to the accident circumstances present in the accident database. The accident database is first subjected to morphological analysis of text representing accident circumstances in order to extract the nouns and verbs. In this analysis, the Japanese concept dictionary (Japanese WordNet) is used to consolidate the noun and verb orthographic variants. Important words are next extracted with TF-IDF weighting of each. In the present study, words with high TF-IDF values were selected as representing accident circumstance feature values. These accident circumstance feature values are assigned to the accident samples in order to construct the accident database with assigned feature values.

5.3.1.3 Similar Accident Circumstance Search

With this second function, the accident circumstances registered by the first function for their assigned feature values are sorted into similar accident circumstance groups. Clustering is performed using the Euclidean distance of the accident circumstance feature value vectors assigned in the accident database. The optimum cluster number is determined with the gap statistic value resulting from the cluster number assessment. Figure 5.3 shows the results of sorting the accident database into similar accident circumstances.

Fig. 5.3 Clustering of injury cases



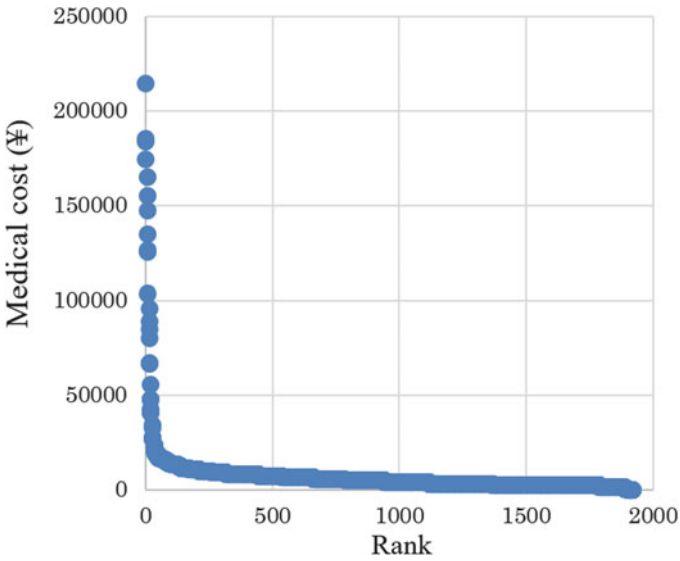


Fig. 5.4 Example of severe injury analysis of injuries occurring under similar situations

5.3.1.4 Severe Injury Accident Search

The medical costs included in the accident database were used to identify severe injury accidents, with medical cost presumed high for severe injury accidents. Figure 5.4 shows medical cost in decreasing order for injuries occurring under similar circumstances. As shown, medical cost may differ substantially even for accidents occurring in similar circumstances, and cliffs marked by specific changes may exist. This indicates that severe injury accidents can be identified by focusing on specific differences in medical cost.

5.3.1.5 Severity Cliff Analysis

Figure 5.5 shows the relation between degree of circumstance similarity and medical cost in similar states of accident, where the degree of circumstance similarity is the degree of cosine similarity in comparison with the highest medical cost accident cases (severe injury accident cases). Figure 5.6 shows the three-dimensional graph obtained on addition of frequency to the graph. Similarity 1.0 denotes the highest similarity. With these graphs, comparison of severe injury and slight injury accidents under similar circumstances enables performance of severity cliff analysis focused on the difference between severe injury and slight injury accidents.

Fig. 5.5 Relationship between similarity and cost

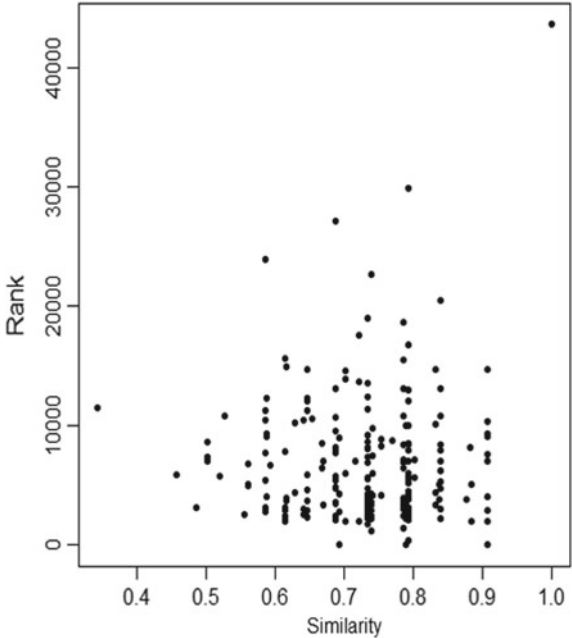
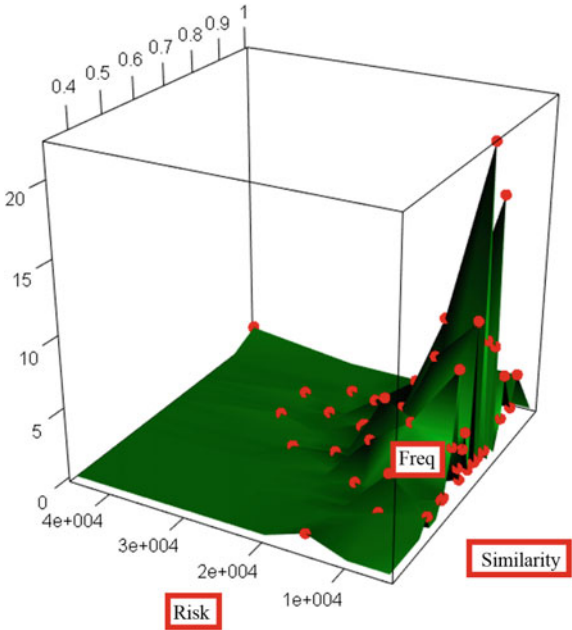


Fig. 5.6 Relationships among similarity, risk, and frequency



5.3.2 Severity Cliff Analysis

To test the effectiveness of the developed method when applied to investigating the causes of actual severe injury accidents, we used the accident data of 19,948 cases from the Injury and Accident Mutual Aid Benefit System for multiple junior high schools gathered by the Japan Sport Council.

We performed the cliff analysis for similar accident circumstances with the relation shown between similarity degree and medical cost as shown in Fig. 5.7. Figure 5.8 shows the graph of Fig. 5.7 with frequency added.

