Advancing Digital Twins in Diabetes Research for Artificial Pancreas and Diabetes Decision Support Applications

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Abstract: Diabetes mellitus (DM) is a crucial chronic disease having a significant impact worldwide. There are therapeutic solutions powered by engineering methods to support people with diabetes; however, there are several areas that are not well covered by the available solutions: for example, personalization, active therapy management, and handling of physical activity in therapy support. Furthermore, most concrete diabetes decision support systems focus on dietary, diabetes education and lifestyle coaching and do not provide exact therapeutic solutions mostly due to the strict liability and regulatory requirements.

In order to provide solutions for the uncovered areas, three main research directions have recently emerged in research: using advanced digital twins for personalization, applying physical activity models and artificial intelligence (AI)-related techniques to handle physical activity, and advanced control engineering methods for active therapy support in daily life. Currently, manual therapy is still predominant in the case of Type 1 DM (T1DM), meaning patients regulate their blood glucose using an insulin pen and some blood glucose measurement technique (e.g., fingerstick or continuous glucose monitoring system (CGMS)). There are more advanced solutions, like the artificial pancreas concept (AP), focusing mostly on the insulin pumps and the advanced engineering algorithms.

Currently, solutions addressing these approaches in a pervasive way are unavailable. The digital twin concept represents the next step in patient modeling, enabling continuous therapy tuning, blood glucose prediction, and personalized decision support on the patient's digital counterpart. Physical activity is one of the main "weapons" in diabetes management. Besides the physiological benefits of exercise, the stress of exercise can lower blood glucose levels without the need for insulin hormone. However, in AP applications, physical activity carries serious risks, as current systems lack algorithms that can safely adjust insulin delivery and correct blood glucose drops caused by exercise in a personalized way. Therefore, physical activity in diabetic patients can be dangerous, highlighting the importance of developing appropriate models and correction algorithms in this field. Adaptive advanced control algorithms are the "soul" of AP, capable of providing patients with therapy recommendations tailored to their ever-changing individual needs or implementing automated therapy. This requires state-of-the-art predictive, adaptive control approaches and artificial intelligence-based solutions, all of which must be based on personalizable digital twins.

These are the keys to providing real help for people with diabetes tobe handled effectively as part of the diabetes decision support system (DDSS).

This applied research focuses on developing an advanced personalizable digital twin platform that can be used in developments, but also can be integrating it into complex DDSS, involving real patient data, in order to make the everyday easier for people with T1DM.