Enhanced Training Through Interactive Visualization of Training Objectives and Models

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ABSTRACT

Military forces operate in complex and dynamic environments [1] where bad decisions might have fatal consequences. A key ability of the commander, team and individual warfighter is to quickly adapt to novel situations. Live, Virtual and Constructive training environments all provide elements of best practices for this type of training. However, many of the virtual training are designed without thorough consideration of the effectiveness and efficiency of embedded instructional strategies [2], and without considering the cognitive capabilities and limitations of trainees. As highlighted recently by Stacy and Freeman [3], large military training exercises require a significant commitment of resources, and to net a return on that investment, training scenarios for these events should systematically address well-specified training objectives, even if they often, do not.

In order to overcome these shortcomings with both Live and Virtual training systems and following our previous work [4,5,6], this paper presents a design solution for a proof-of-concept prototype that visualizes and manages training objectives and performance measures, at individual and collective levels. To illustrate its functionality we use real-world data from Live training exercises. Finally, this paper discusses how to learn from previous training experiences using data mining methods in order to build training models to provide instructional personalized feedback to trainees.

1. INTRODUCTION

Homeland forces operate in complex, dynamic and stressful environments [1] where wrong decisions might have fatal consequences. Quickly adaptation to novel situations and environments has been trained using technology-based experimental learning approaches [7,2]. Live, Virtual and Constructive training environments all provide elements of best practices for this type of training. Virtual training systems offer a safe, effective and efficient training that has practical and economic advantages over more traditional training approaches [2]. Thus, the military has focused much attention on the development of replicable and generalizable computer-based training systems and a large number of companies have spent vast amounts of time and money developing a wide-array of simulators, virtual reality programs and support systems [2].

Nevertheless, many of such training systems are designed without considering the effectiveness and efficiency of embedded instructional strategies [2] and without considering the cognitive capabilities and limitations of trainees. Hence, they are more accurately conceptualized as practice platforms than training devices [8].

In general, goal setting, participation in decision-making, and objective feedback have been shown to increase productivity [9]. Feedback is a fundamental part of the learning process [10], the absence of feedback and the presence of inappropriate feedback are both strong impediments to learning [11]. Feedback provides knowledge of results, and feedback serves as a source of motivation [10]. In the case of novice trainees, there is overwhelming evidence that direct instructional support is necessary for optimal training [12,2].

Military training exercises require significant resources; such exercises might last several days and involve many participants using large amounts of equipment. As Stacy and Freeman [3] highlight, training scenarios for these events should systematically address well-specified training objectives, even if that is not the common practice at the moment: *"Clearly, large military training exercises require a significant commitment of resources. To net a return on that investment, training scenarios for these events should systematically address well-specified training objectives. Often, they do not."* [3].

The recent review by Stacy and Freeman [3] stresses the importance of representing training objectives, training conditions and measures for successful training. The authors claim that training objectives define the purpose of instructional events, but that it is challenging to apply training objectives in large, complex, multiparty military exercises. Similar claims were done by Vicenzi et al. [13]: *"In order for training exercises such as [Fleet Synthetic Training] to be effective and worthwhile, specific training objectives associated with relevant performance measures linked to mission essential tasks must be identified and incorporated into the training events"*. [13]

Not addressing well-specified training objectives and feedback violates well-established practices from the literature [3], as shown previously in the works by e.g. [9,10]. Earlier experiments showed materials [14] and instructional processes [15] that are crafted to address well-specified training objectives do reliably strengthen the performance on the target task, near transfer, and on new tasks, far transfer [3]. As such, training objectives have long been a requirement of instructional design, see [16], and of institutional training practices, as discussed in [3].

The analyses of musicians, athletes and other professionals show that expertise is primarily a function of practice and feedback that are deliberately designed to strengthen weak skills [17,3].

Training in the military context can be influenced by results obtained in the area of performance evaluation in sports. Performance improvement guidance is perhaps the least investigated area of computer science within sports. Already in 2006, Bartlett [18] argued for the potential of using expert systems and machine learning techniques in sports biomechanics analysis for improvement of performance. Bartlett [18] however, concluded that the usage so far is low. Owusu [19] presented a general model: recognize-critique-recommend, which can be used for performance improvement in sports. Owusu [19] discussed the use of neural networks and expert systems for recognition and critique, but concludes that very little has been investigated on these topics and especially on the final step of providing recommendations for improved performance. Examples of the organization of training processes in sports are presented in white papers by e.g. Verkhoshansky [20].