The severe injury accidents in the similarity range of 1.0–0.6 in Fig. 5.8 were as follows:

- Strongly impacted and injured right shoulder in fall on contact with opponent during soccer match. (first-year junior high school, bone fracture, ¥174,504)
- In competing for ball with opponent, on contact with that opponent fell from the left side, impacting with the ground and injuring the left clavicle. (third-year junior high school, bone fracture, ¥154,475)
- In competing for the ball with an opponent, encountered strong contact and fell over from the right shoulder, thereby strongly impacting the right shoulder on the ground and fracturing the right clavicle. (3rd year junior high school, ¥147,297)

In the same similarity range, the slight injury accidents were as follows:

Fig. 5.7 Relationship between similarity and cost

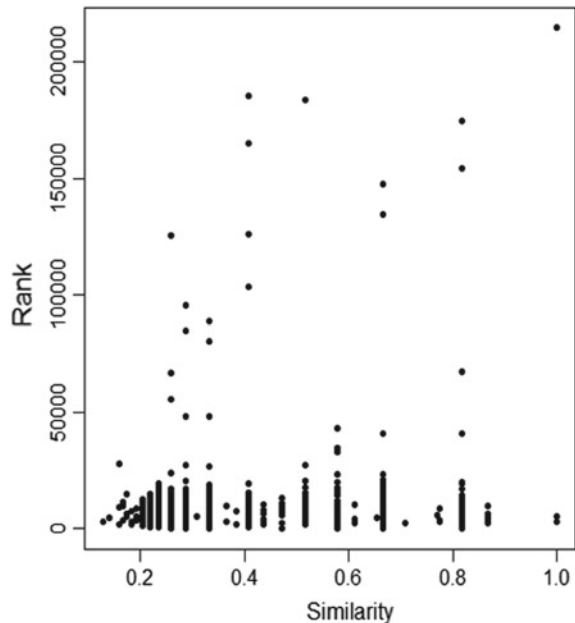
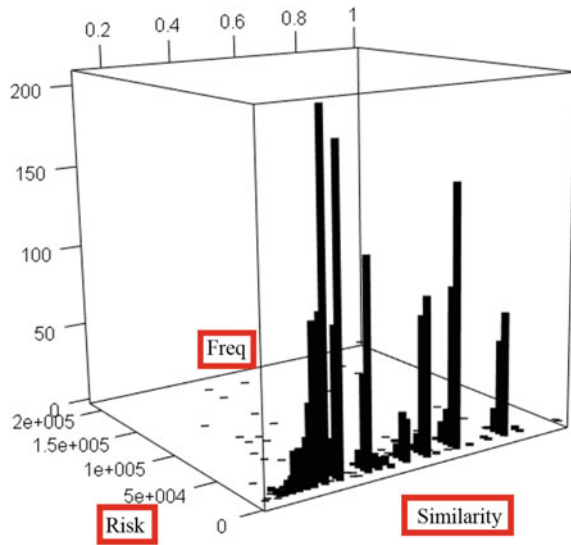


Fig. 5.8 Relationships among similarity, risk, and frequency



- At afternoon homeroom starting time, in carrying a bag from a locker and returning to a seat, the student tripped over the extended leg of a nearby student and fell, impacting his/her jaw on the leg of a desk and injuring a finger on the left hand. (second-year junior high school, contusion/bruise, ¥3,452)
- In recess from third class hour, while walking and conversing with a friend, tripped and fell at entrance to classroom with hands in pockets and therefore impacting jaw on floor. (second-year junior high school, dislocation, ¥3,152)
- In noon recess, while walking in a corridor, tripped on a friend's leg and fell, impacting right eye on wall. (first-year junior high school, contusion/bruise, ¥2,984)
- In classroom before start of class, collided with a friend and fell, impacting face on floor. (first-year junior high school, bone fracture, ¥2,476)
- While cleaning, engaged in shoving match with friend and fell with left elbow impacting floor. (third-year junior high school, contusion/bruise, ¥2,256)

In summary, it was found that severe injury accidents occurred in a soccer match in contacting an opponent and falling, in competing with an opponent for the ball and contacting the opponent and falling, and in competing for the ball with an opponent and encountering strong contact and falling over and thus, all during soccer matches in contact with an opponent and falling, whereas slight injuries occurred in tripping over someone's leg and falling, tripping and falling at an entrance, tripping on a friend's leg and falling, colliding with a friend and falling, and engaging in a shoving match and falling and thus were all in tripping on or colliding with something or someone and falling. Taken together, the results show that among similar instances in a circumstance of tripping and falling, severe injuries more readily occur in colliding with an opponent and falling in a soccer match.

Fig. 5.9 Relationship between similarity and cost

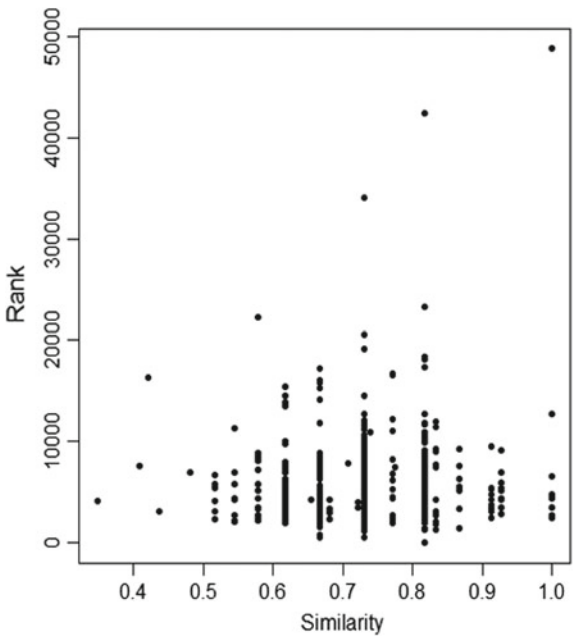
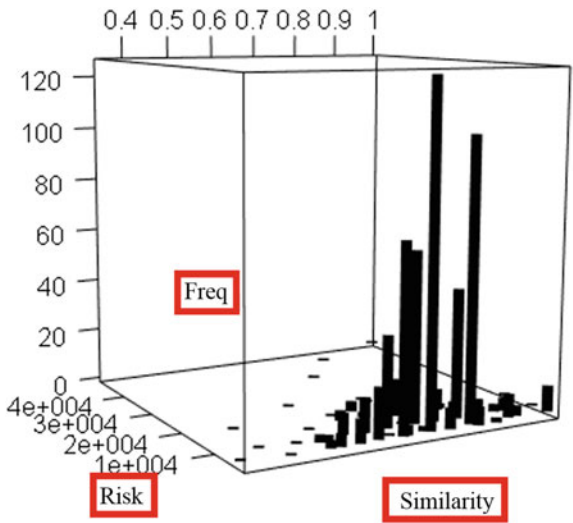


Fig. 5.10 Relationships among similarity, risk, and frequency



Let us next consider the severe injury accidents in the similarity range of 1.0–0.7 in the clusters shown in Figs. 5.9 and 5.10, which were as follows.

