Proceedings of the 2007 IEEE Symposium on Foundations of Computational Intelligence (FOCI 2007)

Methodology of Everyday Life Computing and Application to Children Injury Prevention

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***Abstract*— Scientists and engineers have had little understanding of dynamics and properties of human "everyday life" despite its familiarity. Although in scientific fields such as quantum theory and cosmology, *standard models* exist to explain and generate most phenomena, nothing yet exists which might represent a standard model of everyday life. Recent development of technologies for sensing physical phenomena in total space using ubiquitous sensors, technologies for sensing worldwide social phenomena using Internet technology, and modeling technologies for constructing a computational system based on the large-scale sensory and text data gained using these sensing technologies implies that everyday life is becoming a new target of computing. This paper discusses a unique methodology for everyday life computing with which we can develop the foundations of computational intelligence by tightly coupling with everyday life. In particular, this paper takes up the issue of children injury prevention as a real problem to be tackled with computational intelligence technology, presenting a methodology for everyday life computing through describing some attempts at sensing and modeling of everyday life for injury prevention and will also outline some future prospects in this field.**

I. Introduction

It is delightful to watch children as they grow. From day to day, as their activities continue to diversify, they are a succession of surprises. Households with children enjoy talking about the children's growth. However, the growth of children has less enjoyable aspects. As children develop their rate of injury incidence increases. After a child learns to walk at age 1, the most common cause of death is, surprisingly enough, not illness but unforeseen injuries. According to a recent report[1], every year in the USA 5,600 children under 14 years (an average of 15 per day) lose their life in unforeseen injuries. In Japan, in one year, the incidence of children visiting a medical institution due to injuries is estimated as follows:

- Under 1 year old, 1 in 4 children
- 1 - 4 years old, 1 in 3 children
- 5 - 9 years old, 1 in 3 children

It is clear that injuries are the most significant issue in child health care. Given the decreasing birthrate and the increasing proportion of elderly, there is a pressing need to address this as a social issue affecting the future of nations. WHO (World Health Organization) announces a ten-year plan of action for children injury prevention in 2006[2], [3]. Children injury is a real problem to be responded transdisciplinarily and globally[4].

We need to understand that every kind of injury, not just those injuries involving children, has three phases: 1) before the injury occurs, 2) while the injury is occurring, and 3) after the injury has occurred. Before the injury, we need to consider prevention, during the injury emergency measures, and after the injury treatment and rehabilitation. Amongst these approaches, the most important, and certainly the most economical, is prevention[5].

Projects researching child injury prevention are conducted in many countries. Australia's NISPP (National Injuries Surveillance and Prevention Project)[6], the USA's National Center for Injury Prevention and Control[7], and the British Department of Trade and Industry's Home & Leisure Injuries Surveillance System[8], among others, have constructed surveillance systems to gather data on injuries, and conduct statistical analysis etc., based on this injury data. In Japan, efforts are starting to be made to reduce children injuries through the "Healthy Family 21 (Sukoyaka Oyako 21)" Project[9]. However, effective injury prevention through investigating the circumstances surrounding injuries, spreading injury knowledge, and promoting injury awareness is still far from adequate, and the number of injuries should be reduced much more.

What can we do to prevent injuries? Modeling everyday life behavior is the key. The number of deaths due to unforeseen injuries can be projected by using injuries statistics. The number of deaths caused by injuries in the last few years has leveled off. For example, we can estimate that roughly 800 children under 14 years of age will die of injury causes in 2006. However, in order to *prevent* injuries, we need to consider these injuries not only from a macro perspective, but also from a micro perspective. This is to say, we need to define the circumstances at the level of the behavior that forms the background for these injuries. Injuries are phenomena that necessarily occur following some behavior. A proper approach to injury prevention based on this kind of behavior modeling would need to create a kind of perpetual loop that would:

1) Collect data on children's everyday life activities and injuries
2) Analyze the collected data and construct a model of

children's everyday life activities and the process by which injuries occur
3) Propose injury prevention countermeasures based on this model of activities and injuries
4) Quantitatively evaluate the efficacy of these countermeasures and propose improvements in an ongoing and sustainable fashion

An injury prevention loop of this nature in present circumstances might be sustained, by the barest of margins and extremely incompletely, through human efforts alone. Data on the unfortunately occurred injuries should be treated and preserved so that the human race can share and utilize this as a precious resource in the future. Despite this pressing need, this data is being neglected, without being seriously pursued by the fields of science, engineering, and medicine. Particularly in the case of children's injuries, according to children's medicine clinics, the causes and patterns of injury incidence tend not to be isolated or special cases. Rather, for the great part, the same kinds of injuries tend to repeat themselves in the same kinds of situations. This means that, unlike large-scale disasters occurring only in the most extreme circumstances, the very *everyday* nature of these injuries is clearly a major characteristic.