In order to overcome these shortcomings with both Live and Virtual training systems regarding the management of training objectives and performance evaluation, continuing our initial work [4,5,6], this paper reviews relevant literature regarding managing both individual and collective training objectives, focusing on military and crisis management exercises. Based on requirements specified by experts from our industrial partners in this area, a proof-of-concept prototype was designed and implemented. We describe its use with real-world data from Live training exercises. Finally, this paper discusses how to learn from previous training experiences using data mining methods in order to build training models to provide instructional feedback to trainees.

While the first and second sections of this paper summarizes relevant work in military training, section 3 presents the methods used to design the proof-of-concept prototype, the formative user study carried out for outlining the tasks to support and a description of the system and its functionality. Finally, discussion and conclusions are presented in sections 4 and 5.

2. RELATED WORK

In this section we provide a brief summary of software, frameworks and tools for military and crises management training, both from the scientific literature and off-the shelf commercial ventures, focusing on how such solutions manage training objectives, provide feedback and learn from previous events.

Several training systems have been suggested in the literature, e.g., F-REX [21]. F-REX, developed by the Swedish Defense and Research Agency, is a tool tailored to deal with multimedia rich data for reconstruction and exploration of complex chains of events in distributed tactical operations. F-REX allows playing back the course of events interactively, so analysts can focus on interesting situations, make annotations or create different visualizations. However, F-REX does not seem to support any comparison with training objectives or training models, or learns from historical data. In [22], the authors present a tool for systematic analysis, modeling and visualization of rescue scenarios. Several views that can be customized according to the needs of the analysts are presented; nevertheless, the mission history data stored is not exploited for performance evaluation. Various requirements of modeling, simulation, data collection, and visualization as important parts of live task force training are presented in [23], as well as a re-play system called MIND, that allows the display of the exercises for after-exercise analysis for emergency response training.

There are various commercial off-the-shelf simulation and training platforms, such as AKKA by Saab (see [6]), Exonaut by C4I-Strategies, RUAG, Rheinmetall, Cubic and live fire Megit, Thiessen, LookheadMartin, etc. To the best of our knowledge, these solutions do not apply data mining or machine learning algorithms to learn from historical data in order to provide personalized feedback.

3. DESIGN AND IMPLEMENTATION

Using an iterative task-driven design based on a formative user study with various experts at Combitech and Saab Training Systems, an interactive proof-of concept prototype was designed and implemented. The recommendations and descriptions presented in [24,25], and lessons learned from the development of interactive visual support tools previously built by our research group in other domains, i.e. [26,27,28], were used to frame our design and development work. The main framework used during the design process is presented in Figure 1 (adapted from [24]).

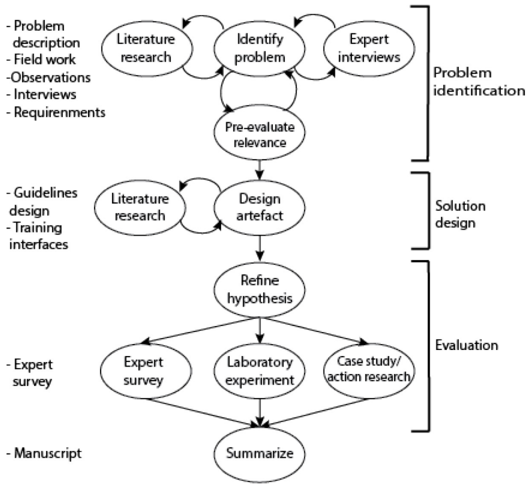

Figure 1: Design process used in this work, adapted from Offermann et al. [24].

3.1 Formative User Study

The formative user study carried out with expert system developers and experts in training systems from our industrial partners highlighted that the following tasks (*Ti*) needed to be supported:

T1. Identify different groups of trainees.

T2. Create statistical models that characterize each of the identified groups.

T3. Define training objectives (*skill*, *conditions* and *expected performance*).

T4. Interactive support for after-action support: (a) what happened? (b) Why did it happened (c) How do we improve it in the future?

T5. Support for comparison tasks both at the individual and collective level: compare results with training objectives and training models.

T6. Play back multimedia data associated to exercises, combining all the information collected and the information from the aforementioned tasks.

T7. Highlight differences and similarities between groups of trainees.

