

Do I have a problem with negative IOB – or else?

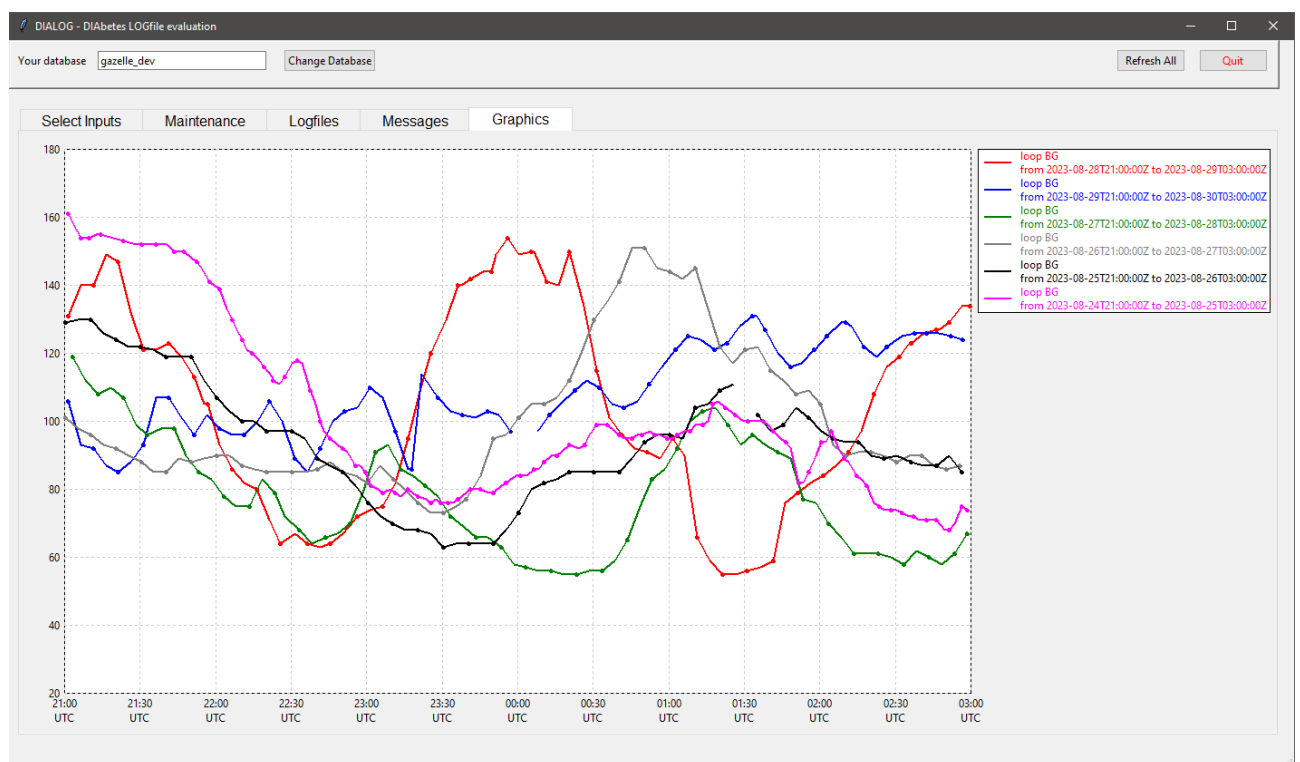
A case study using the emulator

This documents explains the steps I recently went through to analyse a recurring situation that I wanted to improve. It describes how the emulator helped me come up with a satisfactory solution. BGs used to drop below target and IOB turned negative. So was it a problem with negative IOB or something else? After all the loop tries to bring me to target and keep me there. Its goal is not to achieve zero IOB. What could I do to improve things?

Background

Subjectively I observed repeated cases of ending up low before going to bed. Sometimes that even happened after having brushed the teeth, very annoying to have to eat again. So were these occasional events or a systematic situation? When it happened again the other day I had enough of it and started to investigate.