- In a “soft tennis” club morning practice session, a ball came flying unseen and unevaded, directly striking a student in the right eye. (first-year junior high school, contusion/bruise, ¥48,740)

- In a “soft tennis” club morning practice session, while throwing ball on the tennis court for a two-step hit, a student was struck in the left eye by a ball hit by an opponent, suffering a bruised left eyeball, left retinal tear, and left eye conjunctivitis. (first-year junior high school, contusion/bruise, ¥42,416)
- In a softball club activity, a student playing catch with a third-year student on the school ground was struck in the face by the ball after losing sight of it and having it hit his/her own glove. (second-year junior high school, bone fracture, ¥18,112)

In the same similarity range, the slight injuries were as follows:

- While a student was playing handball in a physical education class on the school-yard in the fourth school period, during the match, the ball came flying toward the student, who tried to catch it but mistakenly was struck by the ball on the ring finger of the left hand. (second-year junior high school, bone fracture, ¥6,304)
- In a volleyball activity, when boys and girls were practicing hitting serves over the net, the ball hit by a boy struck a student on the left thumb, breaking a bone. (second-year junior high school, bone fracture, ¥4,484)
- During a volleyball club tournament in a seaside region, in a practice serve at a gymnasium before a match, a hit ball from the opposite side of the court struck and injured the right hand of the student. (third-year junior high school, contusion/bruise, ¥3,492)
- During dribbling practice in a club activity at a gymnasium, a ball bounced off the leg of a club member and struck the right hand and sprained the thumb of the student. (second-year junior high school, sprain, ¥2,164)
- During bunting practice of the baseball club after class, in a bunting attempt, the bat was mispositioned and the ball struck the thumb of the right hand. (third-year junior high school, sprain, ¥2,032)

Concerning these severe and slight injury accidents, in summary, it was found that the severe injury accidents involved a tennis ball that came flying and struck the right eye, a tennis ball hit by an opponent that struck the eye, and softball a ball striking the eye, and thus, all involving an eye being struck by a ball, whereas that the slight injury accidents involved a handball striking a finger, a hit volleyball striking a thumb, a basketball striking the right hand, and a baseball striking the right thumb, and thus, all involving a ball striking a hand or leg. These findings clearly show that, for accident circumstances in which a ball similarly strikes the body, those in which the ball strikes an eye tend to result in severe injury. This in turn indicates the existence of certain parts of the body and types of sports for which injuries tend to be serious and for which a preventive measure such as an eye protector is seldom implemented but necessary.

5.4 Trend Analysis of School Injury

5.4.1 Trend Analysis for Evaluating Intervention

Annual trends can provide an effective perspective in the search for problems that need to be solved. Examples include accidents that have sharply increased in recent years and cases that have been large in number with no change over many years, which may represent problems requiring consideration of preventive measures. It is also important to focus on annual trends when assessing the effects of measures or interventions. In this light, we have developed a trend analysis function that can be integrated and applied in combination with the previously developed severe injury accident analysis system. It has thus become possible to analyze changes in trends focused on circumstances and on verbal words characteristic of accident occurrence.

5.4.2 Analysis of Judo Accident

We have applied this trend analysis function to analyze data on 60,300 senior high school cases among 152,695 cases of judo-related injury included in the Injury and