T8. Provide feedback based on the models and the expected results, both at individual and collective level.

Thus, the main objective of the proof-of-concept prototype designed and developed was to support the aforementioned tasks, in particular, to support the analysis of (1) the fulfillment of training objectives, both individual and collective, (2) the cumulative and over time values of performance, (3) analyze the different groups of trainees (clusters) and their characteristics, and (4) compare results of performance with trainee groups in order to suggest feedback.

3.2 System Overview and Functionality

The architecture of the system designed is presented in Figure 2. The modules that learn training models from historical data are inspired by our previous work in anomaly detection for maritime traffic, presented for instance in [29,26], where behavioral models of different types of vessels were built from sensor data.

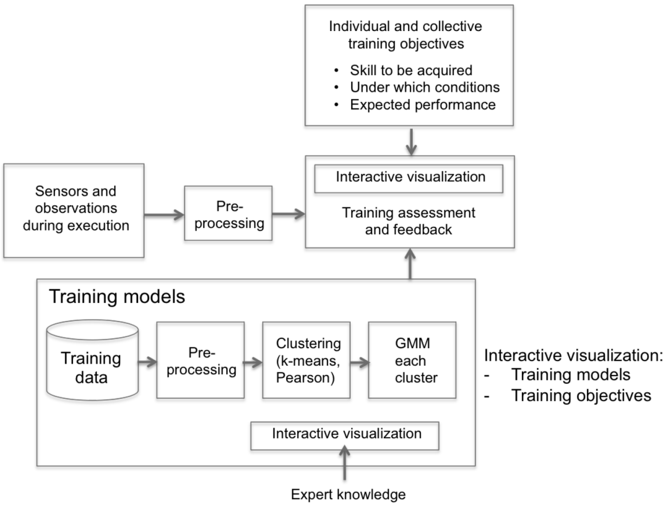

Figure 2: System architecture: (1) sensor observations, pre-processing, training assessment and feedback; (2) training models; (3) individual and collective training objectives. The analysts can interact with the various the modules.

The prototype is a web-based solution developed using JavaScript, PHP and Three.js (using WebGL), with swappable building blocks that allow for easily incorporated expansions in the future. Zooming and panning capabilities are included, as well as a high level of flexibility regarding choice of color schemes, sizes, views and modes. The following pictures show several screen captures of the prototype. Figure 3 shows an overall view of the system, with the interfaces for following the training objectives and analysis of the trainee groups established from the historical training data.

Figure 3: Main proof-of-concept interface, (a) 3D view of the exercise; (b) player status over time; (c) summary of the training exercise; (d) visualization of the training models and objectives; (e) playing bar and detailed view of the high-dimensional dataset.

The prototype allows loading multimedia data sets from training exercises, where filtering options are allowed (e.g. a segments of an exercise can be opened). The user might also select which soldier, vehicle or entity is in focus. The web-based prototype is divided in five main modules, shown in Figure 3. The multimedia spatio-temporal data can be played in the left module (figure 3, a), both 2D and 3D views can be selected; moreover, the user can select to follow a particular soldier, vehicle or entity. The data can be played back and forth using the time and event bar located under it. Figure 3 (b) shows real-time particular information regarding the selected soldier, vehicle or entity. On the right side, modules (c) and (d) manage training objectives, results and models. Module (c) shows the training objectives analyzed (i.e. skill, conditions and expected performance) and the results of the selected trainee compared to the expected results, and the collective performance (both expected and actual). On the rightmost module (d) the prototype shows how many groups have been found in the historical data set collected (3 in our case) and how is the collective performance for each of the groups. The comparison of an individual performance with its group is also depicted. Finally, the high-dimensional data is visualized on the interactive module located at the lower part of the display (figure 3, e).

