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Noise rejection methods and apparatus for sparsely sampled analyte sensor data

Abstract

Systems, methods and apparatus are provided for rejecting noise from sparsely sampled analyte sensor data. Embodiments of the present disclosure include receiving a raw set of sensor data from an on-body device including an in vivo analyte sensor, determining an interpolation-based estimate of an analyte level over time based on the raw set of sensor data, determining an extrapolation-based estimate of the analyte level over time based on the raw set of sensor data, determining a combined estimate of the analyte level over time based on the interpolation-based estimate and the extrapolation-based estimate, and displaying a representation of the combined estimate of the analyte level over time on an output device. Numerous additional aspects are disclosed.

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References Cited

U.S. PATENT DOCUMENTS

Patent No.	Issued Date	Patentee Name	U.S. Cl.	CPC
3581062	12/1970	Aston	N/A	N/A
3926760	12/1974	Allen et al.	N/A	N/A
3949388	12/1975	Fuller	N/A	N/A
3960497	12/1975	Acord et al.	N/A	N/A
3978856	12/1975	Michel	N/A	N/A
4036749	12/1976	Anderson	N/A	N/A
4055175	12/1976	Clemens et al.	N/A	N/A
4129128	12/1977	McFarlane	N/A	N/A
4245634	12/1980	Albisser et al.	N/A	N/A
4327725	12/1981	Cortese et al.	N/A	N/A
4344438	12/1981	Schultz	N/A	N/A
4349728	12/1981	Phillips et al.	N/A	N/A
4373527	12/1982	Fischell	N/A	N/A
4392849	12/1982	Petre et al.	N/A	N/A
4425920	12/1983	Bourland et al.	N/A	N/A
4441968	12/1983	Emmer et al.	N/A	N/A
4462048	12/1983	Ross	N/A	N/A
4478976	12/1983	Goertz et al.	N/A	N/A
4494950	12/1984	Fischell	N/A	N/A
4509531	12/1984	Ward	N/A	N/A
4527240	12/1984	Kvitash	N/A	N/A
4538616	12/1984	Rogoff	N/A	N/A
4545382	12/1984	Higgins et al.	N/A	N/A
4619793	12/1985	Lee	N/A	N/A
4671288	12/1986	Gough	N/A	N/A
4703756	12/1986	Gough et al.	N/A	N/A
4711245	12/1986	Higgins et al.	N/A	N/A
4731051	12/1987	Fischell	N/A	N/A
4731726	12/1987	Allen, III	N/A	N/A
4749985	12/1987	Corsberg	N/A	N/A
4757022	12/1987	Shults et al.	N/A	N/A
4759366	12/1987	Callaghan	N/A	N/A
4777953	12/1987	Ash et al.	N/A	N/A
4779618	12/1987	Mund et al.	N/A	N/A
4854322	12/1988	Ash et al.	N/A	N/A
4871351	12/1988	Feingold	N/A	N/A

4890620	12/1989	Gough	N/A	N/A
4925268	12/1989	Iyer et al.	N/A	N/A
4947845	12/1989	Davis	N/A	N/A
4953552	12/1989	DeMarzo	N/A	N/A
4986271	12/1990	Wilkins	N/A	N/A
4995402	12/1990	Smith et al.	N/A	N/A
5000180	12/1990	Kuypers et al.	N/A	N/A
5002054	12/1990	Ash et al.	N/A	N/A
5019974	12/1990	Beckers	N/A	N/A
5050612	12/1990	Matsumura	N/A	N/A
5055171	12/1990	Peck	N/A	N/A
5068536	12/1990	Rosenthal	N/A	N/A
5077476	12/1990	Rosenthal	N/A	N/A
5082550	12/1991	Rishpon et al.	N/A	N/A
5106365	12/1991	Hernandez	N/A	N/A
5113869	12/1991	Nappholz et al.	N/A	N/A
5122925	12/1991	Inpyn	N/A	N/A
5135004	12/1991	Adams et al.	N/A	N/A
5148812	12/1991	Verrier et al.	N/A	N/A
5165407	12/1991	Wilson et al.	N/A	N/A
5199428	12/1992	Obel et al.	N/A	N/A
5202261	12/1992	Musho et al.	N/A	N/A
5203326	12/1992	Collins	N/A	N/A
5204264	12/1992	Kaminer et al.	N/A	N/A
5210778	12/1992	Massart	N/A	N/A
5231988	12/1992	Wernicke et al.	N/A	N/A
5246867	12/1992	Lakowicz et al.	N/A	N/A
5262035	12/1992	Gregg et al.	N/A	N/A
5262305	12/1992	Heller et al.	N/A	N/A
5264104	12/1992	Gregg et al.	N/A	N/A
5264105	12/1992	Gregg et al.	N/A	N/A
5279294	12/1993	Anderson et al.	N/A	N/A
5285792	12/1993	Sjoquist et al.	N/A	N/A
5293877	12/1993	O'Hara et al.	N/A	N/A
5299571	12/1993	Mastrototaro	N/A	N/A
5313953	12/1993	Yomtov et al.	N/A	N/A
5320715	12/1993	Berg	N/A	N/A
5320725	12/1993	Gregg et al.	N/A	N/A
5322063	12/1993	Allen et al.	N/A	N/A
5328460	12/1993	Lord et al.	N/A	N/A
5330634	12/1993	Wong et al.	N/A	N/A
5340722	12/1993	Wolfbeis et al.	N/A	N/A
5342789	12/1993	Chick et al.	N/A	N/A
5356786	12/1993	Heller et al.	N/A	N/A
5360404	12/1993	Novacek et al.	N/A	N/A
5365426	12/1993	Siegel et al.	N/A	N/A
5372427	12/1993	Padovani et al.	N/A	N/A
5376070	12/1993	Purvis et al.	N/A	N/A
5379238	12/1994	Stark	N/A	N/A
5384547	12/1994	Lynk et al.	N/A	N/A

5390671	12/1994	Lord et al.	N/A	N/A
5391250	12/1994	Cheney, II et al.	N/A	N/A
5400795	12/1994	Murphy et al.	N/A	N/A
5408999	12/1994	Singh et al.	N/A	N/A
5411647	12/1994	Johnson et al.	N/A	N/A
5425749	12/1994	Adams	N/A	N/A
5425868	12/1994	Pedersen	N/A	N/A
5431160	12/1994	Wilkins	N/A	N/A
5431921	12/1994	Thombre	N/A	N/A
5438983	12/1994	Falcone	N/A	N/A
5462645	12/1994	Albery et al.	N/A	N/A
5472317	12/1994	Field et al.	N/A	N/A
5489414	12/1995	Schreiber et al.	N/A	N/A
5497772	12/1995	Schulman et al.	N/A	N/A
5505828	12/1995	Wong et al.	N/A	N/A
5507288	12/1995	Bocker et al.	N/A	N/A
5509410	12/1995	Hill et al.	N/A	N/A
5514718	12/1995	Lewis et al.	N/A	N/A
5520191	12/1995	Karlsson et al.	N/A	N/A
5531878	12/1995	Vadgama et al.	N/A	N/A
5532686	12/1995	Urbas et al.	N/A	N/A
5543326	12/1995	Heller et al.	N/A	N/A
5552997	12/1995	Massart	N/A	N/A
5568400	12/1995	Stark et al.	N/A	N/A
5568806	12/1995	Cheney, II et al.	N/A	N/A
5569186	12/1995	Lord et al.	N/A	N/A
5582184	12/1995	Erickson et al.	N/A	N/A
5586553	12/1995	Halili et al.	N/A	N/A
5593852	12/1996	Heller et al.	N/A	N/A
5601435	12/1996	Quy	N/A	N/A
5609575	12/1996	Larson et al.	N/A	N/A
5628310	12/1996	Rao et al.	N/A	N/A
5628890	12/1996	Nigel et al.	N/A	N/A
5634468	12/1996	Platt et al.	N/A	N/A
5640954	12/1996	Pfeiffer et al.	N/A	N/A
5653239	12/1996	Pompei et al.	N/A	N/A
5660163	12/1996	Schulman et al.	N/A	N/A
5665222	12/1996	Heller et al.	N/A	N/A
5707502	12/1997	McCaffrey et al.	N/A	N/A
5711001	12/1997	Bussan et al.	N/A	N/A
5711861	12/1997	Ward et al.	N/A	N/A
5720295	12/1997	Greenhut et al.	N/A	N/A
5724030	12/1997	Urbas et al.	N/A	N/A
5733259	12/1997	Valcke et al.	N/A	N/A
5735285	12/1997	Albert et al.	N/A	N/A
5741211	12/1997	Renirie et al.	N/A	N/A
5749907	12/1997	Mann	N/A	N/A
5772586	12/1997	Heinonen et al.	N/A	N/A
5785660	12/1997	van Lake et al.	N/A	N/A
5791344	12/1997	Schulman et al.	N/A	N/A

5792065	12/1997	Xue et al.	N/A	N/A
5804047	12/1997	Karube et al.	N/A	N/A
5820551	12/1997	Hill et al.	N/A	N/A
5822715	12/1997	Worthington et al.	N/A	N/A
5891047	12/1998	Lander et al.	N/A	N/A
5891049	12/1998	Cyrus et al.	N/A	N/A
5899855	12/1998	Brown	N/A	N/A
5914026	12/1998	Blubaugh, Jr. et al.	N/A	N/A
5918603	12/1998	Brown	N/A	N/A
5925021	12/1998	Castellano et al.	N/A	N/A
5935224	12/1998	Svancarek et al.	N/A	N/A
5942979	12/1998	Luppino	N/A	N/A
5951485	12/1998	Cyrus et al.	N/A	N/A
5957854	12/1998	Besson et al.	N/A	N/A
5960797	12/1998	Kramer et al.	N/A	N/A
5961451	12/1998	Reber et al.	N/A	N/A
5964993	12/1998	Blubaugh, Jr. et al.	N/A	N/A
5965380	12/1998	Heller et al.	N/A	N/A
5971922	12/1998	Arita et al.	N/A	N/A
5995860	12/1998	Sun et al.	N/A	N/A
6001067	12/1998	Shults et al.	N/A	N/A
6016443	12/1999	Ekwall et al.	N/A	N/A
6021350	12/1999	Mathson	N/A	N/A
6024699	12/1999	Surwit et al.	N/A	N/A
6038469	12/1999	Karlsson et al.	N/A	N/A
6049727	12/1999	Crothall	N/A	N/A
6071391	12/1999	Gotoh et al.	N/A	N/A
6073031	12/1999	Helstab et al.	N/A	N/A
6083710	12/1999	Heller et al.	N/A	N/A
6088608	12/1999	Schulman et al.	N/A	N/A
6091976	12/1999	Pfeiffer et al.	N/A	N/A
6091987	12/1999	Thompson	N/A	N/A
6093172	12/1999	Funderburk et al.	N/A	N/A
6103033	12/1999	Say et al.	N/A	N/A
6108577	12/1999	Benser	N/A	N/A
6112116	12/1999	Fischell	N/A	N/A
6115622	12/1999	Minoz	N/A	N/A
6115628	12/1999	Stadler et al.	N/A	N/A
6117290	12/1999	Say et al.	N/A	N/A
6119028	12/1999	Schulman et al.	N/A	N/A
6120676	12/1999	Heller et al.	N/A	N/A
6121009	12/1999	Heller et al.	N/A	N/A
6121611	12/1999	Lindsay et al.	N/A	N/A
6122351	12/1999	Schlueter, Jr. et al.	N/A	N/A
6128526	12/1999	Stadler et al.	N/A	N/A
6130623	12/1999	MacLellan et al.	N/A	N/A
6134461	12/1999	Say et al.	N/A	N/A
6143164	12/1999	Heller et al.	N/A	N/A
6144837	12/1999	Quy	N/A	N/A
6144871	12/1999	Saito et al.	N/A	N/A

6159147	12/1999	Lichter et al.	N/A	N/A
6161095	12/1999	Brown	N/A	N/A
6162611	12/1999	Heller et al.	N/A	N/A
6175752	12/2000	Say et al.	N/A	N/A
6200265	12/2000	Walsh et al.	N/A	N/A
6212416	12/2000	Ward et al.	N/A	N/A
6219574	12/2000	Cormier et al.	N/A	N/A
6223283	12/2000	Chaiken et al.	N/A	N/A
6233471	12/2000	Berner et al.	N/A	N/A
6233486	12/2000	Ekwall et al.	N/A	N/A
6248067	12/2000	Causey, III et al.	N/A	N/A
6249705	12/2000	Snell	N/A	N/A
6254586	12/2000	Mann et al.	N/A	N/A
6256538	12/2000	Ekwall	N/A	N/A
6264606	12/2000	Ekwall et al.	N/A	N/A
6270455	12/2000	Brown	N/A	N/A
6272379	12/2000	Fischell et al.	N/A	N/A
6275717	12/2000	Gross et al.	N/A	N/A
6283761	12/2000	Joao	N/A	N/A
6284478	12/2000	Heller et al.	N/A	N/A
6291200	12/2000	LeJeune et al.	N/A	N/A
6293925	12/2000	Safabash et al.	N/A	N/A
6294997	12/2000	Paratore et al.	N/A	N/A
6295506	12/2000	Heinonen et al.	N/A	N/A
6299757	12/2000	Feldman et al.	N/A	N/A
6306104	12/2000	Cunningham et al.	N/A	N/A
6309884	12/2000	Cooper et al.	N/A	N/A
6329161	12/2000	Heller et al.	N/A	N/A
6338790	12/2001	Feldman et al.	N/A	N/A
6348640	12/2001	Navot et al.	N/A	N/A
6359444	12/2001	Grimes	N/A	N/A
6360888	12/2001	McIvor et al.	N/A	N/A
6361503	12/2001	Starobin et al.	N/A	N/A
6366794	12/2001	Moussy et al.	N/A	N/A
6377828	12/2001	Chaiken et al.	N/A	N/A
6377852	12/2001	Bornzin et al.	N/A	N/A
6377894	12/2001	Deweese et al.	N/A	N/A
6379301	12/2001	Worthington et al.	N/A	N/A
6381493	12/2001	Stadler et al.	N/A	N/A
6387048	12/2001	Schulman et al.	N/A	N/A
6400974	12/2001	Lesho	N/A	N/A
6405066	12/2001	Essenpreis et al.	N/A	N/A
6413393	12/2001	Van Antwerp et al.	N/A	N/A
6416471	12/2001	Kumar et al.	N/A	N/A
6418346	12/2001	Nelson et al.	N/A	N/A
6424847	12/2001	Mastrototaro et al.	N/A	N/A
6427088	12/2001	Bowman, IV et al.	N/A	N/A
6440068	12/2001	Brown et al.	N/A	N/A
6461496	12/2001	Feldman et al.	N/A	N/A
6471689	12/2001	Joseph et al.	N/A	N/A