Human-centered computing technologies which makes injury prevention loop more robust and meaningful can be developed by combining the following technologies: 1) everyday life behavior sensing technologies that consist of ubiquitous and wearable sensors to collect data on the everyday life behavior of children, and the Internet to collect injury case data. 2) everyday life behavior modeling technologies for extracting causalities among injuries and the background circumstances as reusable knowledge from the collected data. Furthermore, 3) everyday life service technologies in which injuries would be visualized based on the causality structures thus extracted and then made available to children's guardians using the Internet. If this sort of loop can be created, various services to support the safety and security of our society are possible. For example, information on an injury occurring somewhere could be gathered immediately, and rapidly transmitted to the guardians of children in similar situations, thus nipping the same kind of injuries in the bud. Providing designers of consumer product makers with the collected data or the created model would contribute to manufacturing and environmental design safe for children.

This paper will describe some attempts at sensing and modeling of everyday life for child injury prevention to show the possibility of a unique methodology for everyday life computing with which we can develop the foundations of computational intelligence by tightly coupling with everyday life.

II. Current Situation and Issues on Modeling Children Everyday Life

In the field of medicine and child care, research has already been conducted on the behavior of children which occurs in their everyday life spaces. For example, in the medical field, statistical data exists concerning the kinds of behavior known to accompany children's development[10]. In the field of child care, knowledge has been accumulated through the clinical observation of behavior. Also, in the architectural field, fundamental data regarding the bodies and movement capacities of children is starting to be gathered, in order to further the design of environments in which injuries are less likely to occur. However, due to the lack of tools to observe and analyze the behavior of children occurring in the everyday activity space, information on the diverse range of children behavior occurring in this space has been inadequate, meaning that knowledge gained up until this point has been difficult to comprehend in an integrated fashion and from an everyday-activity perspective.

