

# Contents

<b>Alternative Frameworks for Personalized Insulin–Glucose Models . . . .</b>	<b>1</b>
Harald Kirchsteiger, Hajrudin Efendic, Florian Reiterer and Luigi del Re	
1 Introduction . . . . .	1
2 Alternatives for Modeling . . . . .	2
3 Model Structures . . . . .	5
4 Interval Models . . . . .	9
4.1 Continuous Time System Identification . . . . .	9
4.2 Interval Model Results . . . . .	11
5 A Probabilistic Approach . . . . .	18
5.1 Gaussian and Generalized Gaussian Mixture Models . . . . .	19
5.2 Modeling Method and Model Structure . . . . .	20
5.3 Modeling Results . . . . .	22
6 Conclusion and Outlook . . . . .	26
References . . . . .	27
 <b>Accuracy of BG Meters and CGM Systems: Possible Influence Factors for the Glucose Prediction Based on Tissue Glucose Concentrations . . . . .</b>	 <b>31</b>
Guido Freckmann, Stefan Pleus, Manuela Link and Cornelia Haug	
1 Introduction . . . . .	32
2 SMBG Accuracy and CGM Calibration with SMBG Results . . . . .	32
2.1 SMBG Accuracy . . . . .	32
2.2 CGM Calibration with SMBG Results . . . . .	34
3 Accuracy of CGM Systems . . . . .	36
3.1 Mean Absolute Relative Difference . . . . .	36
3.2 Precision Absolute Relative Difference . . . . .	38
4 Glucose Prediction Based on Tissue Glucose Concentrations . . . . .	39
References . . . . .	40

<b>CGM—How Good Is Good Enough? . . . . .</b>	<b>43</b>
Michael Schoemaker and Christopher G. Parkin	
1 Background . . . . .	43
2 CGM Performance Assessment . . . . .	44
2.1 Sensor Signal . . . . .	44
2.2 Reference Methodology . . . . .	45
2.3 Accuracy and Precision . . . . .	46
3 State of the Art . . . . .	48
4 Unresolved Issues . . . . .	49
4.1 Transient Sensor Signal Disruption . . . . .	49
4.2 Transient Significant CGM Inaccuracies . . . . .	50
5 Next Steps in CGM Development . . . . .	51
6 Conclusion . . . . .	51
References . . . . .	52
 <b>Can We Use Measurements to Classify Patients Suffering from Type 1 Diabetes into Subcategories and Does It Make Sense? . . .</b>	 <b>57</b>
Florian Reiterer, Harald Kirchsteiger, Guido Freckmann and Luigi del Re	
1 Introduction . . . . .	57
2 Database of CGMS Recordings . . . . .	60
3 Modelling Using a Simple Transfer Function Model . . . . .	61
3.1 Description of the Model and System Identification . . . . .	61
3.2 Trends and Correlations . . . . .	64
3.3 Clustering and Classification . . . . .	69
3.4 Discussion of Results and Further Outlook . . . . .	70
4 Analysis of the High Frequency Content of CGMS Signals . . . . .	72
4.1 Filtering of CGMS Signals . . . . .	72
4.2 Trends and Classification . . . . .	73
4.3 Discussion of Results and Further Outlook . . . . .	76
References . . . . .	77
 <b>Prevention of Severe Hypoglycemia by Continuous EEG Monitoring . . . . .</b>	 <b>79</b>
Claus Bogh Juhl, Jonas Duun-Henriksen, Jens Ahm Sørensen, Anne Sophie Sejling and Rasmus Elsborg Madsen	
1 Background . . . . .	80
2 Clinical Studies—Proof of Concept . . . . .	81
3 The Device . . . . .	83
4 Quantitative Evaluation of EEG Recorded with the Partly Implanted EEG Recorder . . . . .	84
5 Development of an Algorithm for Detection and Warning of Severe Hypoglycaemia in Type 1 Diabetes . . . . .	85
6 Clinical Studies—Preliminary Results with Implanted Device . . . . .	88

7 Discussion and Perspectives. . . . .	89
8 Conclusion . . . . .	90
References . . . . .	90

## **Meta-Learning Based Blood Glucose Predictor for Diabetic**

<b>Smartphone App . . . . .</b>	<b>93</b>
---------------------------------	-----------

Valeriya Naumova, Lucian Nita, Jens Ulrik Poulsen  
and Sergei V. Pereverzyev

1 Introduction. . . . .	94
2 Fully Adaptive Regularized Learning Algorithm for the Blood Glucose Prediction . . . . .	96
3 Android Version of the FARL Algorithm . . . . .	99
3.1 Translation of the Algorithm from Matlab to Android System . . . . .	99
3.2 Microprocessor and Power Consumption Analysis . . . . .	100
4 Performance Assessment. . . . .	100
4.1 Clinical Accuracy Metrics . . . . .	100
4.2 Performance Assessment . . . . .	102
4.3 Comparison of the Matlab and Android Versions . . . . .	102
5 Conclusions and Discussion. . . . .	104
References . . . . .	105

## **Predicting Glycemia in Type 1 Diabetes Mellitus**

<b>with Subspace-Based Linear Multistep Predictors . . . . .</b>	<b>107</b>
--	------------

Marzia Cescon, Rolf Johansson and Eric Renard

1 Introduction. . . . .	107
2 Subspace-Based Linear Multistep Predictors . . . . .	110
2.1 Notation . . . . .	111
2.2 Predictors Construction . . . . .	111
3 Experimental Conditions and Clinical Data Acquisition. . . . .	114
4 Predicting Diabetes Glycemia with the Multistep Predictors. . . . .	117
5 Results . . . . .	119
6 Discussion and Conclusions. . . . .	129
References . . . . .	130