6478736	12/2001	Mault	N/A	N/A
6484046	12/2001	Say et al.	N/A	N/A
6496729	12/2001	Thompson	N/A	N/A
6497655	12/2001	Linberg et al.	N/A	N/A
6501983	12/2001	Natarajan et al.	N/A	N/A
6503381	12/2002	Gotoh et al.	N/A	N/A
6514460	12/2002	Fendrock	N/A	N/A
6514718	12/2002	Heller et al.	N/A	N/A
6520326	12/2002	McIvor et al.	N/A	N/A
6540891	12/2002	Stewart et al.	N/A	N/A
6544212	12/2002	Galley et al.	N/A	N/A
6549796	12/2002	Sohrab	N/A	N/A
6551494	12/2002	Heller et al.	N/A	N/A
6558320	12/2002	Causey, III et al.	N/A	N/A
6558321	12/2002	Burd et al.	N/A	N/A
6558351	12/2002	Steil et al.	N/A	N/A
6560471	12/2002	Heller et al.	N/A	N/A
6561975	12/2002	Pool et al.	N/A	N/A
6561978	12/2002	Conn et al.	N/A	N/A
6562001	12/2002	Lebel et al.	N/A	N/A
6564105	12/2002	Starkweather et al.	N/A	N/A
6565509	12/2002	Say et al.	N/A	N/A
6571128	12/2002	Lebel et al.	N/A	N/A
6572542	12/2002	Houben et al.	N/A	N/A
6574490	12/2002	Abbink et al.	N/A	N/A
6574510	12/2002	Von Arx et al.	N/A	N/A
6576101	12/2002	Heller et al.	N/A	N/A
6577899	12/2002	Lebel et al.	N/A	N/A
6579231	12/2002	Phipps	N/A	N/A
6579690	12/2002	Bonnecaze et al.	N/A	N/A
6585644	12/2002	Lebel et al.	N/A	N/A
6591125	12/2002	Buse et al.	N/A	N/A
6592745	12/2002	Feldman et al.	N/A	N/A
6595919	12/2002	Berner et al.	N/A	N/A
6600997	12/2002	Deweese et al.	N/A	N/A
6605200	12/2002	Mao et al.	N/A	N/A
6605201	12/2002	Mao et al.	N/A	N/A
6607509	12/2002	Bobroff et al.	N/A	N/A
6610012	12/2002	Mault	N/A	N/A
6616819	12/2002	Liamos et al.	N/A	N/A
6618934	12/2002	Feldman et al.	N/A	N/A
6622045	12/2002	Snell et al.	N/A	N/A
6633772	12/2002	Ford et al.	N/A	N/A
6635014	12/2002	Starkweather et al.	N/A	N/A
6635167	12/2002	Batman et al.	N/A	N/A
6641533	12/2002	Causey, III et al.	N/A	N/A
6648821	12/2002	Lebel et al.	N/A	N/A
6650471	12/2002	Doi	N/A	N/A
6654625	12/2002	Say et al.	N/A	N/A
6656114	12/2002	Poulson et al.	N/A	N/A

6658396	12/2002	Tang et al.	N/A	N/A
6659948	12/2002	Lebel et al.	N/A	N/A
6668196	12/2002	Villegas et al.	N/A	N/A
6675030	12/2003	Ciuczak et al.	N/A	N/A
6676816	12/2003	Mao et al.	N/A	N/A
6687546	12/2003	Lebel et al.	N/A	N/A
6689056	12/2003	Kilcoyne et al.	N/A	N/A
6694191	12/2003	Starkweather et al.	N/A	N/A
6695860	12/2003	Ward et al.	N/A	N/A
6698269	12/2003	Baber et al.	N/A	N/A
6702857	12/2003	Brauker et al.	N/A	N/A
6730200	12/2003	Stewart et al.	N/A	N/A
6731976	12/2003	Penn et al.	N/A	N/A
6731985	12/2003	Poore et al.	N/A	N/A
6733446	12/2003	Lebel et al.	N/A	N/A
6735183	12/2003	O'Toole et al.	N/A	N/A
6736957	12/2003	Forrow et al.	N/A	N/A
6740075	12/2003	Lebel et al.	N/A	N/A
6741877	12/2003	Shults et al.	N/A	N/A
6746582	12/2003	Heller et al.	N/A	N/A
6749740	12/2003	Liamos et al.	N/A	N/A
6758810	12/2003	Lebel et al.	N/A	N/A
6764581	12/2003	Forrow et al.	N/A	N/A
6770030	12/2003	Schaupp et al.	N/A	N/A
6773671	12/2003	Lewis et al.	N/A	N/A
6790178	12/2003	Mault et al.	N/A	N/A
6804558	12/2003	Haller et al.	N/A	N/A
6809653	12/2003	Mann et al.	N/A	N/A
6810290	12/2003	Lebel et al.	N/A	N/A
6811533	12/2003	Lebel et al.	N/A	N/A
6811534	12/2003	Bowman, IV et al.	N/A	N/A
6813519	12/2003	Lebel et al.	N/A	N/A
6850790	12/2004	Berner et al.	N/A	N/A
6862465	12/2004	Shults et al.	N/A	N/A
6865407	12/2004	Kimball et al.	N/A	N/A
6873268	12/2004	Lebel et al.	N/A	N/A
6878112	12/2004	Linberg et al.	N/A	N/A
6881551	12/2004	Heller et al.	N/A	N/A
6882940	12/2004	Potts et al.	N/A	N/A
6892085	12/2004	McIvor et al.	N/A	N/A
6893545	12/2004	Gotoh et al.	N/A	N/A
6895263	12/2004	Shin et al.	N/A	N/A
6895265	12/2004	Silver	N/A	N/A
6912413	12/2004	Rantala et al.	N/A	N/A
6923763	12/2004	Kovatchev et al.	N/A	N/A
6923764	12/2004	Aceti et al.	N/A	N/A
6931327	12/2004	Goode, Jr. et al.	N/A	N/A
6932892	12/2004	Chen et al.	N/A	N/A
6932894	12/2004	Mao et al.	N/A	N/A
6936006	12/2004	Sabra	N/A	N/A

6940403	12/2004	Kail, IV	N/A	N/A
6941163	12/2004	Ford et al.	N/A	N/A
6942518	12/2004	Liamos et al.	N/A	N/A
6950708	12/2004	Bowman IV et al.	N/A	N/A
6958705	12/2004	Lebel et al.	N/A	N/A
6968294	12/2004	Gutta et al.	N/A	N/A
6971274	12/2004	Olin	N/A	N/A
6974437	12/2004	Lebel et al.	N/A	N/A
6990366	12/2005	Say et al.	N/A	N/A
6997907	12/2005	Safabash et al.	N/A	N/A
6998247	12/2005	Monfre et al.	N/A	N/A
7003336	12/2005	Holker et al.	N/A	N/A
7003340	12/2005	Say et al.	N/A	N/A
7003341	12/2005	Say et al.	N/A	N/A
7009511	12/2005	Mazar et al.	N/A	N/A
7010345	12/2005	Hill et al.	N/A	N/A
7011630	12/2005	Desai et al.	N/A	N/A
7016713	12/2005	Gardner et al.	N/A	N/A
7016720	12/2005	Kroll	N/A	N/A
7020508	12/2005	Stivoric et al.	N/A	N/A
7022072	12/2005	Fox et al.	N/A	N/A
7022219	12/2005	Mansouri et al.	N/A	N/A
7024236	12/2005	Ford et al.	N/A	N/A
7024245	12/2005	Lebel et al.	N/A	N/A
7025425	12/2005	Kovatchev et al.	N/A	N/A
7029443	12/2005	Kroll	N/A	N/A
7029444	12/2005	Shin et al.	N/A	N/A
7041068	12/2005	Freeman et al.	N/A	N/A
7041468	12/2005	Drucker et al.	N/A	N/A
7043287	12/2005	Khalil et al.	N/A	N/A
7043305	12/2005	KenKnight et al.	N/A	N/A
7052483	12/2005	Wojcik	N/A	N/A
7056302	12/2005	Douglas	N/A	N/A
7058453	12/2005	Nelson et al.	N/A	N/A
7060031	12/2005	Webb et al.	N/A	N/A
7074307	12/2005	Simpson et al.	N/A	N/A
7076300	12/2005	Kroll et al.	N/A	N/A
7081195	12/2005	Simpson et al.	N/A	N/A
7082334	12/2005	Boute et al.	N/A	N/A
7092891	12/2005	Maus et al.	N/A	N/A
7096064	12/2005	Deno et al.	N/A	N/A
7098803	12/2005	Mann et al.	N/A	N/A
7103412	12/2005	Kroll	N/A	N/A
7108778	12/2005	Simpson et al.	N/A	N/A
7110803	12/2005	Shults et al.	N/A	N/A
7113821	12/2005	Sun et al.	N/A	N/A
7118667	12/2005	Lee	N/A	N/A
7123950	12/2005	Mannheimer	N/A	N/A
7125382	12/2005	Zhou et al.	N/A	N/A
7134999	12/2005	Brauker et al.	N/A	N/A

7136689	12/2005	Shults et al.	N/A	N/A
7142911	12/2005	Boileau et al.	N/A	N/A
7153265	12/2005	Vachon	N/A	N/A
7167818	12/2006	Brown	N/A	N/A
7171274	12/2006	Starkweather et al.	N/A	N/A
7190988	12/2006	Say et al.	N/A	N/A
7192450	12/2006	Brauker et al.	N/A	N/A
7198606	12/2006	Boecker et al.	N/A	N/A
7203549	12/2006	Schommer et al.	N/A	N/A
7225535	12/2006	Feldman et al.	N/A	N/A
7226978	12/2006	Tapsak et al.	N/A	N/A
7228182	12/2006	Healy et al.	N/A	N/A
7237712	12/2006	DeRocco et al.	N/A	N/A
7258673	12/2006	Racchini et al.	N/A	N/A
7267665	12/2006	Steil et al.	N/A	N/A
7272436	12/2006	Gill et al.	N/A	N/A
7276029	12/2006	Goode, Jr. et al.	N/A	N/A
7278983	12/2006	Ireland et al.	N/A	N/A
7295867	12/2006	Berner et al.	N/A	N/A
7297114	12/2006	Gill et al.	N/A	N/A
7299082	12/2006	Feldman et al.	N/A	N/A
7310544	12/2006	Brister et al.	N/A	N/A
7317938	12/2007	Lorenz et al.	N/A	N/A
7318816	12/2007	Bobroff et al.	N/A	N/A
7324850	12/2007	Persen et al.	N/A	N/A
7335294	12/2007	Heller et al.	N/A	N/A
7347819	12/2007	Lebel et al.	N/A	N/A
7354420	12/2007	Steil et al.	N/A	N/A
7364592	12/2007	Carr-Brendel et al.	N/A	N/A
7366556	12/2007	Brister et al.	N/A	N/A
7379765	12/2007	Petisce et al.	N/A	N/A
7384397	12/2007	Zhang et al.	N/A	N/A
7387010	12/2007	Sunshine et al.	N/A	N/A
7399277	12/2007	Saidara et al.	N/A	N/A
7402153	12/2007	Steil et al.	N/A	N/A
7404796	12/2007	Ginsberg	N/A	N/A
7419573	12/2007	Gundel	N/A	N/A
7424318	12/2007	Brister et al.	N/A	N/A
7460898	12/2007	Brister et al.	N/A	N/A
7467003	12/2007	Brister et al.	N/A	N/A
7468125	12/2007	Kraft et al.	N/A	N/A
7471972	12/2007	Rhodes et al.	N/A	N/A
7474992	12/2008	Ariyur	N/A	N/A
7492254	12/2008	Bandy et al.	N/A	N/A
7494465	12/2008	Brister et al.	N/A	N/A
7497827	12/2008	Brister et al.	N/A	N/A
7499002	12/2008	Blasko et al.	N/A	N/A
7502644	12/2008	Gill et al.	N/A	N/A
7519408	12/2008	Rasdal et al.	N/A	N/A
7524287	12/2008	Bharmi	N/A	N/A