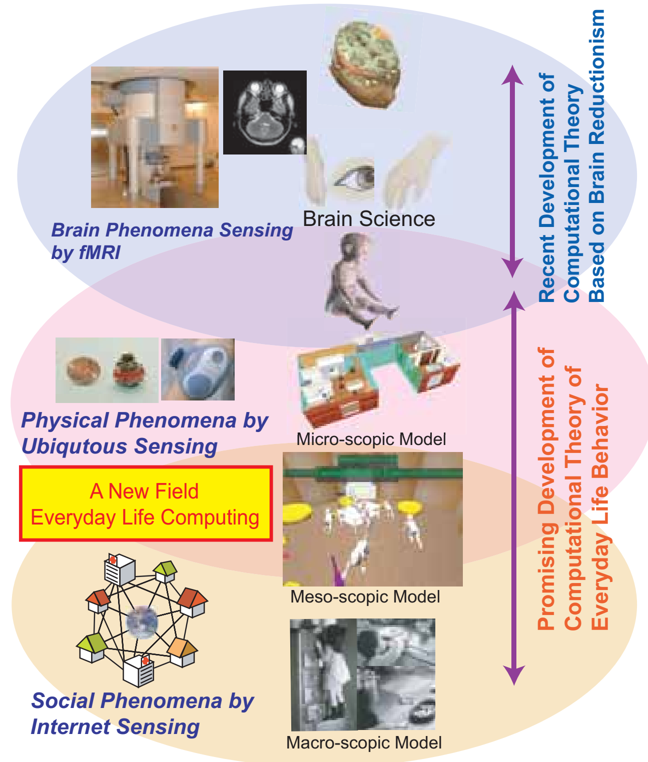

Fig. 1. Computational model of human

On the other hand, in the fields of cognitive psychology and developmental behaviorism, various attempts have long been made to understand the mechanisms of the behavior of children. For example, research is comparatively advanced concerning infants' vision, yielding useful information. Around 3 or 4 months after birth, a child becomes capable of depth perception by using information on binocular disparity[11], [12]. At 7 months, a child has developed not only depth perception, but also a sense of distance to target objects by using pictorial depth cues . This ability develops; a child can, at the age of around 7 months, discriminate between target objects using differences in shape, while at 11 months he/she can use textural differences, and at 12 months can use color differences[13]. As far as the relationship between visual information and infants' grasping behavior goes, it has been clearly shown that the frequency of infants' reaching activities changes, depending on distance to target object, size of target object, movement of target object, etc[14]. However, regardless of this kind of research, modeling has not gone beyond very limited models of behavior and cognitive ability, compared to the diverse range of activities occurring in a child's everyday activity space.

It can be seen that a large gap exists between the behavioral phenomena currently being addressed by neurology, cognitive psychology, and developmental behaviorism, and that knowledge which has been accumulated as statistical data both from children injuries and from clinical knowledge of child behavior. In order to fill in this missing link, a meso-scopic level needs to be struck; somewhere more "micro" than the level of injuries statistical data, but more "macro" than the neurological/cognitive-psychology level. In order to shift to this middle level, the level of everyday life behavior, it is essential to model the diverse range of children behavioral phenomena that occurs in the everyday life space.

III. Methodology of Everyday Life Computing

Is the creation of a model of everyday children behavior really achievable? In order to answer this question, we would like to briefly review the history of the last few years of human modeling. This history can be understood from 3 perspectives: the appearance of new observation devices, the appearance of devices as vehicles for mapping new phenomena, and mesoscopic phenomena which constantly exist as unknown. For example, as Figure 1 shows, recently in the field of brain modeling, modeling of mesoscopic phenomena between nerve cells and brain function has greatly developed, due to the appearance of fMRI for observing these phenomena and the existence of computers for mapping the expression of models. Furthermore, in recent years, the modeling of mesoscopic phenomena between brain function and physical function (bioengineering) is being developed, due to the appearance of robots as a means for expressing new models. This current process marks a powerful new paradigm at present, which might be called brain reductionism computational theory (which emphasizes describing phenomena from the brain-science level).

On the other hand, absolutely new types of observation devices and mapping technologies are appearing. Firstly, considering the appearance of new observation devices, ubiquitous technologies now exist which can sense total space physical phenomena, and Internet technologies now exist which can sense worldwide social phenomena. Accompanying the development of ubiquitous sensors and network technology, it is becoming possible to use devices to observe human behavioral phenomena in the everyday life space. It is also becoming possible to use the massive databases which the Internet represents. Considering cases such as blogging and Wiki, etc., it is clear that despite the Internet's lack of physical sensors, it is possible to consider them as new sensors for describing human activities, on a more "macro" level, with text-based information. With regard to mapping devices for new phenomena, we see that computer clusters exist that utilize massive memory and CPU power, that CG technology can express human behavior , and that technologies now exist to accurately model phenomena that can be difficult to completely express using definitive methods. The emergence of these technologies implies that the construction of models of new mesoscopic phenomena - that is, of the phenomena of human behavior occurring in everyday life - is now possible.

Previously, as Marr[15] has indicated , no single, simple means to model the entire range of human behavior could be found. Even to this day, Marr's question - "what constitutes an explanation, that is, a model?" - has been an essential and continuing problem for modeling human. Accordingly, to tackle this issue of the creation of standard models for human, we need to make concerted efforts to describe and model human activity at the various levels for which observation mechanisms exist. The problem of children injuries addressed by this paper represents a case where the modeling children behavior occurring in the mesoscale of everyday human activity is essential. To model the diverse range of children behavior, a composite approach is required to combine external factors such as the children's surroundings and environment, and internal factors such as the children's physical, cognitive and movement capabilities and the development of these capabilities. This approach might seem outrageous at first glance. However, the modeling of children behavior addresses relatively less diverse behavior than in the case of adults, and environmental factors influencing children behavior are also entirely local. Also, since various clues can be obtained, such as the strong connection between age in months and children behavior, we believe that it is now feasible to construct a standard model of this behavior. This paper will outline behavior modeling based on data gained from the observation of everyday behavior using ubiquitous sensing technology, and information on everyday injuries gathered by using Internet technology.