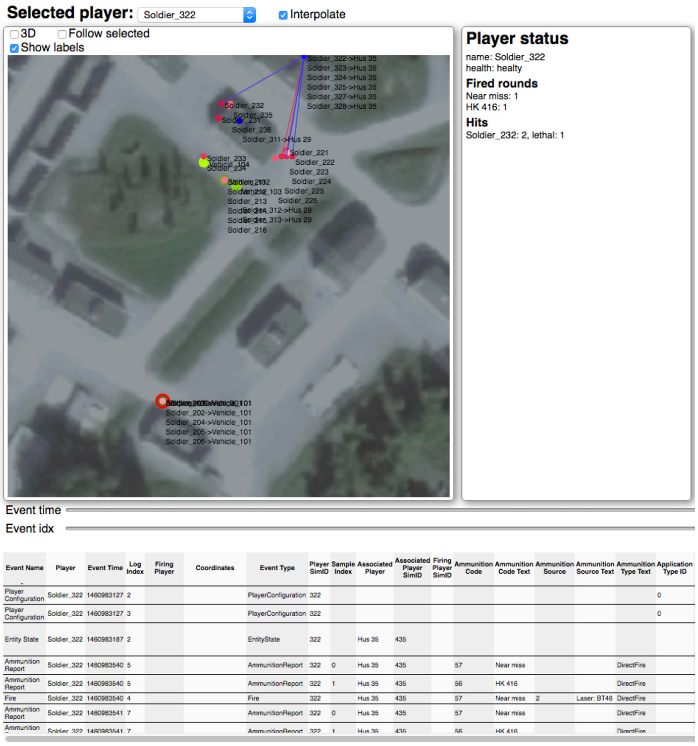

Figure 4: Collective 2D view with details for the selected player.

The data set used in this paper to illustrate the functionality of the prototype is a military live exercise where firing skills were trained. It is a collective exercise involving several vehicles, soldiers and other entities. The data analyzed is a high-dimensional data set with both categorical and numerical variables with events, allocated resources, etc. Moreover, it contains both geographical and temporal information, and thus, it can be described as a complex spatio-temporal data set. Illustrations of the data set can be seen e.g. on Figure 3.

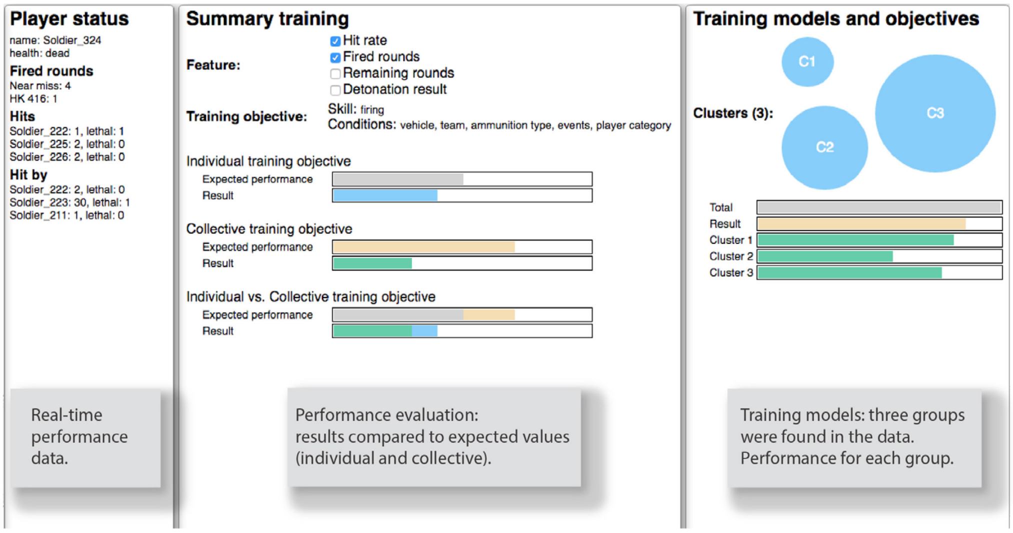

Figure 5: From left to right, real time performance data, comparison between expected and achieved results, visualization of training objectives and groups of trainees (clusters) found in the historical data.

4. DISCUSSION

This paper presents a design solution for a training system that exploits the advantages of learning from historical data from previous training exercises, as well as the management of training objectives at individual and collective levels. We address, thus, some of the challenges highlighted recently by Stacy and Freeman [3] and Vicenzi [13], regarding the need of specifying, managing and evaluating training objectives in military training exercises. Moreover, the prototype aims at supporting the main analytical tasks highlighted by experts from our industrial partners, listed in section 3.1.

Some of the improvements highlighted by the experts from Combitech and Saab Training Systems that will be a matter of future work are, first, the development of innovative visualizations for training objectives and models in an integrated view, over the multimedia data, as well as the development of innovative interactive visualizations for both individual and collective training parameters for on site and live training, and for after-training assessment.