7547281	12/2008	Hayes et al.	N/A	N/A
7565197	12/2008	Haubrich et al.	N/A	N/A
7569030	12/2008	Lebel et al.	N/A	N/A
7574266	12/2008	Dudding et al.	N/A	N/A
7583990	12/2008	Goode, Jr. et al.	N/A	N/A
7591801	12/2008	Brauker et al.	N/A	N/A
7599726	12/2008	Goode, Jr. et al.	N/A	N/A
7602310	12/2008	Mann et al.	N/A	N/A
7604178	12/2008	Stewart	N/A	N/A
7613491	12/2008	Boock et al.	N/A	N/A
7615007	12/2008	Shults et al.	N/A	N/A
7618369	12/2008	Hayter et al.	N/A	N/A
7630748	12/2008	Budiman	N/A	N/A
7632228	12/2008	Brauker et al.	N/A	N/A
7635594	12/2008	Holmes et al.	N/A	N/A
7637868	12/2008	Saint et al.	N/A	N/A
7640048	12/2008	Dobbles et al.	N/A	N/A
7643798	12/2009	Ljung	N/A	N/A
7659823	12/2009	Killian et al.	N/A	N/A
7668596	12/2009	Von Arx et al.	N/A	N/A
7699775	12/2009	Desai et al.	N/A	N/A
7699964	12/2009	Feldman et al.	N/A	N/A
7736310	12/2009	Taub et al.	N/A	N/A
7741734	12/2009	Joannopoulos et al.	N/A	N/A
7766829	12/2009	Sloan et al.	N/A	N/A
7771352	12/2009	Shults et al.	N/A	N/A
7774145	12/2009	Bruaker et al.	N/A	N/A
7778680	12/2009	Goode, Jr. et al.	N/A	N/A
7779332	12/2009	Karr et al.	N/A	N/A
7782192	12/2009	Jeckelmann et al.	N/A	N/A
7783333	12/2009	Brister et al.	N/A	N/A
7791467	12/2009	Mazar et al.	N/A	N/A
7792562	12/2009	Shults et al.	N/A	N/A
7826981	12/2009	Goode, Jr. et al.	N/A	N/A
7831310	12/2009	Lebel et al.	N/A	N/A
7860574	12/2009	Von Arx et al.	N/A	N/A
7866026	12/2010	Wang et al.	N/A	N/A
7882611	12/2010	Shah et al.	N/A	N/A
7889069	12/2010	Fifolt et al.	N/A	N/A
7899511	12/2010	Shults et al.	N/A	N/A
7905833	12/2010	Brister et al.	N/A	N/A
7912674	12/2010	Killoren Clark et al.	N/A	N/A
7914450	12/2010	Goode, Jr. et al.	N/A	N/A
7916013	12/2010	Stevenson	N/A	N/A
7938797	12/2010	Estes	N/A	N/A
7955258	12/2010	Goscha et al.	N/A	N/A
7970448	12/2010	Shults et al.	N/A	N/A
7974672	12/2010	Shults et al.	N/A	N/A
7999674	12/2010	Kamen	N/A	N/A
8072310	12/2010	Everhart	N/A	N/A

8090445	12/2011	Ginggen	N/A	N/A
8093991	12/2011	Stevenson et al.	N/A	N/A
8094009	12/2011	Allen et al.	N/A	N/A
8098159	12/2011	Batra et al.	N/A	N/A
8098160	12/2011	Howarth et al.	N/A	N/A
8098161	12/2011	Lavedas	N/A	N/A
8098201	12/2011	Choi et al.	N/A	N/A
8098208	12/2011	Ficker et al.	N/A	N/A
8102021	12/2011	Degani	N/A	N/A
8102154	12/2011	Bishop et al.	N/A	N/A
8102263	12/2011	Yeo et al.	N/A	N/A
8102789	12/2011	Rosar et al.	N/A	N/A
8103241	12/2011	Young et al.	N/A	N/A
8103325	12/2011	Swedlow et al.	N/A	N/A
8111042	12/2011	Bennett	N/A	N/A
8115488	12/2011	McDowell	N/A	N/A
8116681	12/2011	Baarman	N/A	N/A
8116683	12/2011	Baarman	N/A	N/A
8116837	12/2011	Huang	N/A	N/A
8117481	12/2011	Anselmi et al.	N/A	N/A
8120493	12/2011	Burr	N/A	N/A
8124452	12/2011	Sheats	N/A	N/A
8130093	12/2011	Mazar et al.	N/A	N/A
8131351	12/2011	Kalgren et al.	N/A	N/A
8131365	12/2011	Zhang et al.	N/A	N/A
8131565	12/2011	Dicks et al.	N/A	N/A
8132037	12/2011	Fehr et al.	N/A	N/A
8135352	12/2011	Langsweirdt et al.	N/A	N/A
8136735	12/2011	Arai et al.	N/A	N/A
8138925	12/2011	Downie et al.	N/A	N/A
8140160	12/2011	Pless et al.	N/A	N/A
8140168	12/2011	Olson et al.	N/A	N/A
8140299	12/2011	Siess	N/A	N/A
8150321	12/2011	Winter et al.	N/A	N/A
8150516	12/2011	Levine et al.	N/A	N/A
8160900	12/2011	Taub et al.	N/A	N/A
8179266	12/2011	Hermle	N/A	N/A
8211016	12/2011	Budiman	N/A	N/A
8216137	12/2011	Budiman	N/A	N/A
8216138	12/2011	McGarraugh et al.	N/A	N/A
8224415	12/2011	Budiman et al.	N/A	N/A
8231531	12/2011	Brister et al.	N/A	N/A
8255026	12/2011	Al-Ali	N/A	N/A
8282549	12/2011	Brauker et al.	N/A	N/A
8457703	12/2012	A1-Ali	N/A	N/A
8532935	12/2012	Budiman	N/A	N/A
9113828	12/2014	Budiman	N/A	N/A
2001/0041831	12/2000	Starkweather et al.	N/A	N/A
2002/0019022	12/2001	Dunn et al.	N/A	N/A
2002/0042090	12/2001	Heller et al.	N/A	N/A

2002/0065454	12/2001	Lebel et al.	N/A	N/A
2002/0068860	12/2001	Clark	N/A	N/A
2002/0072784	12/2001	Sheppard et al.	N/A	N/A
2002/0103499	12/2001	Perez et al.	N/A	N/A
2002/0106709	12/2001	Potts et al.	N/A	N/A
2002/0120186	12/2001	Keimel	N/A	N/A
2002/0128594	12/2001	Das et al.	N/A	N/A
2002/0143266	12/2001	Bock	N/A	N/A
2002/0143372	12/2001	Snell et al.	N/A	N/A
2002/0161288	12/2001	Shin et al.	N/A	N/A
2002/0169635	12/2001	Shillingburg	N/A	N/A
2002/0193679	12/2001	Malave et al.	N/A	N/A
2003/0004403	12/2002	Drinan et al.	N/A	N/A
2003/0023317	12/2002	Brauker et al.	N/A	N/A
2003/0023461	12/2002	Quintanilla et al.	N/A	N/A
2003/0028184	12/2002	Lebel et al.	N/A	N/A
2003/0032867	12/2002	Crothall et al.	N/A	N/A
2003/0032874	12/2002	Rhodes et al.	N/A	N/A
2003/0042137	12/2002	Mao et al.	N/A	N/A
2003/0050546	12/2002	Desai et al.	N/A	N/A
2003/0065308	12/2002	Lebel et al.	N/A	N/A
2003/0100821	12/2002	Heller et al.	N/A	N/A
2003/0125612	12/2002	Fox et al.	N/A	N/A
2003/0130616	12/2002	Steil et al.	N/A	N/A
2003/0134347	12/2002	Heller et al.	N/A	N/A
2003/0168338	12/2002	Gao et al.	N/A	N/A
2003/0176933	12/2002	Lebel et al.	N/A	N/A
2003/0187338	12/2002	Say et al.	N/A	N/A
2003/0191377	12/2002	Robinson et al.	N/A	N/A
2003/0199744	12/2002	Buse et al.	N/A	N/A
2003/0199790	12/2002	Boecker et al.	N/A	N/A
2003/0208113	12/2002	Mault et al.	N/A	N/A
2003/0212317	12/2002	Kovatchev et al.	N/A	N/A
2003/0212379	12/2002	Bylund et al.	N/A	N/A
2003/0216630	12/2002	Jersey-Willuhn et al.	N/A	N/A
2003/0217966	12/2002	Tapsak et al.	N/A	N/A
2004/0010186	12/2003	Kimball et al.	N/A	N/A
2004/0010207	12/2003	Flaherty et al.	N/A	N/A
2004/0011671	12/2003	Shults et al.	N/A	N/A
2004/0024553	12/2003	Monfre et al.	N/A	N/A
2004/0039298	12/2003	Abreu	N/A	N/A
2004/0040840	12/2003	Mao et al.	N/A	N/A
2004/0045879	12/2003	Shults et al.	N/A	N/A
2004/0054263	12/2003	Moerman et al.	N/A	N/A
2004/0064068	12/2003	DeNuzzio et al.	N/A	N/A
2004/0077962	12/2003	Kroll	N/A	N/A
2004/0078065	12/2003	Kroll	N/A	N/A
2004/0093167	12/2003	Braig et al.	N/A	N/A
2004/0099529	12/2003	Mao et al.	N/A	N/A
2004/0106858	12/2003	Say et al.	N/A	N/A

2004/0122353	12/2003	Shahmirian et al.	N/A	N/A
2004/0133164	12/2003	Funderburk et al.	N/A	N/A
2004/0135684	12/2003	Steinthal et al.	N/A	N/A
2004/0138588	12/2003	Saikley et al.	N/A	N/A
2004/0138716	12/2003	Kon et al.	N/A	N/A
2004/0146909	12/2003	Duong et al.	N/A	N/A
2004/0152622	12/2003	Keith et al.	N/A	N/A
2004/0167801	12/2003	Say et al.	N/A	N/A
2004/0171921	12/2003	Say et al.	N/A	N/A
2004/0172307	12/2003	Gruber	N/A	N/A
2004/0176672	12/2003	Silver et al.	N/A	N/A
2004/0186362	12/2003	Brauker et al.	N/A	N/A
2004/0186365	12/2003	Jin et al.	N/A	N/A
2004/0193025	12/2003	Steil et al.	N/A	N/A
2004/0193090	12/2003	Lebel et al.	N/A	N/A
2004/0197846	12/2003	Hockersmith et al.	N/A	N/A
2004/0199056	12/2003	Husemann et al.	N/A	N/A
2004/0199059	12/2003	Brauker et al.	N/A	N/A
2004/0204687	12/2003	Mogensen et al.	N/A	N/A
2004/0208780	12/2003	Faries, Jr. et al.	N/A	N/A
2004/0225338	12/2003	Lebel et al.	N/A	N/A
2004/0236200	12/2003	Say et al.	N/A	N/A
2004/0249253	12/2003	Racchini et al.	N/A	N/A
2004/0249420	12/2003	Olson et al.	N/A	N/A
2004/0254433	12/2003	Bandis et al.	N/A	N/A
2004/0254434	12/2003	Goodnow et al.	N/A	N/A
2004/0260478	12/2003	Schwamm	N/A	N/A
2004/0263354	12/2003	Mann et al.	N/A	N/A
2004/0267300	12/2003	Mace	N/A	N/A
2005/0003470	12/2004	Nelson et al.	N/A	N/A
2005/0004439	12/2004	Shin et al.	N/A	N/A
2005/0004494	12/2004	Perez et al.	N/A	N/A
2005/0010087	12/2004	Banet et al.	N/A	N/A
2005/0010269	12/2004	Lebel et al.	N/A	N/A
2005/0016276	12/2004	Guan et al.	N/A	N/A
2005/0017864	12/2004	Tsoukalis	N/A	N/A
2005/0027177	12/2004	Shin et al.	N/A	N/A
2005/0027180	12/2004	Goode et al.	N/A	N/A
2005/0027181	12/2004	Goode et al.	N/A	N/A
2005/0027462	12/2004	Goode et al.	N/A	N/A
2005/0027463	12/2004	Goode et al.	N/A	N/A
2005/0031689	12/2004	Shults et al.	N/A	N/A
2005/0038332	12/2004	Saidara et al.	N/A	N/A
2005/0043598	12/2004	Goode, Jr. et al.	N/A	N/A
2005/0049179	12/2004	Davidson et al.	N/A	N/A
2005/0070774	12/2004	Addison et al.	N/A	N/A
2005/0090607	12/2004	Tapsak et al.	N/A	N/A
2005/0096511	12/2004	Fox et al.	N/A	N/A
2005/0096512	12/2004	Fox et al.	N/A	N/A
2005/0112169	12/2004	Brauker et al.	N/A	N/A