## **Empirical Representation of Blood Glucose Variability**

<b>in a Compartmental Model . . . . .</b>	<b>133</b>
---	------------

Stephen D. Patek, Dayu Lv, Edward A. Ortiz, Colleen Hughes-Karvetski,  
Sandip Kulkarni, Qian Zhang and Marc D. Breton

1 Introduction. . . . .	134
2 Oral Carbohydrate “Net Effect”: Reconciling CGM and Pump Data via Regularized Deconvolution. . . . .	136
2.1 Net Effect Core Algorithm. . . . .	138
2.2 CGM Preprocessing . . . . .	139
2.3 Discussion: “Net Effect” Versus “Meal Estimation” . . . . .	140

3	Net Effect Simulation . . . . .	140
3.1	“Replay” Simulation . . . . .	141
3.2	Simulating Modified Insulin Delivery . . . . .	141
4	Results . . . . .	142
4.1	Net Effects and Net Effect Simulation Replay from Field Data . . . . .	143
4.2	In Silico Experiments: Using Net Effect to Design Basal Rate Adjustments . . . . .	150
5	Conclusions . . . . .	151
	References . . . . .	156

### **Physiology-Based Interval Models: A Framework for Glucose Prediction Under Intra-patient Variability . . . . . 159**

Jorge Bondia and Josep Vehi

1	Introduction . . . . .	159
2	Interval Models . . . . .	161
3	Simulating Interval Models . . . . .	163
3.1	Interval Analysis . . . . .	164
3.2	Monotone Input–Output Systems . . . . .	168
4	Interval Glucose Predictors . . . . .	172
4.1	Bergman Model Predictor Based on Modal Interval Analysis . . . . .	172
4.2	Bergman Model Predictor Based on Monotone Systems Theory . . . . .	173
4.3	Postprandial Glucose Prediction Using Interval Models . . . . .	175
5	Interval Model Identification . . . . .	175
6	Conclusions . . . . .	178
	References . . . . .	179

### **Modeling and Prediction Using Stochastic Differential Equations . . . . 183**

Rune Juhl, Jan Kloppenborg Møller, John Bagterp Jørgensen  
and Henrik Madsen

1	Introduction . . . . .	183
2	Data and Modeling . . . . .	185
2.1	Single Data Series . . . . .	186
2.2	Independent Data Series . . . . .	192
2.3	Population Extension . . . . .	193
2.4	Prior Information . . . . .	196
3	Example: Modeling the Effect of Exercise on Insulin Pharmacokinetics in “Continuous Subcutaneous Insulin Infusion” Treated Type 1 Diabetes Patients . . . . .	197
3.1	Data . . . . .	197
3.2	The Gray Box Insulin Model . . . . .	198
3.3	Exercise Effects . . . . .	199

3.4	Model Comparison . . . . .	200
3.5	Predictions . . . . .	202
4	Other Topics . . . . .	202
4.1	Transformations . . . . .	202
4.2	Identification . . . . .	203
4.3	Simulation/Prediction Models . . . . .	203
4.4	Testing and Confidence Intervals . . . . .	203
5	Summary . . . . .	204
	References . . . . .	208
<b>Uncertainties and Modeling Errors of Type 1 Diabetes Models . . . . .</b>		<b>211</b>
Levente Kovács and Péter Szalay		
1	Introduction . . . . .	211
2	Modeling Diabetes . . . . .	212
2.1	Linear Parameter Varying Model . . . . .	214
3	Model Reduction . . . . .	215
4	State Estimation . . . . .	218
4.1	Sigma-Point Selection . . . . .	219
5	Model Uncertainty . . . . .	221
5.1	Error Weighting Function . . . . .	221
6	Conclusion . . . . .	223
	References . . . . .	224
<b>Recent Results on Glucose–Insulin Predictions by Means of a State Observer for Time Delay Systems . . . . .</b>		<b>227</b>
Pasquale Palumbo, Pierdomenico Pepe, Simona Panunzi and Andrea De Gaetano		
1	Introduction . . . . .	227
2	The DDE Model of the Glucose–Insulin System . . . . .	229
3	Observer-Based Control by Means of Intravenous Insulin Infusion . . . . .	230
3.1	Synthesis of the Glucose Control Law . . . . .	231
3.2	Evaluation Criteria and Validation . . . . .	233
4	Observer-Based Control by Means of Subcutaneous Insulin Infusion . . . . .	236
5	Conclusions . . . . .	239
	References . . . . .	239
<b>Performance Assessment of Model-Based Artificial Pancreas Control Systems . . . . .</b>		<b>243</b>
Jianyuan Feng, Kamuran Turksoy and Ali Cinar		
1	Introduction . . . . .	243
2	GPC and Controller Error Detection . . . . .	245
2.1	GPC in AP System . . . . .	245

2.2	Indexes Used for CPA . . . . .	246
2.3	Detection and Diagnosis of Controller Errors . . . . .	249
3	Controller Retuning . . . . .	252
3.1	Controller Retuning for Model Prediction Error . . . . .	252
3.2	Controller Retuning for Insulin Dose Constraint Error . . . . .	254
3.3	Controller Retuning for Objective Function Weight Ratio Error . . . . .	254
3.4	Controller Retuning for Sensor-Noise-Driven Miscalculation Error . . . . .	255
4	Results . . . . .	256
5	Conclusions. . . . .	263
	References . . . . .	263

Prediction Methods for Blood Glucose Concentration  
Design, Use and Evaluation

Kirchsteiger, H.; Jørgensen, J.B.; Renard, E.; del Re, L.  
(Eds.)

2016, XIV, 265 p. 93 illus., 72 illus. in color., Hardcover

ISBN: 978-3-319-25911-6