IV. Sensing and Modeling of Everyday Life

A. Everyday life sensing with ubiquitous sensor: Sensing physical phenomena in total space

It is becoming even easier to construct a research space with laboratory-level sensing functionality with the development of cheap sensors and home PCs. We developed a sensor home for observing everyday life behavior. The sensor home is a home set up to resemble an everyday life space and it consists of the rooms that an ordinary home has. The sensor home has many kinds of ubiquitous sensors: an embedded type of sensors and a wearable type of sensors. As for embedded sensors, we developed an ultrasonic location sensor (Ultrasonic GPS) capable of measuring location within an error of a centimeter[16]. The sensor home has 1,218 ultrasonic receivers and can measure the location of objects and persons with ultrasonic transmitters. The home also has 10 fisheye cameras and microphones. It can

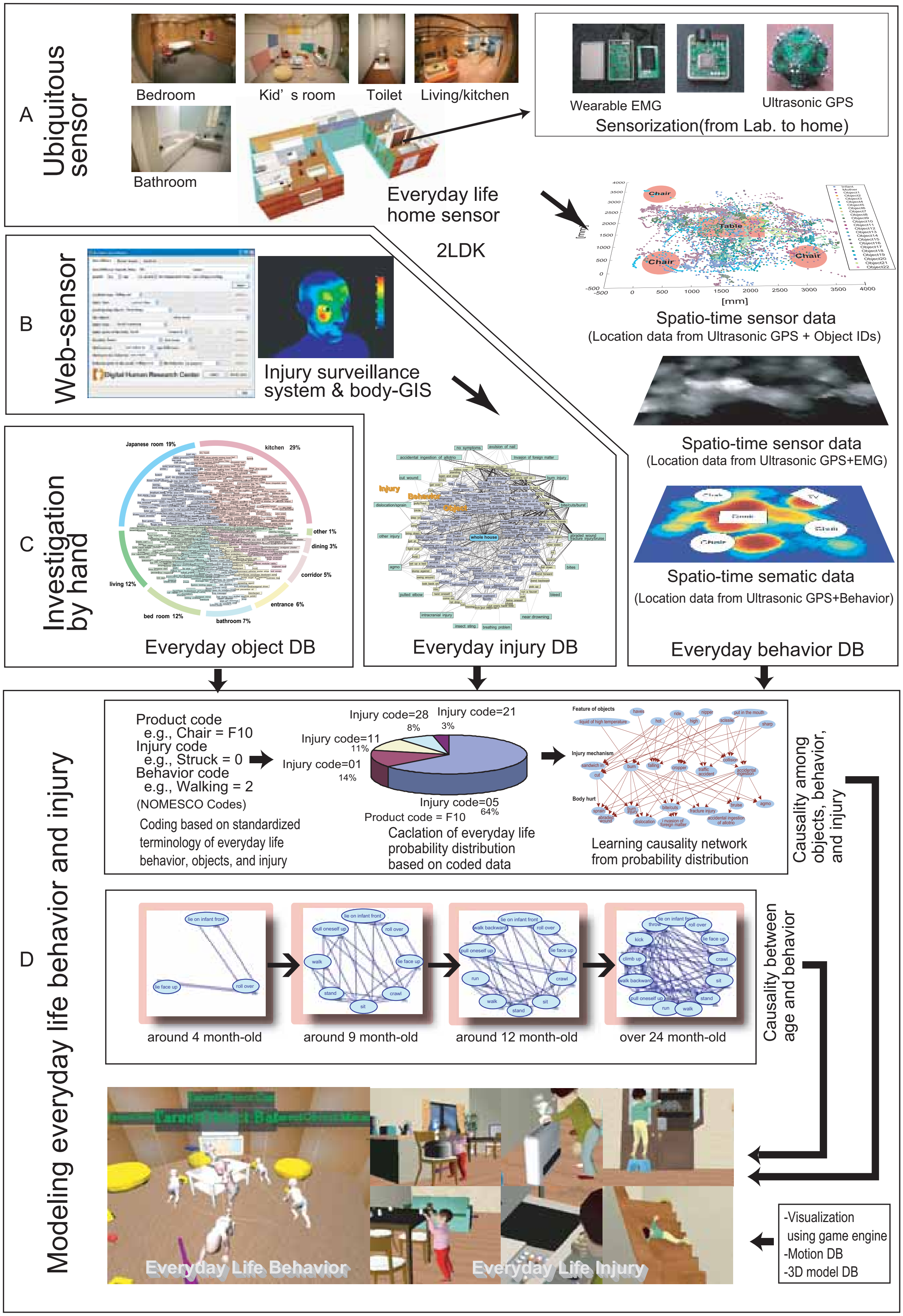

Fig. 2. Modeling and simulating everyday life behavior and injuries

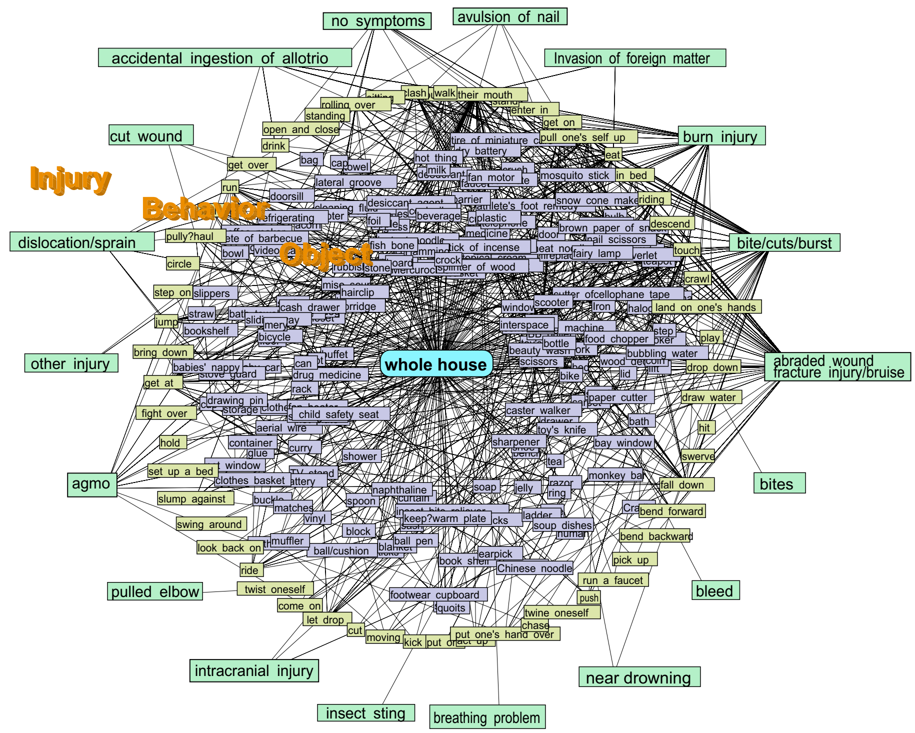

Fig. 3. Everyday life injury dababase

observe the diverse range of children activity occurring in the everyday life space.

In order to manage a large amount of sensory data measured by the sensor home, we developed a spatio-time-semantic mapping system (STS map) that accumulates sensory data and semantic data with location information, and retrieves data by queries such as time, space, and behavior information. The system also has a function for visualizing the retrieved data and the result of analysis. The location data shown in A of Fig. 2 shows an example of location data that were measured by the Ultrasonic GPS and preserved in the STS map. So far, we collected data from 98 children. For example, using this kind of data, it was found that infants between 9 months and 3 years of age will take the greatest interest in target objects at a distance of around 40 cm.

With the use of wearable sensing technology, it is now possible to conduct sensing of everyday human behavior in the general home environment without being limited to a laboratory setting. The recent proliferation of low power-consumption PCs, wireless modules, memory, sensors, etc. means that all the elements needed to construct wearable sensing technology are in place and that sensing of this kind of everyday behavior can now be attempted. For example, to acquire fundamental data regarding grasping behavior and analysis of accidental ingestion, we developed a wearable electromyography (EMG)[17]. This device measured grasping data occurring in everyday activity. The EMG data depicted in the STS map in A of Fig. 2 is an example of data measured by the developed EMG sensor. Thus, since the EMG data were recorded with location data of a child, the STS map system can visualize EMG data in association with the map of the room.

Our system made it possible to estimate grasping times with an error rate of approximately 30%: it is possible, then, to estimate the order of grasping times. We have little understanding of everyday life of a child other than everyday grasping behavior. For example, how many times per day is special grasping behavior carried out? When the children acquired such capacity? We had no way of knowing quantitative data such as these so far. If this kind of information becomes available, it would represent valuable fundamental data in product development and child behavioral science. To this end, there is a clear need for wearable sensing technology in order to gather kinds of data difficult to acquire in the laboratory.