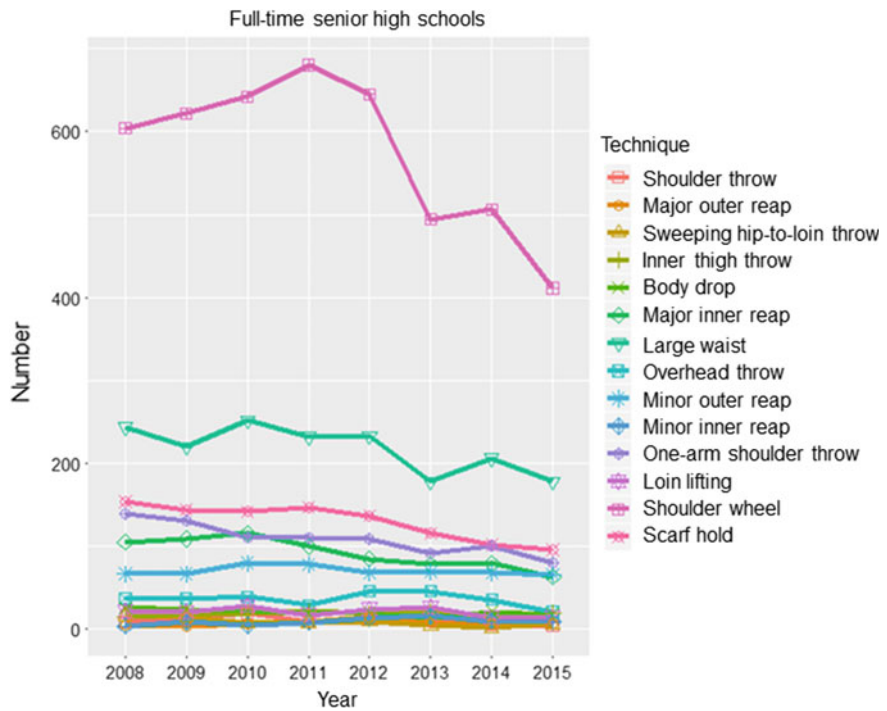


Fig. 5.11 Analysis of judo accident trends relative to judo techniques

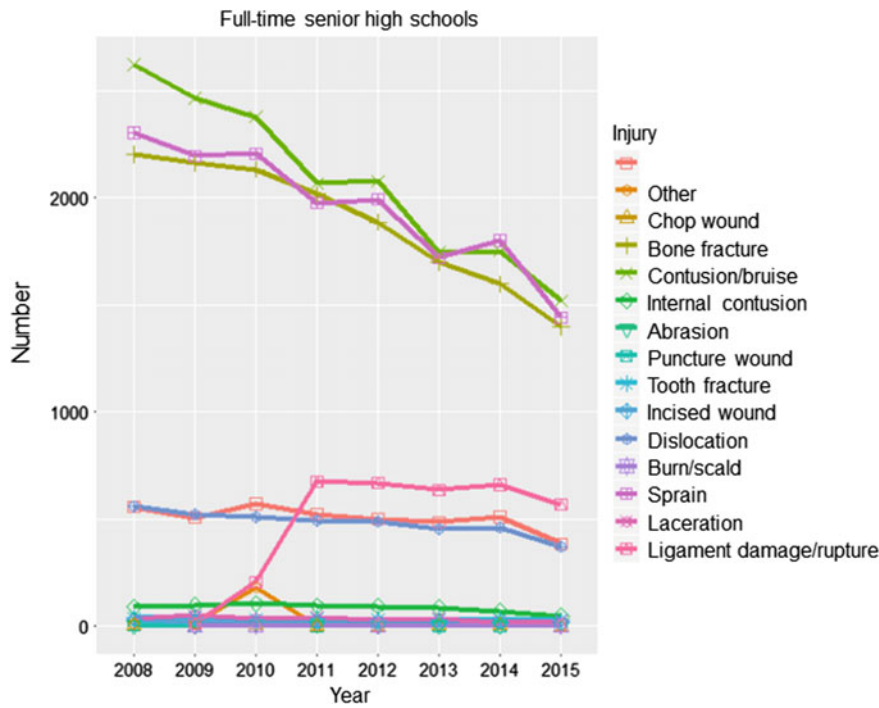


Fig. 5.12 Analysis of trends in injuries in judo accidents

Accident Mutual Aid Benefit System data of the Japan Sport Council from 2008 to 2015.

Figure 5.11 shows the results of an analysis of trends in judo techniques as related to accidents, and Fig. 5.12 shows the results of an analysis of trends in injuries due to judo accidents. A publication on judo accidents was issued in 2013, leading to their recognition as a social problem, issuance of a related alert, and notification of the risks of shoulder throwing and major outer reaping in particular. A manual on safe teaching methods was also produced and on-site initiatives were implemented. All of these apparently had considerable effect.

A marked decrease from 2013 in instances of accident-related shoulder throwing was confirmed by the authors, but they also found that no clear reduction occurred in major outer reap accidents. With this trend analysis, it is thus possible to assess the effects of intervention important for injury prevention. Application of the analysis to moderate injuries showed sharp reductions in contusion and bruise, sprain, and bone fracture, but sharp increases in ligament injury and rupture occurred in 2011 and high levels of their occurrence continued thereafter. It has thus been found possible to sharply reduce the occurrence of some injuries for which sharp increases had preceded, by investigating their cause followed by actions such as intervention for their prevention.

5.5 Childhood Home-Injury Simulation

5.5.1 *Background of Simulation*

Most accidents involving children below the age of five occur within their homes. Since it is important to maintain a safe home environment for children, it is imperative to be able to predict what kinds of accidents may occur in a particular environment and then to find ways to improve that environment. However, the various and scattered statistical data sources and scientific knowledge related to accident prediction have not been structured for integrative utilization. In this section, the authors report on the development of a new simulation technology that can be used to predict the kinds of accidents that may occur in a particular environment by means of a hybrid memory- and model-based approach. The system consists of a graph-structuralized accident database created from large-scale accident data (which enables the memory-based approach) and a development behavior model which describes the statistical relationship between a body interaction abilities and the age of children.

5.5.2 *Home-Injury-Situation Simulation System*

In this study, in order to predict child-related accident situations which may occur in an individual environment, we propose a home-injury-situation simulation system which consists of three functions: a development-related behavior prediction function, an accident situation search function, and a function for classifying products involving similar risks. The configuration of the proposed system is shown in Fig. 5.13.

The development-related behavior prediction function is used to estimate the area that can be reached by a child's hands and then visualize that area in 3D space on a computer.

The accident situation search function is used to look for specific accident situations that involve a product extracted from accident situation structure data. These accident situation structure data reports describe time series changes of the accident situation in a graph-structuralized form by utilizing text mining technique.

The similar-risk-product classification function uses a clustering method to identify products that involve similar risks. In the clustering, shape features and the accident types are used as feature vectors.

With these functions, when a user inputs target environment and child age information, the system calculates possible interactions such as "grasping object" using the developmental behavior model by considering the range of products which exist in the target environment. The system also locates accident data related to such products using the graph-structuralized accident database and then outputs possible accidents corresponding to the target child's development stage. In addition, the system attempts to determine the potential product risks using the third function even

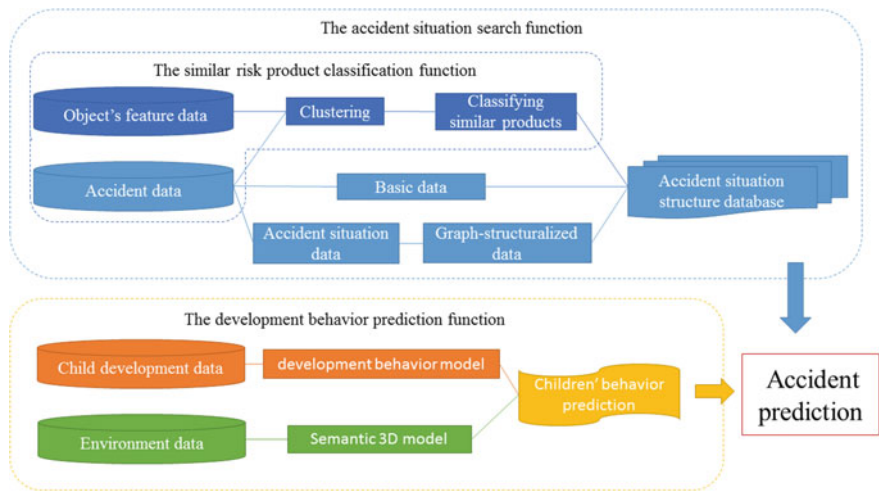


Fig. 5.13 System configuration of Home-injury-situation simulation

if there are very few or no past reports of accidents involving the products in the target environment. This case-based prediction facilitates accident forecasting even if product and children interaction knowledge is insufficient.

In this study, we select accidental ingestion and burn/scald injury as concrete example injuries in order to confirm the effectiveness of the system.

5.5.3 Development Behavior Prediction Function

Since child behavior changes significantly as development progresses, it is necessary to consider developmental stages when predicting child-related accidents. The development-related behavior prediction function visualizes the behavior of children in a virtually constructed environment using the development behavior and semantic 3D models described below.

Touch and climbing behaviors are among the primary causes of accidental ingestion and burn/scald injuries. One example reads, “When an electric cooking plate was being used on the table, a boy climbed onto a chair and touched the edge of the plate, thus burning his finger.” This example shows that even if an object is not placed on a floor, it can burn a child if he or she is capable of climbing. Therefore, in the current system, we implemented a function for predicting climbing and reaching behaviors based on body measurement and behavior characteristics collected from more than 2,000 Japanese children.