The proof-of-concept prototype shows initial steps to future personalized training systems that combine information fusion, situation modelling and visual analytics capabilities. Such capabilities support (1) capturing the complete performance evaluation process, (2) understanding, constructing and maintaining the underlying training models and (3) interpreting and understanding the data collected and feedback. Techniques for integrating data and information, i.e. information fusion, have been identified as key enablers for providing decision support when large amounts of heterogeneous data need to be analyzed [30], as it is in this domain. The domain specific models employed in performance evaluation for training should capture relations between situations and performance, or more specifically, between situation types and performance [31]. To provide rich support, the models should preferably surpass the use of simple and individual measures, for instance, positions, directions, speeds at individual points in time, to instead model more complex behaviors and causal relations that can be used for increased performance. They require the combination of data not only from individual trainees, but also from the environment and the other members of the team at various abstraction levels. In order to provide interactive, personalized and immersive training interfaces to deal with both data and models, visual analytics can be used as a design framework. Visual analytics [32] strives to facilitate the analytical reasoning process by creating software that maximizes the human capacity to perceive, understand, and learn from large, complex and dynamic data and situations.

5. CONCLUSIONS

The main contribution of this paper is a design proposal of a training proof-of-concept prototype that allows the interactive analysis of high-dimensional spatio-temporal data and manages training objectives for performance evaluation of training exercises. Moreover, the prototype uses historical data for building models of training behaviour that then are compared with the results of training exercises in order to provide personalized feedback. Like this, we address some of the most important challenges highlighted recently by Stacy and Freeman [3], regarding the lack of support for specifying, managing and evaluating training objectives in military training.

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REFERENCES

[1] E. Salas, H. A. Priest, K. A. Wilson, and C. S. Burke, "Scenario-- based training: Improving military mission performance and adaptability," in *The psychology of serving in peace and combat operational stress (Vol. 2)*, A. B. Adler, C.A. Castro, and T. W. Britt, Eds. Westport, CT: Greenwood Publishing Group, Inc., 2006.

[2] J. J. Vogel-Walcutt, L. Fiorella, and N. Malone, "Instructional strategies framework for military training systems,". *Computers in Human Behavior*, vol. 29, no. 4, pp. 1490-1498, 2013.

[3] W. Stacy and J. Freeman, "Training objective packages: enhancing the effectiveness of experiential training," *Theoretical Issues in Ergonomics Science*, vol. 17, no. 2, pp. 149-168, 2016.

[4] P. M. Gustavsson and S. Lundmark, "One Step Further Towards the Next Generation Training Systems," in *The Interservice/Industry Training, Simulation & Education Conference (I/ITSEC)*, Orlando, 2007.

[5] P. M. Gustavsson, U. Björkman, and J. Wemmergård, "LVC Aspects and Integration of Live Simulation," in *Fall Interoberability Workshop 2009, Orlando, FL*, 2009.

[6] M. Wallinius, J. Nilsson, P.M. Gustavsson, and E. J. Nawaz, "Enhanced Training by a Systemic Governance of Force Capabilities, Tasks, and Processes," in *18th ICCRTS, 19th June 2013*, Alexandria, Virginia, 2013.

[7] E. M. Raybourn, "Applying simulation experience design methods to creating serious game-based adaptive training systems," *Interacting with Computers*, vol. 19, pp. 206-214, 2007.

[8] D. M. Nicholson, C. M. Fidopiastis, L.D. Davis, D. D. Schmorrow, and K. M. Stanney, "An adaptive instructional architecture for training and education," *Foundations of Augmented Cognition*, pp. 380-384, 2007.

[9] J. C. Brunstein, "Personal goals and subjective well-being: A longitudinal study," *Journal of personality and social psychology*, vol. 65, no. 5, p. 1061, 1993.

[10] E. A. Day, C. Blair, S. Daniels, V. Kligyte, and M. D. Mumford, "Linking instructional objectives to the design of instructional environments: The Integrative Training Design Matrix," *Human Resource Management Review*, vol. 16, no. 3, pp. 376-395, 2006.

[11] A. Klueger and A. DeNisi, "Effects of feedback intervention on performance: A historical review, a meta-analysis, and a preliminary feedback intervention theory," *Psychological Bulletin*, vol. 119, no. 2, pp. 254-284, 1996.

[12] R. E. Mayer, "Should there be a three-strikes rule against pure discovery learning?," *American Psychologist*, vol. 59, no. 1, pp. 14-19, 2004.