B. Everyday life sensing with internet: Sensing worldwide social phenomena

One reason why research on injury prevention is difficult lies in the fact that we cannot reproduce injury in laboratory from the ethical viewpoint. Many social problems to be tackled are this type. One effective approach to this type of problems is embedding sensors to our society and collecting actually occurred data. We cannot control conditions before observing phenomena with this methodology. However, if we can get a large amount of data, it is possible to control conditions retrospectively by retrieving data.

It is becoming possible to collect a large amount of children injury data using Internet technology. In the near future, hospitals will be well-suited for collecting this data. Our research group is developing an intelligent injury surveillance system, which collects injury case data, analyzes and models injury mechanisms, and disseminates new findings [18], [19]. The case study data, recorded with the co-operation of medical practitioners at the leading edge of medical treatment for children injuries, has been collected 4,680 recorded cases. B of Fig. 2 shows developed software for collecting injury data at a hospital.

Figure 3 enlarges examples of collected injury cases. The figure suggests that we can obtain information on which kinds of objects exist in an ordinary home, and how a child interacts with such objects as well as injury data. With a conventional method, it is very difficult to get these kinds of information. Thus, the injury surveillance system has possibility of giving us breakthrough in understanding our everyday lives.

C. Everyday life sensing by hand: Constructing everyday life object database

We also have little knowledge on how many object exists in one home. Investigating everyday life objects is important for developing science and technology of our everyday lives as well as that of children injury prevention. From this viewpoint, we are investigating the number of objects existing in one home, the number of kinds of objects, the size and the image of each object, the frequency of use of each object, and the place of use of each object in every month. Currently we conducted study for one family of two. Figure 4 shows the relationship between objects and places that objects exist. For example, the studied family has 1,116 kinds of objects and 4,289 objects in total. The size of 90% of objects is less than 200 mm. The object existence density is higher in the kitchen and the entrance. Our group has a plan to open the everyday life object database and share with researchers in various fields in the near future.

D. Everyday life modeling

As a concept and a method for learning causality from both a large amount of data and prior knowledge, a Bayesian network (a probabilistic network model) is well known. Children's behavior data collected in the laboratory and injury data collected at a hospital are most often accumulated as statistics. Thus, this study utilizes this probabilistic framework. Using a probabilistic framework, we can express everyday life behavior on a computer as the result of multiple indeterminate factors, such as the existence of objects in the child's surroundings, the interactions between the child and these objects, the developmental relationship between age in months and child behavior, etc.

Probability distributions of child injuries are not uniform. Injuries due to similar objects tend to repeat many times. Therefore, if we can obtain a super large amount of data, we can estimate the risk of an object by retrieving the past injury data. However, modeling becomes very important when

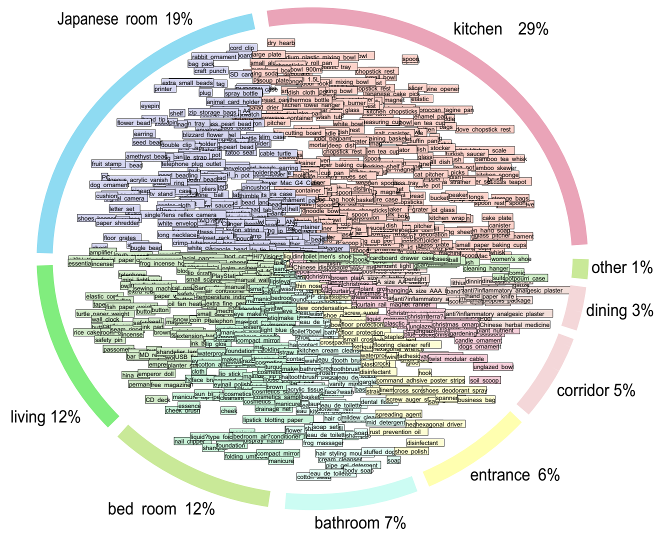

Fig. 4. Everyday life object dababase

the number of injury case data is limited, when we try to understand the mechanisms of injury, or when we want to extract reusable knowledge for injury prevention. For example, according to a survey on everyday life objects stated above, our home has over 4,000 kinds of objects. This means that the frequency of occurrence of the same object in data becomes low. Therefore, the reusability of the data is limited without modeling process.