The statistical data using this database were published as a book for a product designer in 2013. Using this database, we created a behavior model that describes the probabilistic relation between the height of a pedestal that a child can climb to

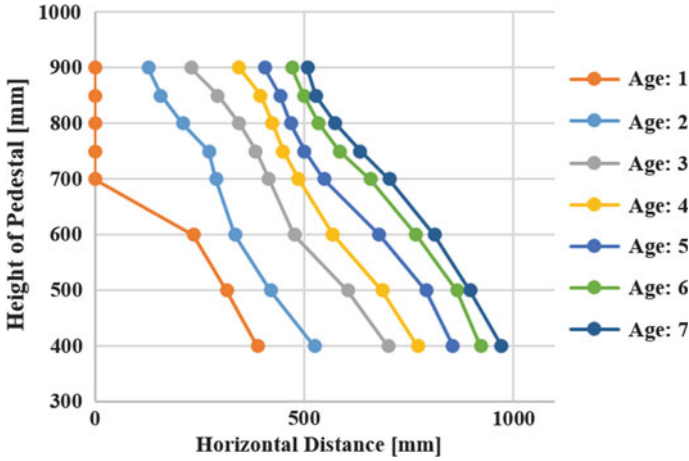


Fig. 5.14 Statistical data on reachable area

and the reachable horizontal distance from the edge of a pedestal. This model allows the system to calculate the probability that the child might touch an object placed at one of a variety of heights. Figure 5.14 shows the relationship between the reachable horizontal distance from the edge of a pedestal and the pedestal height.

When a user inputs information on a target environment, such as a furniture arrangement, as shown in Fig. 5.15, the system can predict the range of child behavior that can occur within the target environment. The user inputs environmental information by constructing and arranging 3D object models in a virtual environment. The system utilizes the 3D game engine Unity to achieve a function suitable for constructing a target 3D environment on a computer. Each 3D object model has semantic information such as the object name and child-related interaction behavior. Figures 5.15 and 5.16 show visualization examples.

Figure 5.15 shows that the child can touch yellow objects and that whether the object is touchable depends on the pedestal height, the horizontal distance from the edge, and child's age. For example, although two-year-old children cannot touch the object put at a height of 800 mm, four-year-old children can touch the object put at a height of 800 mm and a distance of 100 mm from a edge. Figure 5.16 shows that, depending on age, the child can climb to the red top faces.

5.5.4 Accident Situation Search Function

Conventional accident data contain detailed information in a free descriptive sentence format. However, it is difficult to utilize free descriptive data for situation predictions. Recently, our research group has been developing a graph-structuralization-based data mining technique [1] to provide a useful tool for obtaining knowledge on causal

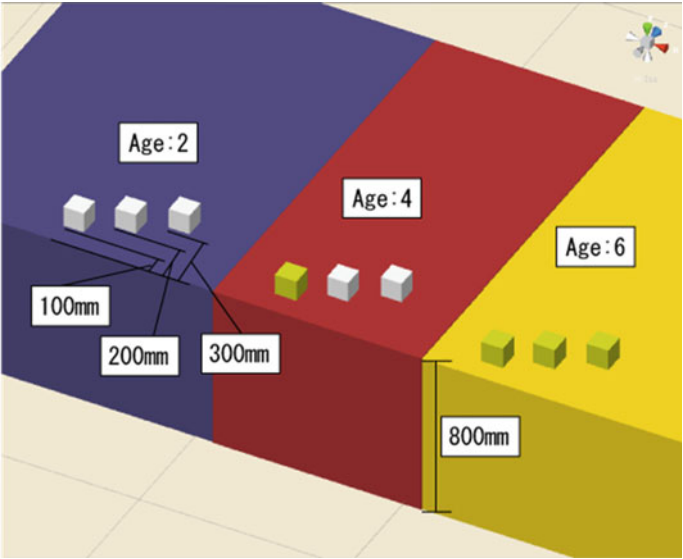


Fig. 5.15 Visualization of reachable objects

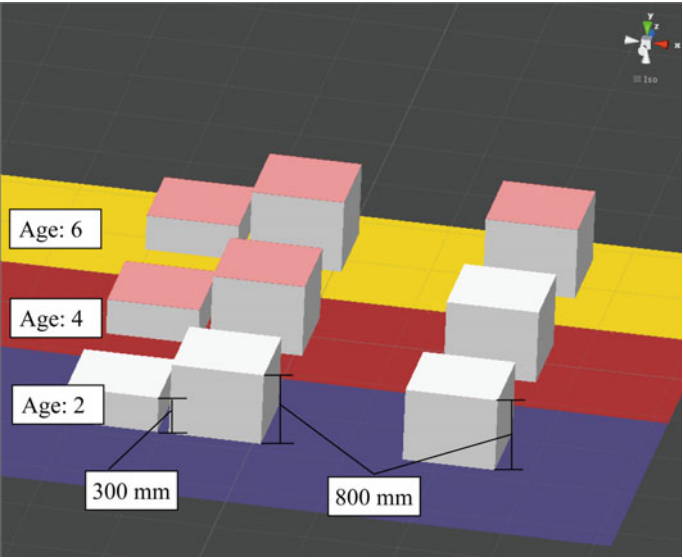


Fig. 5.16 Visualization of climbable places

relationships arising from interactions between objects and human beings. The graph-structuralization-based technique allows data mining by first converting the free descriptive sentence into graph-structured data and then applying a graph analyzing method to the data. Using our software, a user can transform free descriptive data into graph-structured data that express time series relationship changes between agents such as a child and a parent, a product, and interaction behavior with the product. We have also collected over 30,000 childhood injury case data reports in cooperation with hospitals, with which we created an accident situation structure database which consists of the data on 681 burn/scald accidents and 1,221 accidental ingestion incidents. The accident situation search function can be used to find possible accidents from the accident situation structure database by taking into consideration both the child's behavior development stage and the past accident data.

5.5.5 Similar-Risk-Product Classification Function

Objects that cause similar accidents often show shape and characteristic resemblances. For example, objects related to hot water, such as electric kettles and electric pots, can cause burn injuries. Therefore, classification of products from the viewpoint of product characteristics is important for predicting potential risks from products. Such risk predictions allow us to find potential risks even if a new product has not been responsible for any previous injuries. To implement the similar-risk-product classification function, the authors conduct hierarchical clustering using the features of the objects.

5.5.6 Simulation Example of the Accident Situation

Figure 5.17 shows examples of behavior visualization in a target 3D environment. Each simulation was performed using the functions stated above. By visualizing a child's behavior by age, it is possible to check changes in child behavior on the input environment. For example, in Fig. 5.17, although neither a desk nor a chair can be reached at when a child is less than 1 year old, they can both be reached when the child is more than 2 years old.

Figure 5.18 shows an example of similar objects found when an accident situation is input. In this example, the system simulated not only accidents related to tobacco and soup, which exists in the environment, but also those resulting from objects similar to soup, such as boiling water, tea, and heated baby food.

