



UNIVERSITAT
POLITÈCNICA
DE VALÈNCIA

DOCTORADO EN AUTOMÁTICA, ROBÓTICA E INFORMÁTICA INDUSTRIAL

PHD DISSERTATION

New contributions towards meal and exercise announcement-free artificial pancreas systems

Author: Iván Sala Mira

Supervisors: Prof. Jorge Bondia Company
Dr. José Luis Díez Ruano

INSTITUTO DE AUTOMÁTICA E INFORMÁTICA INDUSTRIAL

January 2023

Contents

Abstract	v
Contents	ix
Acronyms	xvii
1 Introduction	1
1.1 Scope and motivation	1
1.2 Objectives	7
1.3 Outline	8
2 Announcement-free artificial pancreas systems: challenges and state of the art	9
2.1 Introduction	9
2.2 Challenges of diurnal control	11
2.3 Strategies to remove meal announcements	15
2.4 Strategies to remove exercise announcements	31
2.5 Conclusion	37
3 Meal disturbance estimation	39
3.1 Introduction	40
3.2 Disturbance estimation	41
3.3 Models	50
3.4 Design and tuning of the observers	68

3.5	Study of the effect of the model and observer structure on the estimation accuracy	82
3.6	Conclusion	86
4	Disturbance reconstruction from clinical datasets	89
4.1	Introduction	89
4.2	Clinical datasets description	90
4.3	Preprocessing	91
4.4	Application of the observer to real meal data	91
4.5	Application of the observer to real exercise data	94
4.6	Conclusions	100
5	Super-twisting-based meal detector	103
5.1	Introduction	104
5.2	Super-twisting-based meal detector	105
5.3	In silico evaluation	111
5.4	Algorithm refinements	113
5.5	Performance evaluation with clinical data	121
5.6	Conclusions	126
6	Unannounced meal compensation based on meal detection	129
6.1	Introduction	130
6.2	Control architecture overview	131
6.3	Bolusing algorithm	133
6.4	Complementary feedforward action	137
6.5	In silico comparison	140
6.6	Conclusions	142
7	Unannounced meal and exercise compensation with a modified IMC	145
7.1	Introduction	147
7.2	Control architecture overview	148
7.3	Internal model control loop	148
7.4	Switching logic	152
7.5	Tuning	158
7.6	In silico validations	163
7.7	Conclusions	175
8	Conclusions and future work	177
8.1	Conclusions	177
8.2	Future work	180

List of publications	181
Journal articles	181
Conference articles	182
Abstracts and posters	182
Patent applications	183
Appendices	185
A Implicit discretization of sliding mode observers	187
B Description of the main controller	191
B.1 Context	191
B.2 Basic controller architecture	192
Bibliography	197