One problem in modeling everyday life stems from that we use many kinds of expressions for the same thing. This terminology problem is common in science and technology of everyday life. To solve this problem, we try to standardize the expression of an object, injury, behavior, and place using the NOMESCO code[20]. We defined the way of describing objects, injury mechanisms, injuries, features of objects and behaviors, and so forth based on the NOMESCO code system, and we created a look-up table for standardizing everyday life terminologies.

After encoding injury data as shown in Fig. 3 with the created look-up table, we conduct cross tabulation and create a probabilistic network model by learning from the data. The upper part of D of Fig. 2 shows this process. Figure 5 shows an example of the learned model. Once we obtain the causal network among features of children, features of objects, and injuries, it is possible to estimate which kind of object can occur which kind of injury.

Our group is developing a comprehensive model of children's everyday life behavior and injuries by applying a similar method stated above to the behavior data measured by the sensor home, the injury data collected at a hospital, and the everyday life object database. By integrating a comprehensive model of children's everyday life with a gaming engine, we can visualize children's everyday life behavior and injuries. The visualizing technologies are key to provide

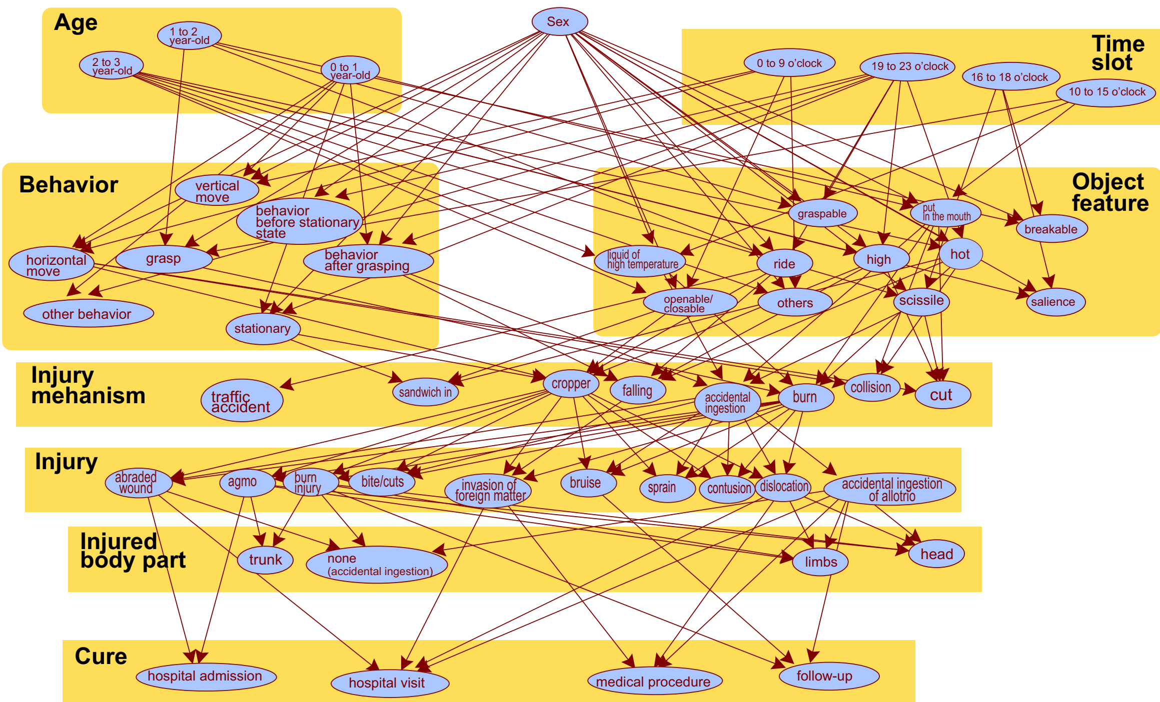

Fig. 5. Causal network created by learning from injury data

child care supporters and guardians with knowledge on injury prevention[21]. The upper part of D of Fig. 2 shows examples of the visualized behavior and injuries.