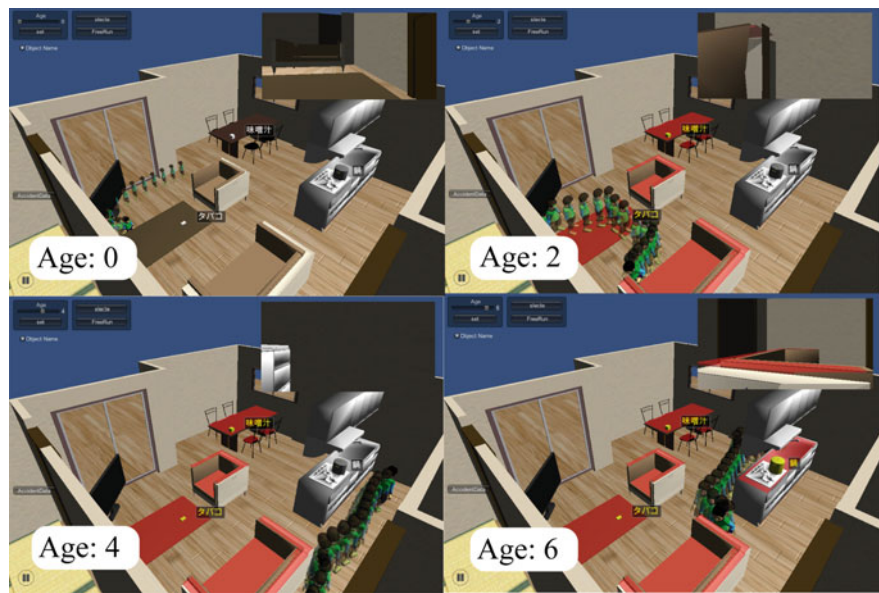


Fig. 5.17 Comparison of accident situation simulations by child age

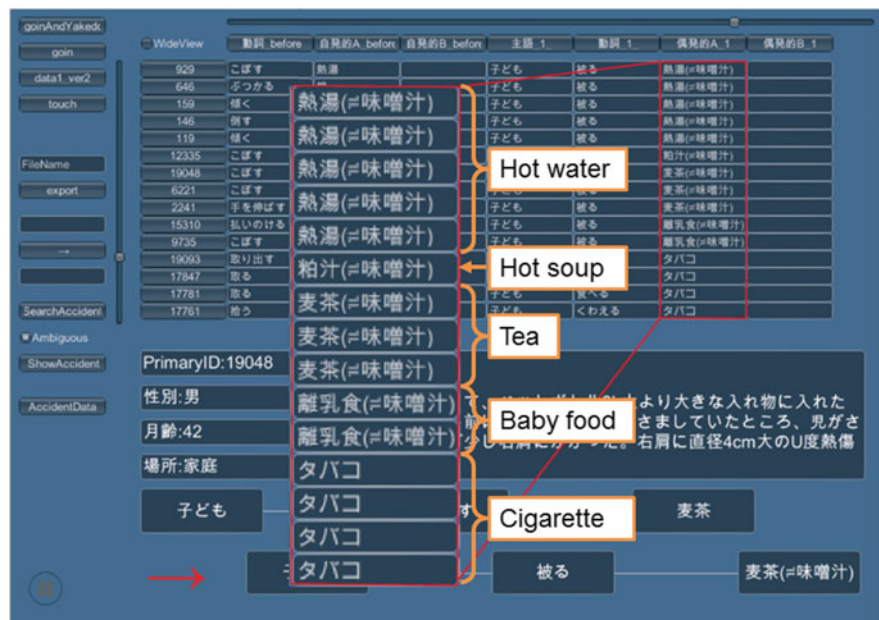


Fig. 5.18 Search for potential risks from objects having similar features



Fig. 5.19 Search for potential risks from objects having similar features

5.5.7 System Verification

To demonstrate the validity of the developed simulation, we reproduced actual ordinary home environments in which accidents had occurred and compared the incident reports with the simulation results predicted by the system. Actual injury data and environmental information were collected during home visit investigations. To date, we have collected such data from 21 ordinary homes where children were injured. At this stage of the evaluation, we selected four environments where burn/scald injuries occurred and one where an accidental ingestion occurred.

The evaluation process proceeded as follows: First, we input environmental information such as the house layout, furniture placement, and the accident situation and conduct a simulation of injury prediction. Figure 5.19 shows the simulated home floor plans and the 3D environmental models created using the information provided in the investigation.

Table 5.1 compares actual data with simulated results. In Table 5.1, the “Product” column indicates a the type of product related to an accident. “Age in accident data” indicates the age of the children when the accident occurred. “Minimum age” indicates the minimum age set in the simulation that children could touch the products that could cause burn/scald and/or accidental ingestion. “Number of accident cases”

Table 5.1 Comparison between actual data and simulation result

Product	Age in accident data (months old)	Minimum age in simulated results (months old)	Number of accident cases
Internal medicine	17	12	10
Pot	57	36	25
Detergent	17	12	21
Stove	50	12	5
Fan heater	11	0	0(8)

indicates the number of accident cases, and the number in the parenthesis indicates the number of accidents due to similar products found by the similar risk product classification function. The minimum age in the simulation is always less than the ages given in the accident data. This suggests that the minimum age set by the simulation was appropriate.

It should also be noted that the simulation succeeded in finding 13 out of 14 accident cases that actually occurred in the environment used for verification in this study. This confirms that the developed simulation works for finding various accident types. The single incident that the simulation failed to identify involved a parent holding a child who grasped an electrical pot located at a high level. Since this incident relates more to the parent’s behavior than to the child’s, we believe that the simulation is capable of replicating all incidents that a child might cause by his or herself.

**5.6 Social Impact Engagement Based on Big Data Analysis
in Cooperation with Multiple Stakeholders**

5.6.1 Engagement for Preventing Soccer Goal Turnover

The developed system was applied to the Injury and Accident Mutual Aid Benefit System data compiled by the Japan Sport Council, to analyze 1,921 cases of injury involving soccer goals that occurred at elementary and junior and senior high schools in AY2014. Accident circumstances included injury suffered from colliding with a soccer goal, tripping on a soccer goal or net and falling, or transporting, installing, cleaning, hanging from, or jumping into a soccer goal, by a soccer goal overturning by wind, from falling while climbing or sitting on a soccer goal, or by tools or weights used to secure a soccer goal. Some of these accidents were fatal, and in analysis for accidents involving soccer goal overturn, we found 29 [2]. More specifically, the circumstances were as follows:

- A student acting as goalkeeper on the school grounds in a soccer match during a physical education class was overjoyed when a shot flew wide of the goal frame and then hung from the goal, fell, and became pinned under the goal and had one or more teeth knocked out by the goal.
- While playing soccer in a tournament, the goalkeeper was struck in the neck by a goal tipped over by strong wind.
- In the lunch-hour break, a student was playing tag at an outlying area of the sports ground when several other children pulled on the net of a mini-soccer goal, which fell over and happened to hit the student, who was passing by, in the right side of his/her face, bruising the student in the head.