2005/0113653	12/2004	Fox et al.	N/A	N/A
2005/0114068	12/2004	Chey et al.	N/A	N/A
2005/0115832	12/2004	Simpson et al.	N/A	N/A
2005/0121322	12/2004	Say et al.	N/A	N/A
2005/0131346	12/2004	Douglas	N/A	N/A
2005/0143635	12/2004	Kamath et al.	N/A	N/A
2005/0154271	12/2004	Rasdal et al.	N/A	N/A
2005/0176136	12/2004	Burd et al.	N/A	N/A
2005/0177398	12/2004	Watanabe et al.	N/A	N/A
2005/0182306	12/2004	Sloan	N/A	N/A
2005/0187720	12/2004	Goode, Jr. et al.	N/A	N/A
2005/0192494	12/2004	Ginsberg	N/A	N/A
2005/0192557	12/2004	Brauker et al.	N/A	N/A
2005/0195930	12/2004	Spital et al.	N/A	N/A
2005/0199494	12/2004	Say et al.	N/A	N/A
2005/0203360	12/2004	Brauker et al.	N/A	N/A
2005/0214892	12/2004	Kovatchev et al.	N/A	N/A
2005/0239154	12/2004	Feldman et al.	N/A	N/A
2005/0239156	12/2004	Drucker et al.	N/A	N/A
2005/0241957	12/2004	Mao et al.	N/A	N/A
2005/0245795	12/2004	Goode, Jr. et al.	N/A	N/A
2005/0245799	12/2004	Brauker et al.	N/A	N/A
2005/0245839	12/2004	Stivoric et al.	N/A	N/A
2005/0245904	12/2004	Estes et al.	N/A	N/A
2005/0277164	12/2004	Drucker et al.	N/A	N/A
2005/0277912	12/2004	John	N/A	N/A
2005/0283208	12/2004	Von Arx et al.	N/A	N/A
2005/0287620	12/2004	Heller et al.	N/A	N/A
2005/0288725	12/2004	Hettrick et al.	N/A	N/A
2006/0001538	12/2005	Kraft et al.	N/A	N/A
2006/0004270	12/2005	Bedard et al.	N/A	N/A
2006/0010098	12/2005	Goodnow et al.	N/A	N/A
2006/0015020	12/2005	Neale et al.	N/A	N/A
2006/0015024	12/2005	Brister et al.	N/A	N/A
2006/0016700	12/2005	Brister et al.	N/A	N/A
2006/0017923	12/2005	Ruchti et al.	N/A	N/A
2006/0019327	12/2005	Brister et al.	N/A	N/A
2006/0020186	12/2005	Brister et al.	N/A	N/A
2006/0020187	12/2005	Brister et al.	N/A	N/A
2006/0020188	12/2005	Kamath et al.	N/A	N/A
2006/0020189	12/2005	Brister et al.	N/A	N/A
2006/0020190	12/2005	Kamath et al.	N/A	N/A
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2006/0020192	12/2005	Brister et al.	N/A	N/A
2006/0025662	12/2005	Buse et al.	N/A	N/A
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2006/0029177	12/2005	Cranford, Jr. et al.	N/A	N/A
2006/0031094	12/2005	Cohen et al.	N/A	N/A
2006/0036139	12/2005	Brister et al.	N/A	N/A
2006/0036140	12/2005	Brister et al.	N/A	N/A

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2006/0036142	12/2005	Brister et al.	N/A	N/A
2006/0036143	12/2005	Brister et al.	N/A	N/A
2006/0036144	12/2005	Brister et al.	N/A	N/A
2006/0036145	12/2005	Brister et al.	N/A	N/A
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2006/0091006	12/2005	Wang et al.	N/A	N/A
2006/0142651	12/2005	Brister et al.	N/A	N/A
2006/0155180	12/2005	Brister et al.	N/A	N/A
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2006/0167365	12/2005	Bharmi	N/A	N/A
2006/0167517	12/2005	Gill et al.	N/A	N/A
2006/0167518	12/2005	Gill et al.	N/A	N/A
2006/0167519	12/2005	Gill et al.	N/A	N/A
2006/0173260	12/2005	Gaoni et al.	N/A	N/A
2006/0173406	12/2005	Hayes et al.	N/A	N/A
2006/0173444	12/2005	Choy et al.	N/A	N/A
2006/0183984	12/2005	Dobbles et al.	N/A	N/A
2006/0183985	12/2005	Brister et al.	N/A	N/A
2006/0189851	12/2005	Tvig et al.	N/A	N/A
2006/0189863	12/2005	Peyser et al.	N/A	N/A
2006/0193375	12/2005	Lee	N/A	N/A
2006/0222566	12/2005	Brauker et al.	N/A	N/A
2006/0224109	12/2005	Steil et al.	N/A	N/A
2006/0226985	12/2005	Goodnow et al.	N/A	N/A
2006/0229512	12/2005	Petisce et al.	N/A	N/A
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2006/0247685	12/2005	Bharmi	N/A	N/A
2006/0247710	12/2005	Goetz et al.	N/A	N/A
2006/0247985	12/2005	Liamos et al.	N/A	N/A
2006/0258929	12/2005	Goode et al.	N/A	N/A
2006/0264785	12/2005	Dring et al.	N/A	N/A
2006/0272652	12/2005	Stocker et al.	N/A	N/A
2006/0281985	12/2005	Ward et al.	N/A	N/A
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2007/0016381	12/2006	Kamath et al.	N/A	N/A
2007/0027381	12/2006	Stafford	N/A	N/A
2007/0032706	12/2006	Kamath et al.	N/A	N/A
2007/0033074	12/2006	Nitzan et al.	N/A	N/A
2007/0038044	12/2006	Dobbles et al.	N/A	N/A
2007/0055799	12/2006	Koehler et al.	N/A	N/A
2007/0056858	12/2006	Chen et al.	N/A	N/A
2007/0060803	12/2006	Liljeryd et al.	N/A	N/A
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2007/0066873	12/2006	Kamath et al.	N/A	N/A
2007/0068807	12/2006	Feldman et al.	N/A	N/A
2007/0071681	12/2006	Gadkar et al.	N/A	N/A
2007/0073129	12/2006	Shah et al.	N/A	N/A
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2007/0078322	12/2006	Stafford	N/A	N/A
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2007/0095661	12/2006	Wang et al.	N/A	N/A
2007/0106135	12/2006	Sloan et al.	N/A	N/A
2007/0108048	12/2006	Wang et al.	N/A	N/A
2007/0118405	12/2006	Campbell et al.	N/A	N/A
2007/0124002	12/2006	Estes et al.	N/A	N/A
2007/0129621	12/2006	Kellogg et al.	N/A	N/A
2007/0149875	12/2006	Ouyang et al.	N/A	N/A
2007/0156033	12/2006	Causey, III et al.	N/A	N/A
2007/0163880	12/2006	Woo et al.	N/A	N/A
2007/0168224	12/2006	Letzt et al.	N/A	N/A
2007/0173706	12/2006	Neinast et al.	N/A	N/A
2007/0173709	12/2006	Petisce et al.	N/A	N/A
2007/0173710	12/2006	Petisce et al.	N/A	N/A
2007/0173761	12/2006	Kanderian et al.	N/A	N/A
2007/0179349	12/2006	Hoyme et al.	N/A	N/A
2007/0179352	12/2006	Randlov et al.	N/A	N/A
2007/0179434	12/2006	Weinert et al.	N/A	N/A
2007/0191701	12/2006	Feldman et al.	N/A	N/A
2007/0199818	12/2006	Petyt et al.	N/A	N/A
2007/0202562	12/2006	Curry et al.	N/A	N/A
2007/0203407	12/2006	Hoss et al.	N/A	N/A
2007/0203966	12/2006	Brauker et al.	N/A	N/A
2007/0213657	12/2006	Jennewine et al.	N/A	N/A
2007/0227911	12/2006	Wang et al.	N/A	N/A
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2007/0232878	12/2006	Kovatchev et al.	N/A	N/A
2007/0232880	12/2006	Siddiqui et al.	N/A	N/A
2007/0233013	12/2006	Schoenberg et al.	N/A	N/A
2007/0235331	12/2006	Simpson et al.	N/A	N/A
2007/0244383	12/2006	Talbot et al.	N/A	N/A
2007/0249922	12/2006	Peyser et al.	N/A	N/A
2007/0253021	12/2006	Mehta et al.	N/A	N/A
2007/0255116	12/2006	Mehta et al.	N/A	N/A
2007/0255321	12/2006	Gerber et al.	N/A	N/A
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2007/0258395	12/2006	Jollota et al.	N/A	N/A
2007/0270672	12/2006	Hayter	N/A	N/A
2007/0282299	12/2006	Hellwig	N/A	N/A
2007/0285238	12/2006	Batra	N/A	N/A
2007/0299617	12/2006	Willis	N/A	N/A
2008/0004515	12/2007	Jennewine et al.	N/A	N/A
2008/0004601	12/2007	Jennewine et al.	N/A	N/A
2008/0009692	12/2007	Stafford	N/A	N/A
2008/0017522	12/2007	Heller et al.	N/A	N/A
2008/0018433	12/2007	Pitt-Pladdy	N/A	N/A
2008/0021666	12/2007	Goode, Jr. et al.	N/A	N/A
2008/0029391	12/2007	Mao et al.	N/A	N/A
2008/0030369	12/2007	Mann et al.	N/A	N/A

2008/0033254	12/2007	Kamath et al.	N/A	N/A
2008/0039702	12/2007	Hayter et al.	N/A	N/A
2008/0045824	12/2007	Tapsak et al.	N/A	N/A
2008/0058625	12/2007	McGarraugh et al.	N/A	N/A
2008/0064937	12/2007	McGarraugh et al.	N/A	N/A
2008/0064943	12/2007	Talbot et al.	N/A	N/A
2008/0066305	12/2007	Wang et al.	N/A	N/A
2008/0071156	12/2007	Brister et al.	N/A	N/A
2008/0071157	12/2007	McGarraugh et al.	N/A	N/A
2008/0071158	12/2007	McGarraugh et al.	N/A	N/A
2008/0071328	12/2007	Haubrich et al.	N/A	N/A
2008/0081977	12/2007	Hayter et al.	N/A	N/A
2008/0083617	12/2007	Simpson et al.	N/A	N/A
2008/0086042	12/2007	Brister et al.	N/A	N/A
2008/0086044	12/2007	Brister et al.	N/A	N/A
2008/0086273	12/2007	Shults et al.	N/A	N/A
2008/0097289	12/2007	Steil et al.	N/A	N/A
2008/0102441	12/2007	Chen et al.	N/A	N/A
2008/0108942	12/2007	Brister et al.	N/A	N/A
2008/0119703	12/2007	Brister et al.	N/A	N/A
2008/0119705	12/2007	Patel et al.	N/A	N/A
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2008/0139910	12/2007	Mastrototaro et al.	N/A	N/A
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2008/0154513	12/2007	Kovatchev et al.	N/A	N/A
2008/0161666	12/2007	Feldman et al.	N/A	N/A
2008/0167543	12/2007	Say et al.	N/A	N/A
2008/0167572	12/2007	Stivoric et al.	N/A	N/A
2008/0172205	12/2007	Breton et al.	N/A	N/A
2008/0177149	12/2007	Weinert et al.	N/A	N/A
2008/0177165	12/2007	Blomquist et al.	N/A	N/A
2008/0183060	12/2007	Steil et al.	N/A	N/A
2008/0183061	12/2007	Goode et al.	N/A	N/A
2008/0183399	12/2007	Goode et al.	N/A	N/A
2008/0188731	12/2007	Brister et al.	N/A	N/A
2008/0188796	12/2007	Steil et al.	N/A	N/A
2008/0189051	12/2007	Goode et al.	N/A	N/A
2008/0194934	12/2007	Ray et al.	N/A	N/A
2008/0194935	12/2007	Brister et al.	N/A	N/A
2008/0194936	12/2007	Goode et al.	N/A	N/A
2008/0194937	12/2007	Goode et al.	N/A	N/A
2008/0194938	12/2007	Brister et al.	N/A	N/A
2008/0195232	12/2007	Carr-Brendel et al.	N/A	N/A
2008/0195967	12/2007	Goode et al.	N/A	N/A
2008/0197024	12/2007	Simpson et al.	N/A	N/A
2008/0200788	12/2007	Brister et al.	N/A	N/A
2008/0200789	12/2007	Brister et al.	N/A	N/A
2008/0200791	12/2007	Simpson et al.	N/A	N/A
2008/0201325	12/2007	Doniger et al.	N/A	N/A
2008/0208025	12/2007	Shults et al.	N/A	N/A

2008/0208113	12/2007	Damiano et al.	N/A	N/A
2008/0214910	12/2007	Buck	N/A	N/A
2008/0214915	12/2007	Brister et al.	N/A	N/A
2008/0214918	12/2007	Brister et al.	N/A	N/A
2008/0228051	12/2007	Shults et al.	N/A	N/A
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2008/0255808	12/2007	Hayter	N/A	N/A
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2008/0262469	12/2007	Brister et al.	N/A	N/A
2008/0267823	12/2007	Wang et al.	N/A	N/A
2008/0275313	12/2007	Brister et al.	N/A	N/A
2008/0287761	12/2007	Hayter	N/A	N/A
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2008/0288180	12/2007	Hayter	N/A	N/A
2008/0288204	12/2007	Hayter et al.	N/A	N/A
2008/0296155	12/2007	Shults et al.	N/A	N/A
2008/0300572	12/2007	Rankers et al.	N/A	N/A
2008/0306368	12/2007	Goode et al.	N/A	N/A
2008/0306434	12/2007	Dobbles et al.	N/A	N/A
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2008/0306444	12/2007	Brister et al.	N/A	N/A
2008/0312518	12/2007	Jina et al.	N/A	N/A
2008/0312841	12/2007	Hayter	N/A	N/A
2008/0312842	12/2007	Hayter	N/A	N/A
2008/0312844	12/2007	Hayter et al.	N/A	N/A
2008/0312845	12/2007	Hayter et al.	N/A	N/A
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2008/0319279	12/2007	Ramsay et al.	N/A	N/A
2009/0005665	12/2008	Hayter et al.	N/A	N/A
2009/0005666	12/2008	Shin et al.	N/A	N/A
2009/0006034	12/2008	Hayter et al.	N/A	N/A
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2009/0006133	12/2008	Weinert et al.	N/A	N/A
2009/0012376	12/2008	Agus	N/A	N/A
2009/0012379	12/2008	Goode et al.	N/A	N/A
2009/0018424	12/2008	Kamath et al.	N/A	N/A
2009/0018425	12/2008	Ouyang et al.	N/A	N/A
2009/0030293	12/2008	Cooper et al.	N/A	N/A
2009/0030294	12/2008	Petisce et al.	N/A	N/A