E. Everyday life service: Sustainable development of sensing and modeling

By integrating the sensing and modeling technologies stated above with a real society through providing service, we can collect a large amount of everyday life data, create a model of everyday life based on the collected data, and improve the sensing and modeling technologies themselves through service. This methodology leads to sustainable development or mutual evolution of them. The methodology contributes to not only sophisticating technologies and knowledge but also improving services. In particular, in recent years, with the spread of the Internet to nearly every household, information on these sorts of injuries and injuries can be easily obtained in the home. Large-scale data can also be rapidly obtained, and large-scale databases can now be constructed to provide useful information to the guardians of children, in their own homes. For example, when guardians of children are viewing child care information on the Internet, they might enter their child's age and what kind of injuries/injuries that child has previously experienced, and immediately, right there, be able to reference accumulated information regarding their child's attributes or injury case studies, including projections for what kinds of injuries might easily happen in the near future. It would be a database with a function to graphically present injuries. It would store information on the child's attributes, injuries, and injuries, and would continue to develop while improving the accuracy of its projections.

With the co-operation of the Benesse Corporation in Japan, we have planned to commence the first step of this service over the Internet, starting from December 2005. It is a service that reproduces images of the kinds of injuries that a certain child might cause, based on information entered by that child's guardian over the Internet (age, what kinds of behavior the child has recently managed to perform, etc.), and also offers virtual animation of the causable injuries and preventative measures for them. So far, the Web server system distributed 61,147 movies of injury scene to 4,933 parents and collected 21,482 questionnaire data from the parents[22].

To develop this service further, necessary child care/support information would be gathered, such as instantaneous information on injury prevention, visible information such as images of injury-causing objects, and presentation of information as footage, allowing guardians to get a real feeling for children's behavior. We are aiming for rapid construction of such large-scale databases and an advanced application of the information.

Our research up to this point has shown that three kinds of information application/collection systems are required. The first is for a better injury information collecting system; one that gathers the right amount of information, not too little nor too much. This system should enable us to grasp the dynamic state of injuries occurring both in Japan and the wider world. The second system is for an information collection system with which we can collect detail information required in reconstructing the circumstances of injuries. The dynamic-state surveillance system mentioned as the first system should lead us to our objectives; what kind of injuries are to be analyzed and prevented? Based on these objectives, the second system will enable the detailed investigation of socially valuable data on injuries and injuries. The third system will condense injury information, and then personalize and communicate this, as meaningful information, to child care supporters and guardians.

Using these knowledge acquisition and circulation systems will enable accumulated injury data and behavioral data obtained both from laboratory research and from within households, as described earlier in this paper, to be utilized in the creation of models integrating children's behavior with injury occurrence. Through repeated evaluation of these models, we believe that we are well on the way to creating, in increments, a standard model to adequately explain and reproduce the everyday activity of children and the attendant injuries and injuries occurring as a result of this activity.

V. Conclusions

This paper described a methodology of everyday life computing by presenting our trials in sensing and modeling everyday behavior for child injury prevention, and providing everyday services based on these sensing and modeling technologies. In the future, as for behavior sensing technology, we would like to see not only the development of dedicated hardware, but also the accumulation of knowledge concerning how to equip children with this gear: the establishment of methods to measure child behavior. Also, as part of the next stage of injuries sensing technologies using the Internet, namely repetitive reproduction of injuries in graphics and database analysis, we want to clarify which items are necessary for explaining and preventing injuries. With the co-operation of on-site doctors, nurses, and carers, we also want to solve any operational problems, thus gradually widening the scope of data collection locations.

The methodology described by this paper is not limited to children injuries. We believe that human-centered computing technologies based on everyday life models could be used in other fields for improving quality of lives of individuals. Such fields include not only safety-related field such as preventing injuries among the elderly, or work-related injuries in factories or hospitals, but also other evidence-based support of human lives. Actually, our group has developed an evidence-based nursing care support system in cooperation with a nursing home [23] with the same methodology.

If we are aiming at developing truly human-centered technologies useful for improving our quality of lives, time has come to address everyday issues in our research. When technological elements of human-centered computing such as sensing technologies, modeling technologies, and service technologies can start to interlock, and engage with each other in everyday life, a new cog will start turning; an information science that will not regard humanity as a laboratory animal, but will rather understand humanity as living within a real society in a deeper sense.

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