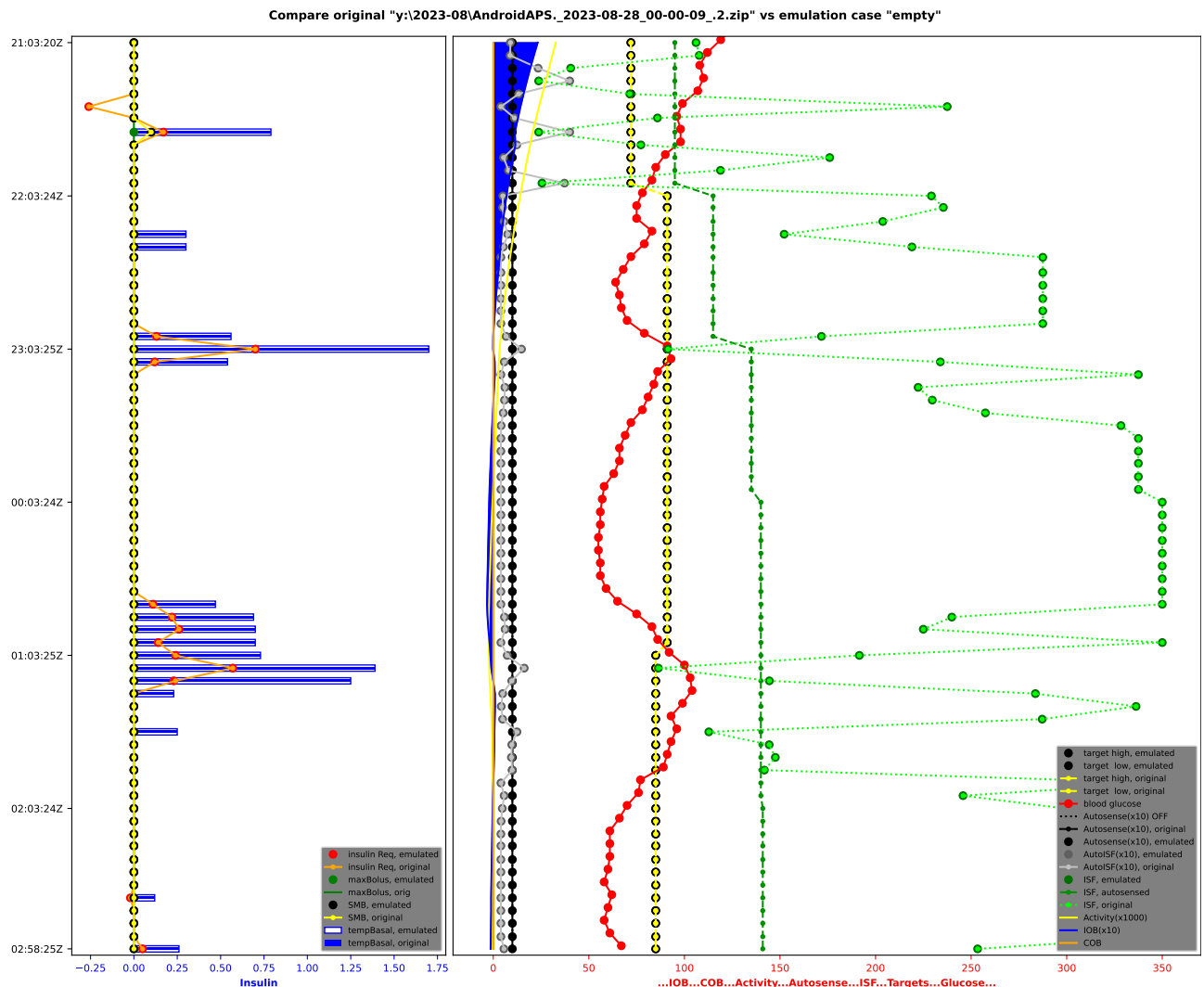
The first step was to look at 6 days in a row to check how often it happens. Here is the plot comparing BG values used by the loop in the relevant time window:



So with hits on 5 out of six days I definitely had a problem somewhere in my settings. I picked the night of Aug, 27th - 28th for a more detailed analysis.