2009/0033482	12/2008	Hayter et al.	N/A	N/A
2009/0036747	12/2008	Hayter et al.	N/A	N/A
2009/0036758	12/2008	Brauker et al.	N/A	N/A
2009/0036760	12/2008	Hayter	N/A	N/A
2009/0036763	12/2008	Brauker et al.	N/A	N/A
2009/0043181	12/2008	Brauker et al.	N/A	N/A
2009/0043182	12/2008	Brauker et al.	N/A	N/A
2009/0043525	12/2008	Brauker et al.	N/A	N/A
2009/0043541	12/2008	Brauker et al.	N/A	N/A
2009/0043542	12/2008	Brauker et al.	N/A	N/A
2009/0045055	12/2008	Rhodes et al.	N/A	N/A
2009/0048503	12/2008	Dalal et al.	N/A	N/A
2009/0054737	12/2008	Magar et al.	N/A	N/A
2009/0054745	12/2008	Jennewine et al.	N/A	N/A
2009/0054748	12/2008	Feldman et al.	N/A	N/A
2009/0054753	12/2008	Robinson et al.	N/A	N/A
2009/0055149	12/2008	Hayter et al.	N/A	N/A
2009/0062633	12/2008	Brauker et al.	N/A	N/A
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2009/0085768	12/2008	Patel et al.	N/A	N/A
2009/0099436	12/2008	Brister et al.	N/A	N/A
2009/0105554	12/2008	Stahmann et al.	N/A	N/A
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2009/0105570	12/2008	Sloan et al.	N/A	N/A
2009/0105636	12/2008	Hayter et al.	N/A	N/A
2009/0112478	12/2008	Mueller, Jr. et al.	N/A	N/A
2009/0118589	12/2008	Ueshima et al.	N/A	N/A
2009/0124877	12/2008	Goode, Jr. et al.	N/A	N/A
2009/0124878	12/2008	Goode et al.	N/A	N/A
2009/0124879	12/2008	Brister et al.	N/A	N/A
2009/0124964	12/2008	Leach et al.	N/A	N/A
2009/0131768	12/2008	Simpson et al.	N/A	N/A
2009/0131769	12/2008	Leach et al.	N/A	N/A
2009/0131776	12/2008	Simpson et al.	N/A	N/A
2009/0131777	12/2008	Simpson et al.	N/A	N/A
2009/0137886	12/2008	Shariati et al.	N/A	N/A
2009/0137887	12/2008	Shariati et al.	N/A	N/A
2009/0143659	12/2008	Li et al.	N/A	N/A
2009/0143660	12/2008	Brister et al.	N/A	N/A
2009/0143725	12/2008	Peyser et al.	N/A	N/A
2009/0150186	12/2008	Cohen et al.	N/A	N/A
2009/0156919	12/2008	Brister et al.	N/A	N/A
2009/0156924	12/2008	Shariati et al.	N/A	N/A

2009/0163790	12/2008	Brister et al.	N/A	N/A
2009/0163791	12/2008	Brister et al.	N/A	N/A
2009/0163855	12/2008	Shin et al.	N/A	N/A
2009/0164190	12/2008	Hayter	N/A	N/A
2009/0164239	12/2008	Hayter et al.	N/A	N/A
2009/0164251	12/2008	Hayter	N/A	N/A
2009/0178459	12/2008	Li et al.	N/A	N/A
2009/0182217	12/2008	Li et al.	N/A	N/A
2009/0182517	12/2008	Gandhi et al.	N/A	N/A
2009/0189738	12/2008	Hermle	N/A	N/A
2009/0192366	12/2008	Mensinger et al.	N/A	N/A
2009/0192380	12/2008	Shariati et al.	N/A	N/A
2009/0192722	12/2008	Shariati et al.	N/A	N/A
2009/0192724	12/2008	Brauker et al.	N/A	N/A
2009/0192745	12/2008	Kamath et al.	N/A	N/A
2009/0192751	12/2008	Kamath et al.	N/A	N/A
2009/0198118	12/2008	Hayter et al.	N/A	N/A
2009/0203981	12/2008	Brauker et al.	N/A	N/A
2009/0204341	12/2008	Brauker et al.	N/A	N/A
2009/0216103	12/2008	Brister et al.	N/A	N/A
2009/0234200	12/2008	Husheer	N/A	N/A
2009/0240120	12/2008	Mensinger et al.	N/A	N/A
2009/0240128	12/2008	Mensinger et al.	N/A	N/A
2009/0240193	12/2008	Mensinger et al.	N/A	N/A
2009/0242399	12/2008	Kamath et al.	N/A	N/A
2009/0242425	12/2008	Kamath et al.	N/A	N/A
2009/0247855	12/2008	Boock et al.	N/A	N/A
2009/0247856	12/2008	Boock et al.	N/A	N/A
2009/0247857	12/2008	Harper et al.	N/A	N/A
2009/0253973	12/2008	Bashan et al.	N/A	N/A
2009/0267765	12/2008	Greene et al.	N/A	N/A
2009/0281407	12/2008	Budiman	N/A	N/A
2009/0287073	12/2008	Boock et al.	N/A	N/A
2009/0287074	12/2008	Shults et al.	N/A	N/A
2009/0289796	12/2008	Blumberg	N/A	N/A
2009/0291634	12/2008	Saarisalo	N/A	N/A
2009/0294277	12/2008	Thomas et al.	N/A	N/A
2009/0299155	12/2008	Yang et al.	N/A	N/A
2009/0299156	12/2008	Simpson et al.	N/A	N/A
2009/0299162	12/2008	Brauker et al.	N/A	N/A
2009/0299276	12/2008	Brauker et al.	N/A	N/A
2010/0010324	12/2009	Brauker et al.	N/A	N/A
2010/0010331	12/2009	Brauker et al.	N/A	N/A
2010/0010332	12/2009	Brauker et al.	N/A	N/A
2010/0057040	12/2009	Hayter	N/A	N/A
2010/0057041	12/2009	Hayter	N/A	N/A
2010/0057042	12/2009	Hayter	N/A	N/A
2010/0057044	12/2009	Hayter	N/A	N/A
2010/0057057	12/2009	Hayter et al.	N/A	N/A
2010/0063372	12/2009	Potts et al.	N/A	N/A

2010/0081906	12/2009	Hayter et al.	N/A	N/A
2010/0081909	12/2009	Budiman et al.	N/A	N/A
2010/0081953	12/2009	Syeda-Mahmood et al.	N/A	N/A
2010/0121167	12/2009	McGarraugh et al.	N/A	N/A
2010/0141656	12/2009	Krieftewirth	N/A	N/A
2010/0160759	12/2009	Celentano et al.	N/A	N/A
2010/0160761	12/2009	Say et al.	N/A	N/A
2010/0168538	12/2009	Keenan et al.	N/A	N/A
2010/0168546	12/2009	Kamath et al.	N/A	N/A
2010/0174266	12/2009	Estes	N/A	N/A
2010/0190435	12/2009	Cook et al.	N/A	N/A
2010/0191085	12/2009	Budiman	N/A	N/A
2010/0191472	12/2009	Doniger et al.	N/A	N/A
2010/0198034	12/2009	Thomas et al.	N/A	N/A
2010/0198142	12/2009	Sloan et al.	N/A	N/A
2010/0204557	12/2009	Kiaie et al.	N/A	N/A
2010/0213057	12/2009	Feldman et al.	N/A	N/A
2010/0230285	12/2009	Hoss et al.	N/A	N/A
2010/0234710	12/2009	Budiman et al.	N/A	N/A
2010/0265073	12/2009	Harper et al.	N/A	N/A
2010/0274515	12/2009	Hoss et al.	N/A	N/A
2010/0277342	12/2009	Sicurello et al.	N/A	N/A
2010/0280441	12/2009	Willinska et al.	N/A	N/A
2010/0280782	12/2009	Harper et al.	N/A	N/A
2010/0312176	12/2009	Lauer et al.	N/A	N/A
2010/0313105	12/2009	Nekoomaram et al.	N/A	N/A
2010/0317952	12/2009	Budiman et al.	N/A	N/A
2010/0324392	12/2009	Yee et al.	N/A	N/A
2010/0326842	12/2009	Mazza et al.	N/A	N/A
2011/0004276	12/2010	Blair et al.	N/A	N/A
2011/0021889	12/2010	Hoss et al.	N/A	N/A
2011/0024043	12/2010	Boock et al.	N/A	N/A
2011/0024307	12/2010	Simpson et al.	N/A	N/A
2011/0027127	12/2010	Simpson et al.	N/A	N/A
2011/0027453	12/2010	Boock et al.	N/A	N/A
2011/0027458	12/2010	Boock et al.	N/A	N/A
2011/0028815	12/2010	Simpson et al.	N/A	N/A
2011/0028816	12/2010	Simpson et al.	N/A	N/A
2011/0029247	12/2010	Kalathil	N/A	N/A
2011/0040163	12/2010	Telson et al.	N/A	N/A
2011/0058485	12/2010	Sloan	N/A	N/A
2011/0060530	12/2010	Fennell	N/A	N/A
2011/0077490	12/2010	Simpson et al.	N/A	N/A
2011/0077494	12/2010	Doniger et al.	N/A	N/A
2011/0081726	12/2010	Berman et al.	N/A	N/A
2011/0082484	12/2010	Saravia et al.	N/A	N/A
2011/0105873	12/2010	Feldman et al.	N/A	N/A
2011/0106126	12/2010	Love et al.	N/A	N/A
2011/0112696	12/2010	Yodfat et al.	N/A	N/A
2011/0148905	12/2010	Simmons et al.	N/A	N/A

2011/0152637	12/2010	Kateraas et al.	N/A	N/A
2011/0184268	12/2010	Taub	N/A	N/A
2011/0190603	12/2010	Stafford	N/A	N/A
2011/0191044	12/2010	Stafford	N/A	N/A
2011/0193704	12/2010	Harper et al.	N/A	N/A
2011/0208027	12/2010	Wagner et al.	N/A	N/A
2011/0208155	12/2010	Palerm et al.	N/A	N/A
2011/0210830	12/2010	Talty et al.	N/A	N/A
2011/0213225	12/2010	Bernstein et al.	N/A	N/A
2011/0224523	12/2010	Budiman	N/A	N/A
2011/0257495	12/2010	Hoss et al.	N/A	N/A
2011/0257895	12/2010	Brauker et al.	N/A	N/A
2011/0263958	12/2010	Brauker et al.	N/A	N/A
2011/0288574	12/2010	Curry et al.	N/A	N/A
2011/0319729	12/2010	Donnay et al.	N/A	N/A
2011/0320130	12/2010	Valdes et al.	N/A	N/A
2011/0320167	12/2010	Budiman	N/A	N/A
2012/0010642	12/2011	Lee et al.	N/A	N/A
2012/0078071	12/2011	Bohm et al.	N/A	N/A
2012/0084053	12/2011	Yuen et al.	N/A	N/A
2012/0108931	12/2011	Taub	N/A	N/A
2012/0108934	12/2011	Valdes et al.	N/A	N/A
2012/0165626	12/2011	Irina et al.	N/A	N/A
2012/0165640	12/2011	Galley et al.	N/A	N/A
2012/0173200	12/2011	Breton et al.	N/A	N/A
2012/0209099	12/2011	Ljuhs et al.	N/A	N/A
2012/0215462	12/2011	Goode et al.	N/A	N/A
2012/0233679	12/2011	Shedrinsky	N/A	N/A
2012/0238851	12/2011	Kamen et al.	N/A	N/A
2012/0245447	12/2011	Karan et al.	N/A	N/A
2012/0255875	12/2011	Vicente et al.	N/A	N/A
2012/0277565	12/2011	Budiman	N/A	N/A
2012/0309302	12/2011	Buhot	N/A	N/A
2013/0035575	12/2012	Mayou et al.	N/A	N/A
2013/0184547	12/2012	Taub et al.	N/A	N/A
2014/0121480	12/2013	Budiman et al.	N/A	N/A
2014/0121488	12/2013	Budiman	N/A	N/A
2014/0221966	12/2013	Buckingham et al.	N/A	N/A
2015/0216456	12/2014	Budiman	N/A	N/A
2015/0366510	12/2014	Budiman	N/A	N/A
2016/0022221	12/2015	Ou et al.	N/A	N/A

FOREIGN PATENT DOCUMENTS

Patent No.	**Application Date**	**Country**	**CPC**
0098592	12/1983	EP	N/A
0127958	12/1983	EP	N/A
0320109	12/1988	EP	N/A
0353328	12/1989	EP	N/A
0390390	12/1989	EP	N/A
0396788	12/1989	EP	N/A