In the analysis, it was possible to roughly identify the circumstances of accidental overturning of the soccer goal, but quantitative determination of the size of the risk in analysis with these data alone was difficult, and it was therefore difficult to quantitatively assess the importance and specific method of preventive measures. In our attempt to determine means of prevention, we therefore measured the impact of the overturning soccer goal and the force required to overturn it. Because a soccer goal overturning accident had occurred when someone hung from the crossbar, we also measured the force on the soccer goal when an individual hung and swung from it.

For two aluminum goals and one steel goal, we overturned each by ropes attached to the crossbar and measured the resulting impact with an impact force gauge holding a load cell sensor mounted on the crossbar where it hit the ground.

In each case, the ropes were pulled gently to avoid imparting a shock load and the pulling was stopped when the soccer goal began to tip over, and the goal was thereafter left to turn over under its own weight. The pulling force was simultaneously measured by a small load cell sensor attached between the ropes.

As shown in Fig. 5.20, for the measured impacts when each goal overturned, the maximum value was 9,521 N for one aluminum goal, 18,980 N for the other, and 29,283 N for the steel goal. The impact of the steel goal was thus found to be 1.5–3 times those of the aluminum goals. Consideration of the relation between impact and injury indicates that the human skull will fracture under an impact of 3,000–5,000 N [3], and the results thus showed that impact by any one of these goals would be sufficient to pose a risk of skull fracture.

As noted above, we measured the force required to overturn a goal in the experiment with a small load cell sensor mounted between the ropes used to pull on the goal. The measurement was performed for an aluminum goal alone and with one of the various weights (from 20 to 80 kg in 20 kg increments) attached to its lower rear bar, with the results shown in Fig. 5.21. With no weight attached, the goal was found to be overturned by the small minimum force of 242.2 N (24.7 kgf), and the pulling force required to overturn the goal was found to increase in an approximately linear correlation with the increase in the attached weight, with a slope of 0.94 when the pulling force was expressed in kilograms. This was approximately equal to the 0.89 ratio of the 223 cm length of the rearward-directed bar relative to the goal post height of 250 cm, thus indicating that the goal post lower end functioned as the fulcrum in the principle of the lever.

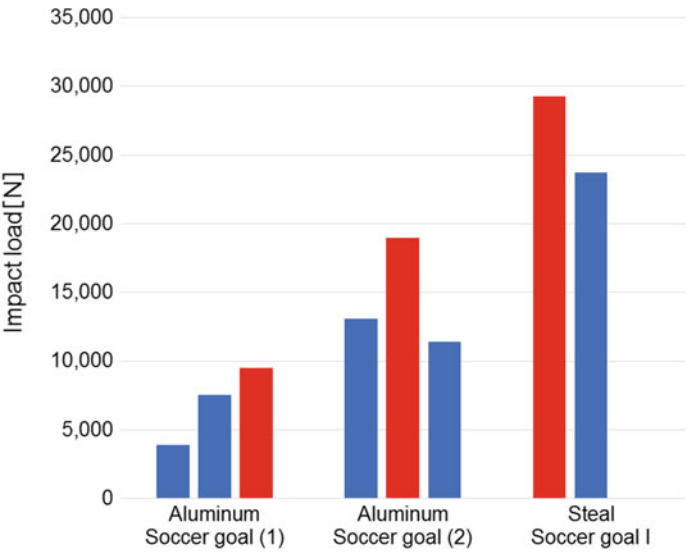


Fig. 5.20 Impact of overturning soccer goal

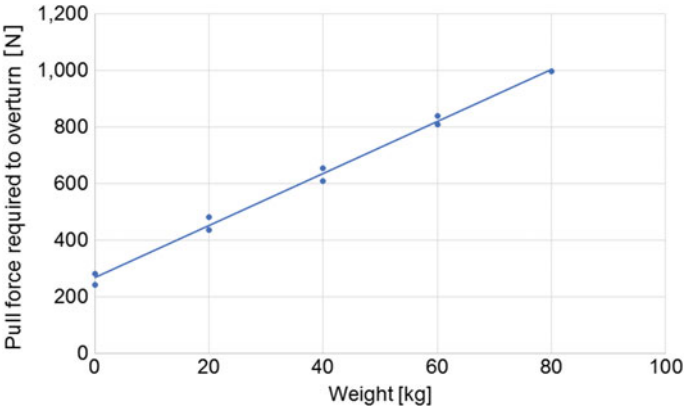


Fig. 5.21 Force required to overturn soccer goal

The most common circumstance of soccer goal accidents at schools is that of a child hanging and swinging forward and rearward from the goal crossbar. The horizontal load required to overturn the goal in such circumstances was simulated and measured in an experiment with a constructed steel-post assembly in which a biaxial load sensor was attached to each of the two ends of the horizontal bar and the horizontal and vertical loads were measured. The experiment was performed as one of 10 cooperating junior high school students hung and swung. Figure 5.22 shows the maximum horizontal loads found in the trials. Overall, the maximum applied force found for any of the forward and rearward swinging was 405.4 N (41.4 kgf).

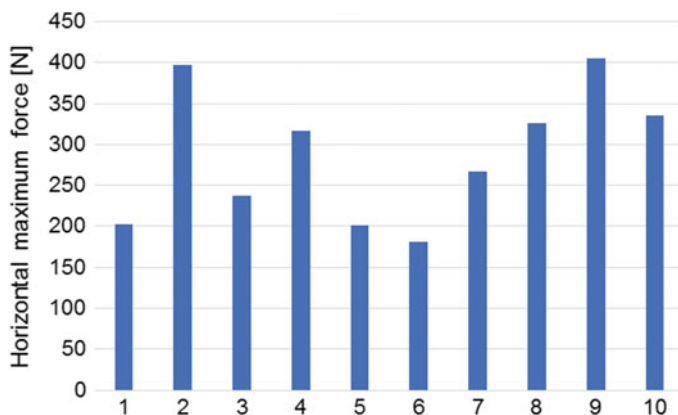


Fig. 5.22 Horizontal load with forward and rearward swinging

Taken together, the results indicated that the force of crossbar impacts near ground level when the goal overturned ranged from a minimum of 3,887 N to a maximum of 29,283 N and thus posed a high risk of causing skull fracture. It was found that an aluminum goal was overturned by a small force of 242.2 N (24.7 kgf) and that a child hanging and swinging forward and rearward imparted a horizontal force of 405.4 N (41.4 kgf) on the crossbar, and thus, it was found that a soccer goal will be readily overturned by the swinging action of just one student if not securely fastened down or having movement curtailed by a mounted weight.