What did the loop actually do?

I used the emulator to get enough detail about what happened. My first step always is to re-execute the original loop by using an empty VDF-file, i.e. there are no variations of any settings. The PDF-file generated gives a first overview:



The left frame shows SMB and basal deliveries. There was only one minor SMB around 21:38 and some groups of TBRs. I can focus on those loops because some of them must be the culprits for delivering the surplus insulin which eventually led to the low values.

On the left edge of the right frame the blue area shows IOB which became negative around 23:18 and stayed negative for longer than 1 hour. I never use any automations to raise targets in such situations. I feel autoISF should stay in control without interfering from outside and competing for control. During all that time autoISF had weakened ISF compared to its profile values. Zero temping ended around 0:45 and TBR started rising. At that time the BG curve takes a left hand turn, i.e. BG is accelerating. In autoISF that acceleration is the most likely reason for insulin demand rather than the negative IOB.

That is all I deduce or rather estimate from the graph without looking at the numbers. All 3 phases of BG below target were preceded by short intervals of SMB or TBRs.

Comparing Influences

So what can I do to reduce insulin delivery? With the emulator I define variants to reduce profile basal by 10% with this VDF-file

```
profile    current_basal    profile['current_basal']*0.9
```

or to weaken ISF by 10% with this VDF-file

```
profile    sens    profile['sens']*1.1
```

That will tell me which of them has more impact, i.e. where I should start adapting settings. I then imported the CSV-files into a Spreadsheet because they contain the interesting numbers. After merging both variants together into a single sheet and hiding the less interesting columns and rows I got this:

	B	E	L	AL	AM	AN	AO	AP	AQ	AR	AS	AT	
1				Basal 10% weaker					ISF 10% weaker				
2	UTC			SMB	SMB	TBR	TBR		SMB	SMB	TBR	TBR	
3	time	BG	iob	orig	emul	orig	emul		orig	emul	orig	emul	
4	21:03:20	119	2,32	0	0	0	0		0	0	0	0	
10													
11	21:32:51	96	1,29	0	0	0	0		0	0	0	0	
12	21:38:25	98	1,14	0,1	0,1	0,79	0,75		0,1	0	0,79	0	
13	21:43:25	98	1,16	0	0	0	0		0	0	0	0	
19													
20	22:13:25	75	0,51	0	0	0	0		0	0	0	0	
21	22:18:24	83	0,43	0	0	0,3	0,27		0	0	0,3	0,3	
22	22:23:23	79	0,38	0	0	0,3	0,27		0	0	0,3	0,3	
23	22:27:27	72	0,34	0	0	0	0		0	0	0	0	
28													
29	22:53:26	70	0,04	0	0	0	0		0	0	0	0	
30	22:58:26	79	-0,01	0	0	0,56	0,53		0	0	0,56	0,54	
31	23:03:25	91	-0,01	0	0	1,7	1,67		0	0	1,7	1,52	
32	23:08:26	93	0,08	0	0	0,54	0,51		0	0	0,54	0,5	
33	23:13:25	86	0,08	0	0	0	0		0	0	0	0	
49													
51	24:38:25	59	-0,32	0	0	0	0		0	0	0	0	
52	24:43:24	65	-0,33	0	0	0,47	0,45		0	0	0,47	0,49	
53	24:48:26	75	-0,3	0	0	0,69	0,67		0	0	0,69	0,69	
54	24:53:11	83	-0,25	0	0	0,7	0,7		0	0	0,7	0,7	
55	24:58:24	86	-0,2	0	0	0,7	0,7		0	0	0,7	0,7	
56	25:03:25	92	-0,15	0	0	0,73	0,71		0	0	0,73	0,71	
57	25:08:25	100	-0,1	0	0	1,39	1,37		0	0	1,39	1,29	
58	25:13:24	103	0	0	0	1,25	1,25		0	0	1,25	1,25	
59	25:18:24	104	0,09	0	0	0,23	0,21		0	0	0,23	0,13	
60	25:23:25	99	0,09	0	0	0	0		0	0	0	0	
61	25:28:25	93	0,08	0	0	0	0		0	0	0	0	
62	25:33:24	96	0,06	0	0	0,25	0,23		0	0	0,25	0,25	
63	25:38:26	93	0,06	0	0	0,01	0		0	0	0,01	0	
64	25:43:24	91	0,04	0	0	0	0		0	0	0	0	
78													
81	Minimum:			0	0				0	0			
82	Maximum:			0,1	0,1				0,1	0			
83	Totals:			0,1	0,1	0,91	0,88		0,1	0	0,91	0,81	
84													