0472411	12/1991	EP	N/A
0286118	12/1994	EP	N/A
0867146	12/1997	EP	N/A
1048264	12/1999	EP	N/A
1419731	12/2003	EP	N/A
0939602	12/2003	EP	N/A
1850909	12/2009	EP	N/A
1677668	12/2009	EP	N/A
2 498 196	12/2011	EP	N/A
WO-1996/025089	12/1995	WO	N/A
WO-1996/035370	12/1995	WO	N/A
WO 97/18639	12/1996	WO	N/A
WO-1997/015227	12/1996	WO	N/A
WO-2000/049940	12/1999	WO	N/A
WO-2000/059370	12/1999	WO	N/A
WO-2000/074753	12/1999	WO	N/A
WO-2001/052935	12/2000	WO	N/A
WO-2001/054753	12/2000	WO	N/A
WO-2002/016905	12/2001	WO	N/A
WO-2003/076893	12/2002	WO	N/A
WO-2003/082091	12/2002	WO	N/A
WO-2004/060455	12/2003	WO	N/A
WO-2005/065542	12/2004	WO	N/A
WO-2006/024671	12/2005	WO	N/A
WO-2006/081336	12/2005	WO	N/A
WO-2007/097754	12/2006	WO	N/A
WO-2008/001366	12/2007	WO	N/A
WO-2008/086541	12/2007	WO	N/A
WO 2013/019225	12/2012	WO	N/A

OTHER PUBLICATIONS

Naumova et al. (Recent Patents on Computer Science (2012) vol. 5:177-187). cited by examiner

"Blood glucose monitoring" retrieved from "https://web.archive.org/web/20111215063153/http://en.wikipedia.org/wiki/Blood_glucose_monitoring" on Aug. 1, 2021, 6 pages. cited by applicant

"In Vivo Glucose Sensing", Chemical Analysis, A Series of Monographs on Analytical Chemistry and its Applications, vol. 174, 62 pages (2010). cited by applicant

"Near field communication" retrieved from "http://en.wikipedia.org/w/index.php?title=Near_field_communication&oldid=543740757" on Jun. 27, 2014, 14 pages. cited by applicant

Decuir, "Bluetooth 4.0:Low Energy", Standards Architect, CSR Technology, Councilor, Bluetooth Architecture Review Board, IEEE Region 6 Northwest Area Chair, 104 pages (2012). cited by applicant

Dementyev, et al., "Power Consumption Analysis of Bluetooth Low Energy, ZigBee and ANT Sensor Nodes in a Cyclic Sleep Scenario", IEEE International Wireless Symposium (IWS), 5 pages (2013). cited by applicant

Klonoff, "A Review of Continuous Glucose Monitoring Technology", Diabetes Technology & Therapeutics, 7(5):770-775 (2005). cited by applicant

Klonoff, "Continuous Glucose Monitoring: Roadmap for 21st century diabetes therapy", Diabetes Care, 28(5):1231-1239 (2005). cited by applicant

Morak, et al., "Design and Evaluation of a Telemonitoring Concept Based on NFC-Enabled Mobile Phones and Sensor Devices", IEEE Transactions on Information Technology in Biomedicine, 16(1):17-

23 (2012). cited by applicant
Movassaghi, et al., “Wireless Technologies for Body Area Networks: Characteristics and Challenges”, IEEE, International Symposium on Communications and Information Technologies (ISCIT), pp. 42-47 (2012). cited by applicant
Specification of the Bluetooth System, Experience More, Specification vol. 0, Covered Core Package Version: 4.0, 2 302 pages (2010). cited by applicant
Townsend, et al., “Getting Started with Bluetooth Low Energy [Book]”, O'Reilly, retrieved from https://www.oreilly.com/library/view/getting-started-with/9781491900550/ch01.html on May 5, 2020, 26 pages. cited by applicant
Arnold, M. A., et al., “Selectivity Assessment of Noninvasive Glucose Measurements Based on Analysis of Multivariate Calibration Vectors”, *Journal of Diabetes Science and Technology*, vol. 1, No. 4, 2007, pp. 454-462. cited by applicant
Boyne, M. S., et al., “Timing of Changes in Interstitial and Venous Blood Glucose Measured With a Continuous Subcutaneous Glucose Sensor”, *Diabetes*, vol. 52, Nov. 2003, pp. 2790-2794. cited by applicant
Eren-Oruklu, M., et al., “Estimation of Future Glucose Concentrations with Subject-Specific Recursive Linear Models”, *Diabetes Technology& Therapeutics* vol. 11(4), 2009, pp. 243-253. cited by applicant
Hovorka, R., et al., “Nonlinear Model Predictive Control of Glucose Concentration in Subjects with Type 1 Diabetes”, *Physiological Measurement*, vol. 55, Jul. 2004, pp. 905-920. cited by applicant
Kovatchev, B. P., et al., “Graphical and Numerical Evaluation of Continuous Glucose Sensing Time Lag”, *Diabetes Technology & Therapeutics*, vol. 11, No. 3, 2009, pp. 139-143. cited by applicant
Steil, G. M., et al., “Determination of Plasma Glucose During Rapid Glucose Excursions with a Subcutaneous Glucose Sensor”, *Diabetes Technology & Therapeutics*, vol. 5, No. 1, 2003, pp. 27-31. cited by applicant
Steil, G.M., et al., “Closed-Loop Insulin Delivery—the Path of Physiological Glucose Control”, *Advanced Drug Delivery Reviews*, vol. 56, 2004, pp. 125-144. cited by applicant
Armour, J. C., et al., “Application of Chronic Intravascular Blood Glucose Sensor in Dogs”, *Diabetes*, vol. 39, 1990, pp. 1519-1526. cited by applicant
Bennion, N., et al., “Alternate Site Glucose Testing: A Crossover Design”, *Diabetes Technology & Therapeutics*, vol. 4, No. 1, 2002, pp. 25-33. cited by applicant
Blank, T. B., et al., “Clinical Results From a Non-Invasive Blood Glucose Monitor”, *Optical Diagnostics and Sensing of Biological Fluids and Glucose and Cholesterol Monitoring II, Proceedings of SPIE*, vol. 4624, 2002, pp. 1-10. cited by applicant
Bremer, T. M., et al., “Benchmark Data from the Literature for Evaluation of New Glucose Sensing Technologies”, *Diabetes Technology & Therapeutics*, vol. 3, No. 3, 2001, pp. 409-418. cited by applicant
Brooks, S. L., et al., “Development of an On-Line Glucose Sensor for Fermentation Monitoring”, *Biosensors*, vol. 3, 1987/88, pp. 45-56. cited by applicant
Cass, A. E., et al., “Ferrocene-Medicated Enzyme Electrode for Amperometric Determination of Glucose”, *Analytical Chemistry*, vol. 56, No. 4, 1984, 667-671. cited by applicant
Cheyne, E. H., et al., “Performance of a Continuous Glucose Monitoring System During Controlled Hypoglycaemia in Healthy Volunteers”, *Diabetes Technology & Therapeutics*, vol. 4, No. 5, 2002, pp. 607-613. cited by applicant
Choleau, C., et al., “Calibration of a Subcutaneous Amperometric Glucose Sensor Implanted for 7 Days in Diabetic Patients Part 2. Superiority of the One-Point Calibration Method”, *Biosensors and Bioelectronics*, vol. 17, No. 8, 2002, pp. 647-654. cited by applicant
Csoregi, E., et al., “Design and Optimization of a Selective Subcutaneously Implantable Glucose Electrode Based on ‘Wired’ Glucose Oxidase”, *Analytical Chemistry*, vol. 67, No. 7, 1995, pp. 1240-1244. cited by applicant
Diabetes Control and Complications Trial Research Group, “The Effect of Intensive Treatment of

Diabetes on the Development and Progression of Long-Term Complications in Insulin-Dependent Diabetes Mellitus," *New England J. Med*. vol 329, 1993, pp. 977-986. cited by applicant
Feldman, B., et al., "A Continuous Glucose Sensor Based on Wired Enzyme™ Technology—Results from a 3-Day Trial in Patients with Type 1 Diabetes", *Diabetes Technology & Therapeutics*, vol. 5, No. 5, 2003, pp. 769-779. cited by applicant
Feldman, B., et al., "Correlation of Glucose Concentrations in Interstitial Fluid and Venous Blood During Periods of Rapid Glucose Change", *Abbott Diabetes Care, Inc. Freestyle Navigator Continuous Glucose Monitor Pamphlet*, 2004, 1 page. cited by applicant
Georgescu, B., et al., "Real-Time Multimodel Tracking of Myocardium in Echocardiography Using Robust Information Fusion", *Medical Image Computing and Computer-Assisted Intervention*, 2004, pp. 777-785. cited by applicant
Goldman, J. M., et al., "Masimo Signal Extraction Pulse Oximetry", *Journal of Clinical Monitoring and Computing*, vol. 16, No. 7, 2000, pp. 475-483. cited by applicant
Guerci, B., et al., "Clinical Performance of CGMS in Type 1 Diabetic Patients Treated by Continuous Subcutaneous Insulin Infusion Using Insulin Analogs", *Diabetes Care*, vol. 26, 2003, pp. 582-589. cited by applicant
Isermann, R., "Supervision, Fault-Detection and Fault-Diagnosis Methods—An Introduction", *Control Engineering Practice*, vol. 5, No. 5, 1997, pp. 639-652. cited by applicant
Isermann, R., et al., "Trends in the Application of Model-Based Fault Detection and Diagnosis of Technical Processes", *Control Engineering Practice*, vol. 5, No. 5, 1997, pp. 709-719. cited by applicant
Johnson, P. C., "Peripheral Circulation", *John Wiley & Sons*, 1978, pp. 198. cited by applicant
Jungheim, K., et al., "How Rapid Does Glucose Concentration Change in Daily Life of Patients with Type 1 Diabetes?", 2002, pp. 250. cited by applicant
Jungheim, K., et al., "Risky Delay of Hypoglycemia Detection by Glucose Monitoring at the Arm", *Diabetes Care*, vol. 24, No. 7, 2001, pp. 1303-1304. cited by applicant
Kaplan, S. M., "Wiley Electrical and Electronics Engineering Dictionary", *IEEE Press*, 2004, pp. 141, 142, 548, 549. cited by applicant
Kovatchev, B. P., et al., "Evaluating the Accuracy of Continuous Glucose-Monitoring Sensors", *Diabetes Care*, vol. 27, No. 8, 2004, pp. 1922-1928. cited by applicant
Kuure-Kinsey, M., et al., "A Dual-Rate Kalman Filter for Continuous Glucose Monitoring", *Proceedings of the 28th IEEE, EMBS Annual International Conference*, New York City, 2006, pp. 63-66. cited by applicant
Lodwig, V., et al., "Continuous Glucose Monitoring with Glucose Sensors: Calibration and Assessment Criteria", *Diabetes Technology & Therapeutics*, vol. 5, No. 4, 2003, pp. 573-587. cited by applicant
Lortz, J., et al., "What is Bluetooth? We Explain The Newest Short-Range Connectivity Technology", *Smart Computing Learning Series, Wireless Computing*, vol. 8, Issue 5, 2002, pp. 72-74. cited by applicant
Maher, "A Method for Extrapolation of Missing Digital Audio Data", *Preprints of Papers Presented at the AES Convention*, 1993, pp. 1-19. cited by applicant
Maher, "Audio Enhancement using Nonlinear Time-Frequency Filtering", *AES 26th International Conference*, 2005, pp. 1-9. cited by applicant
Malin, S. F., et al., "Noninvasive Prediction of Glucose by Near-Infrared Diffuse Reflectance Spectoscopy", *Clinical Chemistry*, vol. 45, No. 9, 1999, pp. 1651-1658. cited by applicant
Mcgarraugh, G., et al., "Glucose Measurements Using Blood Extracted from the Forearm and the Finger", *TheraSense, Inc*., 2001, 16 Pages. cited by applicant
Mcgarraugh, G., et al., "Physiological Influences on Off-Finger Glucose Testing", *Diabetes Technology & Therapeutics*, vol. 3, No. 3, 2001, pp. 367-376. cited by applicant
Mckean, B. D., et al., "A Telemetry-Instrumentation System for Chronically Implanted Glucose and Oxygen Sensors", *IEEE Transactions on Biomedical Engineering*, vol. 35, No. 7, 1988, pp. 526-532. cited by applicant