[13] D. Vincenzi et al., "Training Value of Fleet Synthetic Training for Hawkeye E2-C.," in *Proceedings of the Human Systems Integration Symposium*, Annapolis, MD, 2007.

[14] D.L. Schwartz, T. Martin, and N. Nasir, "Designs for Knowledge Evolution: Towards a Prescriptive Theory for Integrating First- and Second-Hand Knowledge," in *In Cognition, Education, and Communication Technology*, 2005, pp. 21-54.

[15] K. van Lehn and M. Chi, "daptive Expertise as Acceleration of Future Learning," in *Adaptive Technologies for Training and Education*, P.J. Durlach and A.M. Lesgold, Eds. West Nyack, NY: Cambridge University Press, 2012, pp. 28-45.

[16] R. Gagne, *The Conditions of Learning*, 4th ed. New York: Holt, Rinehart & Winston, 1985.

[17] K. A. Ericsson and A. C. Lehmann, "Expert and Exceptional Performance: Evidence on Maximal Adaptations on Task Constraints," *Annual Review of Psychology*, vol. 47, pp. 273-305, 1996.

[18] R. Bartlett, "Artificial intelligence in sports biomechanics: New dawn or false hope," *Journal of Sports Science and Medicine*, vol. 5, no. 4, pp. 474-479, 2006.

[19] G. Owusu, "AI and computer-based methods in performance evaluation of sporting feats: an overview," *Artificial Intelligence Review*, vol. 27, no. 1, pp. 57-70, 2007.

[20] Y. Verkhohansky, "Organization of the training process," *New Studies in Athletics*, vol. 13, pp. 21-32, 1998.

[21] D. Andersson, "F-REX: Event-driven synchronized multimedia model visualization.," in *Proceedings of the 15th International Conference on Distributed Multimedia Systems*, 2009, pp. 140-145.

[22] M. Morin, J. Jenvald, and M. Thorstensson, "Computer-supported visualization of rescue operations," *Safety Science*, vol. 35, no. 1-3, pp. 3-27, 2000.

[23] J. Jenvald and M Morin, "Simulation-supported live training for emergency response in hazardous environments," *Simulation & Gaming*, vol. 35, no. 3, pp. 363-377, 2004.

[24] P. Offermann, O. Levina, O. Schönherr, and U. Bub, "Outline of a design science research process," in *Proceedings of the 4th International Conference on Design Science Research in Information Systems and Technology*, New York, NY, USA, 2009, pp. 1-11.

[25] K. Vredenburg, J.-Y. Mao, P. W. Smith, and T. Carey, "A survey of user-centered design practice," in *Proc. of the SIGCHI Conf. on Human Factors in Computing Systems, ser. CHI'02. New York*, NY, USA, 2002, pp. 471-478.

[26] M. Riveiro, G. Falkman, T. Ziemke, and H. Warston, "VISAD: an interactive and visual analytical tool for the detection of behavioral anomalies in maritime traffic data," in *Visual Analytics for Homeland Defense and Security*, vol. 7346, Orlando, FL, USA, 2009.

[27] M. Riveiro, T. Helldin, M. Lebram, and G. Falkman, "Towards future threat evaluation systems: user study, proposal and precepts for design," in *16th International Conference on In Information Fusion*, Istanbul, Turkey, 2013, pp. 1863-1870.

[28] M. Riveiro, M. Lebram, C. X. Andersson, P. Sartipy, and J. Synnergren, "Interactive visualization of large-scale gene expression data," in *20th International Conference Information Visualisation*, Lisbon, Portugal, 2016.

[29] M. Riveiro, F. Johansson, G. Falkman, and T. Ziemke, "Supporting maritime situation awareness using self organizing maps and gaussian mixture models," in *Frontiers in Artificial Intelligence and Applications*, 2008, pp. 84-91.

[30] M. Liggins II, D. Hall, and J. Llinas, Eds., *Handbook of multisensor data fusion: theory and practice.*: CRC Press, 2008.

[31] A. Dahlbom and M. Riveiro, "Situation modeling and visual analytics for decision support in sports," in *In 16th International Conference on Enterprise Information Systems*, 2014, pp. 539-544.

[32] J. J. Thomas and K. A. Cook, *Illuminating the Path: The Research and Development Agenda for Visual Analytics.*: National Visualization and Analytics Ctr., 2005.