These results have been presented at symposia, and the specific data have been shown and led to consciousness-raising activities.

5.6.2 Engagement for Preventing Vaulting Box Accidents

Analysis of 97,716 accidents relating to elementary school exercise activities recorded in the Injury and Accident Mutual Aid Benefit System data of the Japan Sport Council in AY2014 showed that vaulting box exercise accidents were most numerous [4]. They numbered 14,715 and thus accounted for approximately 15% of the total accident number. Among injuries suffered in vaulting box accidents, bone fractures were most numerous and accounted for approximately 37% of all injuries. The circumstances of vaulting box accident occurrence include run-up, takeoff, time from start to end of hand contact, landing, and forward somersault on platform, with accidents occurring in the largest number during the time from start to end of hand contact. Data analysis showed that many bone fractures occurred in the vaulting box exercise, again with most occurring during the time from start to end of hand contact. Further details are lacking, however, and in the present state of data on accident circumstances or child movements, application to injury prevention would be difficult.

We therefore performed observation and pattern classification of the relationship between vaulting box vaulting, and the risks involved in actual classes, in collaboration with Toshima Ward Fujimidai Elementary School and physical therapists. The patterns found included low momentum in takeoff, incorrect arm support, and insufficient center of gravity movement resulting in contact of buttocks with hand on vaulting box and leading to wrist sprain or failure to vault from vaulting box and impact of buttocks on vaulting box, and concentration on forward movement alone leading to loss of balance and falling on landing. Based on this analysis, we have developed a system that shows vaulting with risk of accident, vaulting action check-points, and practice methods for correction of ineffective moves (Fig. 5.23) and will proceed with its evaluation and modification through actual utilization at elementary schools.

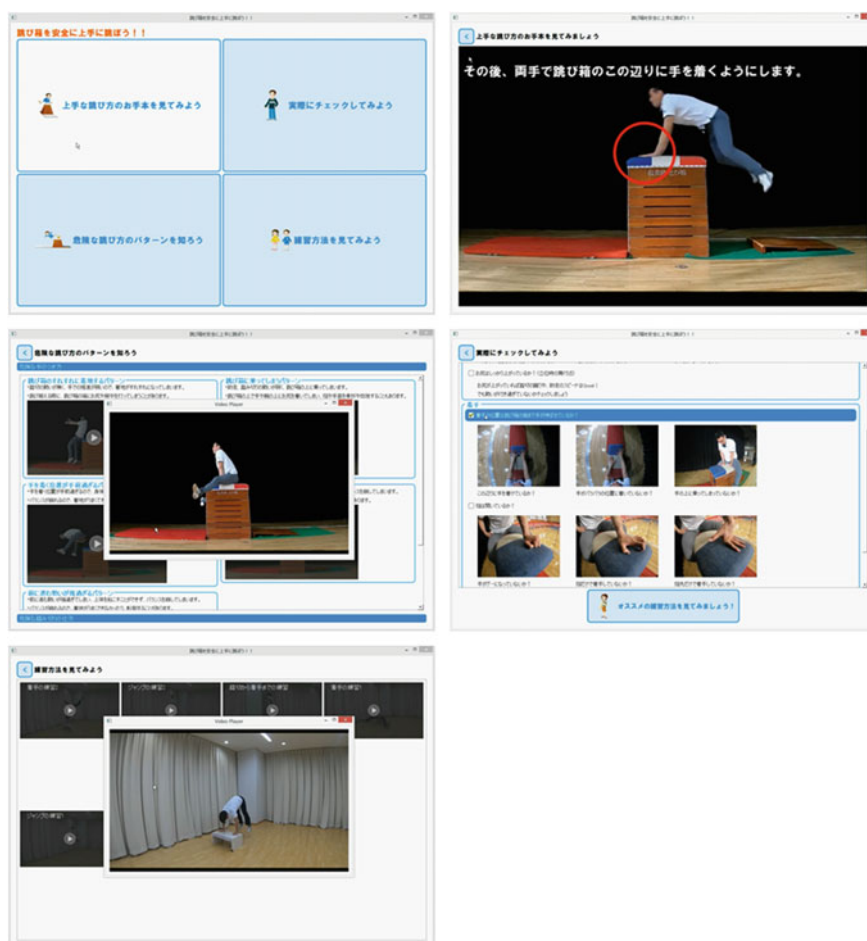


Fig. 5.23 Software supporting guidance on vaulting box safety

5.7 Conclusion

In this report, we have described trend analysis functions important for advancement of school safety in application to multi-organizational dispersed data utilizing basic security technology and performance analysis of actual judo accidents at schools. In problems elucidated through use of the system under development in this study, we have engaged in acquisition and analysis of detailed data necessary for injury prevention and described our engagement in studies on accidents in soccer goal overturning and vaulting box activities.

We will further apply our system currently under development to actual sites of activity while further advancing verification and investigate ecosystems for performance of injury prevention in actual on-site utilization of the system.

References

1. A. Hirata, K. Kitamura, Y. Nishida, Y. Motomura, H. Mizoguchi, Accident-data-aided design: visualizing typical and potential risks of consumer products by data mining an accident database, in *Proceedings of 2013 IEEE/SICE International Symposium on System Integration* (2013), pp. 376–381
2. T. Yamanaka, K. Kitamura, M. Oono, Y. Nishida, Importance of anchoring soccer goal posts based on scientific evidence, in *Injury Prevention*, vol. 24, supp. 2 (2018), pp. A12
3. N. Yoganandan, F.A. Pintar, Biomechanics of temporo-parietal skull fracture. *Clin. Biomech.* **19**(3), 225–239 (2004)
4. M. Oono, Y. Nishida, K. Kitamura, M. Nonoyama, H. Saito, H. Itakura, Prevention of vaulting box-related injuries in PE class: developing an educational tool by collaboration between physical therapists and artificial intelligence, in *The 9th Asian Regional Conference on Safe Communities in Atsugi* (2018)

Open Access This chapter is licensed under the terms of the Creative Commons Attribution 4.0 International License (<http://creativecommons.org/licenses/by/4.0/>), which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license and indicate if changes were made.

The images or other third party material in this chapter are included in the chapter's Creative Commons license, unless indicated otherwise in a credit line to the material. If material is not included in the chapter's Creative Commons license and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder.