Morbiducci, U, et al., "Improved Usability of the Minimal Model of Insulin Sensitivity Based on an Automated Approach and Genetic Algorithms for Parameter Estimation", *Clinical Science*, vol. 112, 2007, pp. 257-263. cited by applicant
Mougiakakou, et al., "A Real Time Simulation Model of Glucose-Insulin Metabolism for Type 1 Diabetes Patients", *Proceedings of the 2005 IEEE*, 2005, pp. 298-301. cited by applicant
Panteleon, A. E., et al., "The Role of the Independent Variable to Glucose Sensor Calibration", *Diabetes Technology & Therapeutics*, vol. 5, No. 3, 2003, pp. 401-410. cited by applicant
Parker, R., et al., "Robust Hoo Glucose Control in Diabetes Using a Physiological Model", *AIChE Journal*, vol. 46, No. 12, 2000, pp. 2537-2549. cited by applicant
Pickup, J., et al., "Implantable Glucose Sensors: Choosing the Appropriate Sensing Strategy", *Biosensors*, vol. 3, 1987/88, pp. 335-346. cited by applicant
Pickup, J., et al., "In Vivo Molecular Sensing in Diabetes Mellitus: An Implantable Glucose Sensor with Direct Electron Transfer", *Diabetologia*, vol. 32, 1989, pp. 213-217. cited by applicant
Pishko, M. V., et al., "Amperometric Glucose Microelectrodes Prepared Through Immobilization of Glucose Oxidase in Redox Hydrogels", *Analytical Chemistry*, vol. 63, No. 20, 1991, pp. 2268-2272. cited by applicant
Quinn, C. P., et al., "Kinetics of Glucose Delivery to Subcutaneous Tissue in Rats Measured with 0.3-mm Amperometric Microsensors", *The American Physiological Society*, 1995, E155- E161. cited by applicant
Roe, J. N., et al., "Bloodless Glucose Measurements", *Critical Review in Therapeutic Drug Carrier Systems*, vol. 15, Issue 3, 1998, pp. 199-241. cited by applicant
Sakakida, M., et al., "Development of Ferrocene-Mediated Needle-Type Glucose Sensor as a Measure of True Subcutaneous Tissue Glucose Concentrations", *Artificial Organs Today*, vol. 2, No. 2, 1992, pp. 145-158. cited by applicant
Sakakida, M., et al., "Ferrocene-Mediated Needle-Type Glucose Sensor Covered with Newly Designed Biocompatible Membrane", *Sensors and Actuators B*, vol. 13-14, 1993, pp. 319-322. cited by applicant
Salehi, C., et al., "A Telemetry-Instrumentation System for Long-Term Implantable Glucose and Oxygen Sensors", *Analytical Letters*, vol. 29, No. 13, 1996, pp. 2289-2308. cited by applicant
Schmidtke, D. W., et al., "Measurement and Modeling of the Transient Difference Between Blood and Subcutaneous Glucose Concentrations in the Rat After Injection of Insulin", *Proceedings of the National Academy of Sciences*, vol. 95, 1998, pp. 294-299. cited by applicant
Shaw, G. W., et al., "In Vitro Testing of a Simply Constructed, Highly Stable Glucose Sensor Suitable for Implantation in Diabetic Patients", *Biosensors & Bioelectronics*, vol. 6, 1991, pp. 401-406. cited by applicant
Shichiri, M., et al., "Glycaemic Control in Pancreatectomized Dogs with a Wearable Artificial Endocrine Pancreas", *Diabetologia*, vol. 24, 1983, pp. 179-184. cited by applicant
Shichiri, M., et al., "In Vivo Characteristics of Needle-Type Glucose Sensor—Measurements of Subcutaneous Glucose Concentrations in Human Volunteers", *Hormone and Metabolic Research Supplement Series*, vol. 20, 1988, pp. 17-20. cited by applicant
Shichiri, M., et al., "Membrane Design for Extending the Long-Life of an Implantable Glucose Sensor", *Diabetes Nutrition and Metabolism*, vol. 2, 1989, pp. 309-313. cited by applicant
Shichiri, M., et al., "Needle-type Glucose Sensor for Wearable Artificial Endocrine Pancreas", *Implantable Sensors for Closed-Loop Prosthetic Systems*, Chapter 15, 1985, pp. 197-210. cited by applicant
Shichiri, M., et al., "Telemetry Glucose Monitoring Device With Needle-Type Glucose Sensor: A Useful Tool for Blood Glucose Monitoring in Diabetic Individuals", *Diabetes Care*, vol. 9, No. 3, 1986, pp. 298-301. cited by applicant
Shichiri, M., et al., "Wearable Artificial Endocrine Pancreas With Needle-Type Glucose Sensor", *The Lancet*, 1982, pp. 1129-1131. cited by applicant
Shults, M. C., et al., "A Telemetry-Instrumentation System for Monitoring Multiple Subcutaneously

Implanted Glucose Sensors", *IEEE Transactions on Biomedical Engineering*, vol. 41, No. 10, 1994, pp. 937-942. cited by applicant
Sternberg, R., et al., "Study and Development of Multilayer Needle-Type Enzyme-Based Glucose Microsensors", *Biosensors*, vol. 4, 1988, pp. 27-40. cited by applicant
Thompson, M., et al., "In Vivo Probes: Problems and Perspectives", *Clinical Biochemistry*, vol. 19, 1986, pp. 255-261. cited by applicant
Turner, A., et al., "Diabetes Mellitus: Biosensors for Research and Management", *Biosensors*, vol. 1, 1985, pp. 85-115. cited by applicant
Updike, S. J., et al., "Principles of Long-Term Fully Implanted Sensors with Emphasis on Radiotelemetric Monitoring of Blood Glucose from Inside a Subcutaneous Foreign Body Capsule (FBC)", *Biosensors in the Body: Continuous in vivo Monitoring*, Chapter 4, 1997, pp. 117-137. cited by applicant
Velho, G., et al., "Strategies for Calibrating a Subcutaneous Glucose Sensor", *Biomedica Biochimica Acta*, vol. 48, 1989, pp. 957-964. cited by applicant
Whipple, G., "Low Residual Noise Speech Enhancement Utilizing Time-Frequency", *Proceedings of the International Conference on Acoustics, Speech, and Signal Processing*, vol. 19, 1994, pp. I5-I8. cited by applicant
Wilson, G. S., et al., "Progress Toward the Development of an Implantable Sensor for Glucose", *Clinical Chemistry*, vol. 38, No. 9, 1992, pp. 1613-1617. cited by applicant
Wolfe, P. J., et al., "Interpolation of Missing Data Values for Audio Signal Restoration Using a Gabor Regression Model", *2005 IEEE International Conference on Acoustics, Speech, and Signal Processing*, vol. 5, 2005, pp. 517-520. cited by applicant

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Background/Summary

RELATED APPLICATION (1) The present application claims priority under 35 U.S.C. § 119 (e) to U.S. Provisional Application No. 61/794,549 filed Mar. 15, 2013, entitled "Noise Rejection Methods and Apparatus For Sparsely Sampled Analyte Sensor Data," the disclosure of which is incorporated herein by reference for all purposes.

BACKGROUND
(1) The detection of the concentration level of glucose or other analytes in certain individuals may be vitally important to their health. For example, the monitoring of glucose levels is particularly important to individuals with diabetes or pre-diabetes. People with diabetes may need to monitor their glucose levels to determine when medication (e.g., insulin) is needed to reduce their glucose levels or when additional glucose is needed.
(2) Devices have been developed for automated in vivo monitoring of analyte time series characteristics, such as glucose levels, in bodily fluids such as in the blood stream or in interstitial fluid. Some of these analyte level measuring devices are configured so that at least a portion of a sensor of an on-body device is positioned below a skin surface of a user, e.g., in a blood vessel or in the subcutaneous tissue of a user. As used herein, the term analyte monitoring system is used to refer to any type of in vivo monitoring system that uses a sensor disposed with at least a subcutaneous portion to measure and store sensor data representative of analyte concentration levels automatically over time. Analyte monitoring systems include both (1) systems such as continuous glucose monitors (CGMs) which transmit sensor data continuously or at regular time

intervals (e.g., once per minute) to a processor/display unit and (2) systems that transfer stored sensor data in one or more batches in response to data request from a processor/display unit (e.g., based on an activation action and/or proximity using, for example, a near field communications protocol).

(3) Some analyte monitoring systems may store samples relatively infrequently. For example, the sensor data may only include measurements or samples taken once every ten or fifteen minutes. In some cases, such sparsely sampled analyte sensor data may not accurately reflect the analyte concentration levels, particularly if signal noise is present. Thus, what are needed are systems, methods and apparatus that can reliably represent the analyte concentration level even of sparsely sampled data is used.

SUMMARY

(4) As mentioned above, accurate monitoring of analyte levels can be important to a person's health. To insure that sensor data does accurately reflect analyte concentration, embodiments of the present disclosure provide systems, methods, and apparatus for rejecting noise from sparsely sampled analyte sensor data that does not alter or distort true sensor data excursions. Conventional noise filtering from sparsely sampled sensor data can result in undesirable side effects such as over-filtering, particularly where an actual rapid change (e.g., a relatively fast change compared to the sample rate) in analyte concentration (i.e., a fast true sensor data excursion) occurs. In effect, conventional analyte sensor data filtering methods may not reliably distinguish between noise that should be rejected and rapid changes in analyte concentration that should be preserved. As a result, the analyte sensor can appear less responsive, and, in addition, can lag as compared to reference analyte measurements. The present disclosure provides novel noise rejection methods that take advantage of the similarities and differences of interpolation-based and extrapolation-based estimation methods to filter noise without attenuating fast true sensor data excursions.

(5) In some embodiments, the present disclosure provides systems, methods and apparatus for rejecting noise from sparsely sampled analyte sensor data. The invention includes receiving a raw set of sensor data from an on-body device including an in vivo analyte sensor, determining an interpolation-based estimate of an analyte level over time based on the raw set of sensor data, determining an extrapolation-based estimate of the analyte level over time based on the raw set of sensor data, determining a combined estimate of the analyte level over time based on the interpolation-based estimate and the extrapolation-based estimate, and displaying a representation of the combined estimate of the analyte level over time on an output device.

(6) The invention also includes a computer system and a computer program product for rejecting noise in sparsely sampled analyte monitoring system sensor data. Numerous other aspects and embodiments are provided. Other features and aspects of the present disclosure will become more fully apparent from the following detailed description, the appended claims, and the accompanying drawings.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

(1) The accompanying drawings, which are incorporated herein, form part of the specification. Together with this written description, the drawings further serve to explain the principles of, and to enable a person skilled in the relevant arts, to make and use the present disclosure.

(2) FIG. **1** depicts an example graph illustrating a Least Squares fit of a straight line to estimate a sensor data value in accordance with some embodiments of the present disclosure.

(3) FIG. **2** depicts an example graph illustrating the smoothing effect of the Least Squares fit based calculation in accordance with some embodiments of the present disclosure.

(4) FIG. **3** depicts an example graph illustrating the Least Squares fit based calculation applied

outside the measurement window in accordance with some embodiments of the present disclosure.
(5) FIG. **4** depicts an example graph illustrating the combination of an interpolation-based calculation and an extrapolation-based calculation in accordance with some embodiments of the present disclosure.
(6) FIG. **5** depicts an example graph illustrating the effectiveness of applying methods of the present disclosure to noisy sensor data in accordance with some embodiments of the present disclosure.
(7) FIG. **6** is a flow chart depicting an example method of noise rejection for sparsely sampled analyte sensor data in accordance with some embodiments of the present disclosure.

DETAILED DESCRIPTION

(8) Before the embodiments of the present disclosure are described, it is to be understood that this invention is not limited to the particular embodiments described, as such may, of course, vary. It is also to be understood that the terminology used herein is for the purpose of describing particular embodiments only, and is not intended to be limiting, since the scope of the embodiments of the invention will be limited only by the appended claims.
(9) The present disclosure provides systems, methods, and apparatus to reject noise from sparsely sampled analyte sensor data that does not alter or distort true sensor data excursions. As used herein, the term “sparsely sampled” is intended to mean a sample rate that is low enough such that first phase responses to meal and/or insulin may be difficult to discern in real-time. For example, based on average human physiology, a sample rate of once every ten minutes or slower is a sparsely sampled rate. The invention can be applied to sensor data from an analyte monitoring system, such as, for example, any type of in vivo monitoring system that uses a sensor disposed with at least a subcutaneous portion to measure and store sensor data representative of analyte concentration levels automatically over time. Analyte monitoring systems may include CGMs which are programmed to transmit sensor data according to a predetermined transmission schedule, continuously, or at regular time intervals to a processor/display unit and systems that transfer stored sensor data in one or more batches in response to a request from a processor/display unit, i.e., not according to a predetermined transmission schedule. Without requiring a patient to provide blood samples for in vitro reference glucose readings, the present disclosure is operable to reject noise from sparsely sampled data from an in vivo analyte sensor.
(10) According to some embodiments of the present disclosure, a dataset representative of a patient's monitored analyte concentration level (herein referred to as “sensor data”) over time is received from an on-body device that includes sensor electronics operatively coupled to an analyte sensor that is in fluid contact with interstitial fluid. In some embodiments, the sensor data may represent a collection of data received from the on-body device at several different times during a wear period of the on-body device. In some other embodiments, the sensor data may represent data collected and stored over an entire wear period of the on-body device and only received from the on-body device at the end of the wear period or at the end of the useful life of the on-body device. In other words, the sensor data can be transmitted continuously, on a regular schedule, in multiple batches over time, in batches on demand, or in a single batch.
(11) Embodiments of the present disclosure may be applied to any analyte concentration level determination system that may exhibit or at least be suspected of exhibiting, or that may be susceptible to noise in the sensor data. Embodiments of the invention are described primarily with respect to continuous glucose monitoring devices and systems but the present disclosure may be applied to other analytes and analyte characteristics, as well as data from measurement systems that transmit sensor data from a sensor unit to another unit such as a processing or display unit in response to a request from the other unit. For example, other analytes that may be monitored include, but are not limited to, acetyl choline, amylase, bilirubin, cholesterol, chorionic gonadotropin, creatine kinase (e.g., CK-MB), creatine, DNA, fructosamine, glutamine, growth hormones, hormones, ketones, lactate, peroxide, prostate-specific antigen, prothrombin, RNA,

thyroid stimulating hormone, and troponin. The concentration of drugs, such as, for example, antibiotics (e.g., gentamicin, vancomycin, and the like), digitoxin, digoxin, drugs of abuse, theophylline, and warfarin, may also be monitored. In the embodiments that monitor more than one analyte, the analytes may be monitored at the same or different times. The present disclosure also provides numerous additional embodiments.