In the bulk section you can see that the reduction in basal had less impact. Especially that initial SMB would remain. The ISF variant has more impact although some of the TBRs are not reduced. In the emulator changes do not propagate to later time steps and therefore do not gross up. Nevertheless the totals line at the bottom is a useful although only a coarse indication of the overall result.

The result

I ran another variant, namely 20% reduction in ISF which showed more reduction in TBR. Therefore I went ahead and reduced profile ISF for that time window by 20%. With that I have not seen any of the situations mentioned. Meanwhile my belt feels a bit loose because with less calories before bedtime I lost some weight.

Minimum:	0	0
Maximum:	0,1	0
Totals:	0,1	0

The negative IOB

Once on the case I wanted to check whether there was something special here due to negative IOB. In the code I found 2 places where negative IOB gets specific attention:

1. Naive BG forecast is calculated from current BG, net IOB and sensitivity. If IOB is negative use the lower of profile sensitivity and modified sensitivity so resulting in a lower forecast which in turn results in a lower insulin demand. So there is no punishment here for having negative IOB.
2. Original comment in the code: don't low glucose suspend if IOB is already super negative and BG is rising faster than predicted.
 "Super negative" means at least the amount equivalent to 20 minutes of profile basal is missing. And it is only relevant if BG is predicted to rise which is similar to the objectives questions whether insulin might be released although being below target. The consequence of this condition is just not to go for LGS but calculate insulin required as usual. There is nothing in the code that adds extra insulin because IOB was negative.

In my case this condition was met at 0:43 with a message in the loops reasoning saying

"...IOB -0.326 < -0.08 and minDelta 4.0 > expectedDelta 3.0..."

to be found in the logfile and in the emulators TXT-files. At all other times this condition was not triggered.

So far I did not get into trouble during longer periods of negative IOB. But what could I do to make it even safer? I tested five alternatives and focussed just on the 90 minutes time window when IOB was negative and insulin was released in the original loop. Here is the compilation of results:

	B	E	L	AE	AH	AN	AP	AQ	AR	AS	AT	AU	AV	AW	AX	AY	AZ	BA	BB	BC	BD	
1				orig				TT=120		no autoISF			no autoISF; TT=120			without specials			w/o specials; TT=120			
2				Ins.				Ins.		Ins.			Ins.			Ins.			Ins.			
3	UTC			ISF	Req.	TBR	ISF	Req.	TBR	ISF	Req.	TBR	ISF	Req.	TBR	ISF	Req.	TBR	ISF	Req.	TBR	
4	time	bg	ioB	orig	orig	orig	emul	emul	emul	emul	emul	emul	emul	emul	emul	emul	emul	emul	emul	emul	emul	
5	00:03:24	57	-0.21	350	0	0	350	0	0	140	0	0	140	0	0	140	0	0	140	0	0	0
6	00:08:25	56	-0.23	350	0	0	350	0	0	140	0	0	140	0	0	140	0	0	140	0	0	0
7	00:13:25	56	-0.25	350	0	0	350	0	0	140	0	0	140	0	0	140	0	0	140	0	0	0
8	00:18:25	55	-0.26	350	0	0	350	0	0	140	0	0	140	0	0	140	0	0	140	0	0	0
9	00:23:25	55	-0.28	350	0	0	350	0	0	140	0	0	140	0	0	140	0	0	140	0	0	0
10	00:28:24	56	-0.29	350	0	0	350	0	0	140	0	0	140	0	0	140	0	0	140	0	0	0
11	00:33:25	56	-0.3	350	0	0	350	0	0	140	0	0	140	0	0	140	0	0	140	0	0	0
12	00:38:25	59	-0.32	350	0	0	350	0	0	140	0	0.25	140	0	0	140	0	0.25	140	0	0	0
13	00:43:24	65	-0.33	350	0.11	0.47	350	0.06	0.37	140	0.06	0.37	140	0	0.25	140	0.14	0.53	140	0	0.25	0
14	00:48:26	75	-0.3	239.9	0.22	0.69	350	0.13	0.48	140	0.29	0.83	140	0.13	0.48	140	0.34	0.93	140	0.13	0.48	0
15	00:53:11	83	-0.25	225	0.26	0.7	350	0.14	0.7	140	0.37	0.99	140	0.18	0.7	140	0.43	1.11	140	0.18	0.7	0
16	00:58:24	86	-0.2	350	0.14	0.7	350	0.07	0.39	140	0.23	0.71	140	0.04	0.33	140	0.25	0.75	140	0.04	0.33	0
17	01:03:25	92	-0.15	191.5	0.24	0.73	350	0.07	0.7	140	0.29	0.83	140	0.04	0.33	140	0.29	0.83	140	0.04	0.33	0
18	01:08:25	100	-0.1	86.4	0.57	1.39	218.1	0.1	0.73	140	0.36	0.97	140	0.11	0.73	140	0.36	0.97	140	0.11	0.73	0
19	01:13:24	103	0	144.5	0.24	1.25	334.4	0	0.15	140	0.24	1.25	140	0	0.25	140	0.24	1.25	140	0	0.25	0
20	01:18:24	104	0.09	283.6	0	0.23	325	0	0	140	0.09	0.43	140	0	0	140	0.09	0.43	140	0	0	0
21	01:23:25	99	0.09	336.3	0	0	350	0	0	140	0	0	140	0	0	140	0	0.23	140	0	0	0
22	01:28:25	93	0.08	287.2	0	0	350	0	0	140	0	0	140	0	0	140	0	0	140	0	0	0
23	Minimum:	55		86.4			218.1			140			140			140			140			
24	Maximum:	104		350			350			140			140			140			140			
25	Totals:					0.51			0.29			0.55			0.26			0.61			0.26	

Automation to set TT=120

This is a very popular method and can easily be tested in the emulator with this VDF-file:

```
profile min_bg 120 ### popular automation
profile max_bg 120 ### popular automation
profile temptargetSet True ### activate as TT
```

No surprise here. A very effective way to reduce TBRs. May be a lower value would have been sufficient like TT=102 to still keep SMBs off.

Switch off autoISF

Disabling all ISF modulations in autoISF is also easy in the emulator with this VDF-file:

```
profile enable_autoISF False ### check -ve IOB case
```

The effect shows a minor advantage for keeping autoISF enabled. The reason is that without autoISF sensitivity is not increased while below target and therefore the loop needs more insulin to manage the expected BG rise. Interestingly at time 0:38 there now is another case of “super negative” mentioned above and leads to an additional non-zero TBR.

Switch off autoISF plus automation to set TT=120

Combining the first two is very similar to using just the TT=120 method.

Switch off private specials

For BG close to target or even below I use some private modifications to reduce insulin required. Together with switching off autoISF this makes the loop behave like vanilla AAPS. This is the least favourable case. Interestingly at time 0:38 there now is another case of “super negative” mentioned above and leads to an additional non-zero TBR.

Switch off private specials plus automation to set TT=120

This configuration of vanilla AAPS plus automation is what many users have. It clearly is a very good way if I wanted to keep the lid on insulin delivery during such situations.

Conclusion

As expected an automation for setting TT=120 has the dominant effect. My private modifications contribute less than expected but then their main purpose is to limit SMBs below or close to target.