(12) Embodiments of the present disclosure may include a programmed computer system adapted to receive and store data from an analyte monitoring system. The computer system may include one or more processors for executing instructions or programs that implement the methods described herein. The computer system may include memory and persistent storage devices to store and manipulate the instructions and sensor data received from the analyte monitoring system. The computer system may also include communications facilities (e.g., wireless and/or wired) to enable transfer of the sensor data from the analyte monitoring system to the computer. The computer system may include a display and/or output devices for identifying dropouts in the sensor data to a user. The computer system may include input devices and various other components (e.g., power supply, operating system, clock, etc.) that are typically found in a conventional computer system. In some embodiments, the computer system may be integral to the analyte monitoring system. For example, the computer system may be embodied as a handheld or portable receiver unit within the analyte monitoring system.

(13) The various methods described herein for performing one or more processes also described herein may be embodied as computer programs (e.g., computer executable instructions and data structures) developed using an object oriented programming language that allows the modeling of complex systems with modular objects to create abstractions that are representative of real world, physical objects and their interrelationships. However, any practicable programming language and/or techniques may be used. The software for performing the inventive processes, which may be stored in a memory or storage device of the computer system described herein, may be developed by a person of ordinary skill in the art based upon the present disclosure and may include one or more computer program products. The computer program products may be stored on a computer readable medium such as a server memory, a computer network, the Internet, and/or a computer storage device. Note that in some cases the methods embodied as software may be described herein with respect to a particular order of operation or execution. However, it will be understood by one of ordinary skill that any practicable order of operation or execution is possible and such variations are contemplated by this specification of the present disclosure.

(14) Rejecting noise can be essential in generating an accurate representation of an analyte concentration level using an analyte monitoring system. In some analyte monitoring systems, for example, the sensor data can include a window of sparsely sampled data long enough to cover a significant portion of a day, e.g., a 6 to 12 hour window with datapoints every 10 to 20 minutes. In addition to noise, some of the data points may not be available due to data quality issues. A reliable analyte measurement system according to the present disclosure can reject noise and recover missing data using the remaining sparsely sampled data.

(15) Conventional filtering methods can apply a relatively simple approach that is robust to intermittent signal loss and noise. This method includes fitting one or more parameters of a pre-determined polynomial structure over a window of sensor data using the Least-Squares Error (LS) fit method. An analytical solution can be derived for each of the parameters, as long as there is sufficiency of excitation and the number of parameters identified remain small (e.g. up to 3 parameters). This means that polynomials with up to three degrees of freedom (e.g., linear (a straight line with 0 intercept); affine (straight line with general intercept); or parabolic) can be considered. For numerical robustness with respect to noise, affine functions are considered. Up to two parameters are estimated, namely the slope and intercept.

(16) FIG. **1** is a graph **100** of sensor data values plotted over time. The graph **100** illustrates an example of a LS fit of a straight line **102** to estimate a value at a time of interest **104** and the rate of

change (i.e. the slope of the LS fit), whether or not the source data at time of interest **104** is available. In the example shown in FIG. **1**, the time of interest **104** is inside the measurement window **106**. The filled solid circles represent available and valid data points within the measurement window **106**. As will be shown in more detail with respect to FIG. **2**, the LS fit method allows recovery of missing data based on neighboring raw sensor data. However, as will also be illustrated below, obtaining an estimate outside the window **106**, whose instance is relatively distant from the center of the measurement window **106** and large relative to the size of the measurement window **106**, can exaggerate the negative effects of extrapolation.

(17) LS fit of a straight line of data in a measurement window can be used to achieve robust signal recovery and noise rejection. For example, suppose an LS fit of a straight line is determined using three data points spaced fifteen minutes apart and the LS fit estimate at the center data point is used as the output. FIG. **2** depicts a graph **200** of an example of a raw sensor data set plot z stored at fifteen minute intervals. In this example, curve y.sub.c is the resulting LS fit estimate using the method described above with respect to FIG. **1**, based on three z neighboring values and estimating the center value. In general, curve y.sub.c is a smoother representation of the sensor data values compared to plot z. However, the values around fast transitions (e.g., around the peak at 26 Hr. and valley at 27 Hr.) are severely attenuated, which is evident from the reduced dynamic range (or roughly peak-to-peak distance) of the LS fit result compared to plot z.

(18) When the LS fit is used to estimate a value at the edge of the window or slightly outside of the window, the attenuation rounding effect is replaced by noise amplification associated with extrapolation. However, when results of two extrapolations (or near extrapolation in the case where the estimate lies on the edge of the window) are combined such that the estimate lies on the same sample instance, and one window uses past data while the other uses future data, the result is a reasonably smooth signal with exaggerated sharp apexes. This result is shown as curve y.sub.s in the graph **300** of FIG. **3**, which is generally smoother than plot z, but errs on the opposite side of plot z compared to curve y.sub.c.

(19) To overcome the attenuation around fast transitions introduced by interpolation filtering methods and the exaggerated fast transitions introduced by extrapolation filtering methods, the methods of the present disclosure combine interpolation based estimates and extrapolation based estimates. As shown in the graph **400** of FIG. **4**, when the interpolation-based calculation for curve y.sub.c (LS fit based calculation inside the measurement window) and the extrapolation-based calculation for curve y.sub.s (LS fit based calculation outside the measurement window) are combined, the result is curve y.sub.a. Note that curve y.sub.a traces plot z relatively accurately in this example that does not contain significant noise to reject and/or data loss to recover. However, turning now to FIG. **5**, the efficacy of this combination in rejecting noisy sensor data is graphically demonstrated.

(20) FIG. **5** is a graph **500** that depicts methods of the present disclosure applied to an example of a noisy sensor data segment. Plot z represents noisy raw sensor data sampled and presented in one minute increments. Curve y.sub.b represents reference glucose measurements taken every fifteen minutes, visually connected by dotted lines. When the noisy sensor data of plot z is used for a sensor output calculation that involves a rate of change calculation, the resulting output at fifteen minute intervals is shown as curve y.sub.b′. Plot z.sub.c represents conditioned sensor data sampled and presented in fifteen minute increments. If the same sensor output calculation uses the conditioning of the present disclosure (i.e., uses plot z.sub.c as the input data) instead of plot z, the resulting output at fifteen minute intervals is shown as curve y.sub.b″. As can be seen in FIG. **5**, using the methods of the present disclosure, there is a significant reduction of the noise in the analyte measurement system output in the presence of noisy raw analyte sensor data input. Further, as illustrated in FIG. **4**, the estimation methods of the present disclosure do not attenuate the amplitude of true analyte sensor data excursions and sensor data segments with low noise are not affected.

(21) Turning now to FIG. **6**, a flow chart **600** depicting example methods of the present disclosure is provided. As indicated above, the methods of the present disclosure can be implemented on a computer or other processing device. In some embodiments, raw sensor data is received from an on-body device that includes an in vivo analyte sensor (**602**). The raw sensor data may represent data sampled over a period of time during the use of the on-body device. The sample rate may be less than ten or fifteen minutes such that the data collected is sparsely sampled as defined above. In some embodiments, the set of data received may include data collected and stored over an entire wear period.

(22) An interpolation-based estimate of the analyte level over time is determined based on the raw set of sensor data (**604**). The interpolation-based estimate can be computed based on a least squares fit based calculation of analyte sensor data values within a predefined measurement window. For example, given values z(t**0**), z(t**1**), z(t**2**), up to z(tN), the estimate y.sub.c(te) at time te as well as the slope v.sub.c(te) at time te based on a least-squares fit of a line can be computed by the following equation:

(23) $$\begin{bmatrix} yc(te) \\ vc(te) \end{bmatrix} = [\Phi^T \Phi]^{-1} \Phi^T Y$$

(24) $$Y = \begin{bmatrix} z(t0) \\ .Math. \\ z(tN) \end{bmatrix}, \quad \Phi = \begin{bmatrix} 1 & t0 - te \\ .Math. & .Math. \\ 1 & tN - te \end{bmatrix}$$

where:

Without loss of generality, suppose only up to three values of z are used to form a window at any time, and that the values are spaced at regular sample interval Ts. Then, for the least-squares estimate at the center:

*t*1=*te*−*Ts*

*t*2=*te*

*t*3=*te*+*Ts*

The estimated values y.sub.c(te) and v.sub.c(te) are then computed as follows:

(25) $$\begin{bmatrix} yc(te) \\ vc(te) \end{bmatrix} = [\Phi^T \Phi]^{-1} \Phi^T Y$$

(26) $$Y = \begin{bmatrix} z(t1) \\ z(t2) \\ z(t3) \end{bmatrix}, \Phi = \begin{bmatrix} 1 & t1 - te \\ 1 & t2 - te \\ 1 & t3 - te \end{bmatrix} = \begin{bmatrix} 1 & -Ts \\ 1 & 0 \\ 1 & Ts \end{bmatrix}$$

where:

Likewise, an extrapolation-based estimate of the analyte level over time is determined based on the raw set of sensor data (**606**). The extrapolation-based estimate can be computed based on a least squares fit based calculation of analyte sensor data values outside or at the left edge of a predefined measurement window. Then, for the least-squares estimate yl(te) and vl(te) at the left of a window of data values z(t**2**), z(t**3**), z(t**4**) with te at t**2**:

*t*2=*te*

*t*3=*te*+*Ts*

*t*4=*te*+2*Ts*

The estimated values yl(te) and vl(te) are then computed as follows:

(27) $$\begin{bmatrix} yl(te) \\ vl(te) \end{bmatrix} = [\Phi^T \Phi]^{-1} \Phi^T Y$$

$$(28)\quad Y = \begin{bmatrix} z(t2) \\ z(t3) \\ z(t4) \end{bmatrix}, \Phi = \begin{bmatrix} 1 & t2 - te \\ 1 & t3 - te \\ 1 & t4 - te \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ 1 & Ts \\ 1 & 2Ts \end{bmatrix}$$

where:

(29) Similarly, the extrapolation-based estimate of the analyte level over time can be computed based on a combination of an extrapolation using a least squares fit based calculation of analyte sensor data values from the right side or at the right edge of a predefined measurement window of preceding values and a second extrapolation using a least squares fit based calculation of analyte sensor data values from the right side or at the right edge of a predefined measurement window of succeeding values. Then, for the least-squares estimate y.sub.r(te) and v.sub.r(te) at the right of a window of data values z(t**0**), z(t**1**), z(t**2**) with te at t**2**:

$t0 = te - 2Ts$

$t1 = te - Ts$

$t2 = te$

The estimated values y.sub.l(te) and v.sub.l(te) are then computed as follows:

$$(30)\quad \begin{bmatrix} \text{yr(te)} \\ \text{vr(te)} \end{bmatrix} = [\Phi^T \Phi]^{-1} \Phi^T Y$$

$$(31)\quad Y = \begin{bmatrix} z(t0) \\ z(t1) \\ z(t2) \end{bmatrix}, \Phi = \begin{bmatrix} 1 & t0 - te \\ 1 & t1 - te \\ 1 & t2 - te \end{bmatrix} = \begin{bmatrix} 1 & -2Ts \\ 1 & -Ts \\ 1 & 0 \end{bmatrix}$$

where:

(32) A combined estimate of the analyte level over time is determined based on the interpolation-based estimate and the extrapolation-based estimate (**608**). For example, when all calculations yc, yr, and yl are available, an estimate can be calculated by taking the average of the left and right:

$ys(te) = [yr(te) + yl(te)]/2$

Which is then combined with the interpolation based estimate to obtain a final estimated value:

$ya(te) = [ys(te) + y.sub.c(te)]/2$

Alternatively, a final estimate can be obtained by a weighted average of the calculations yc, yr and yl in a more general manner:

$ya(te) = Kc\ y.sub.c(te) + Kl\ yl(te) + Kr\ yr(te)$

where the sum of Kc, Kl and Kr equals 1.

(33) In a more general embodiment, when the number of analyte data points z within a predetermined window may vary, the weights applied to each element of the estimate, for example, yc, yl, and yr, can be a function of the number of available data points. The number of data points available can vary due to certain data points having been disqualified by an upstream data integrity check, having been disqualified by an upstream physiological feasibility check, or having been provided with varying time gaps by an upstream process. Conceptually, elements of the estimate such as yc, yl, or yr, whose number of available points are lower than the desired amount, will have a lower weighting factor in order for the less reliable measurement to exert less influence into the final estimate ya.

(34) In some embodiments, yc, yl, and yr are calculated in the same manner as previously described. Instead of fixed weights Kc, Kl, and Kr as previously described, Kc, Kl, and Kr can take on different values as a function of the number of available data points z in their respective windows. Let the number of available data points be denoted Qc, Ql, and Qr. Then, Kc, Kl, and Kr are such that when Qc, Ql, and Qr is equal to the maximum number of points, Kc, Kl, and Kr will take on their largest possible respective values. As Qc, Ql, and Qr approach zero, then Kc, Kl, and Kr will take on their smallest possible respective values, which may or may not be zero. One way

to achieve this is to use a smooth function that relates Kc, Kl, and Kr to Qc, Ql, and Qr, respectively. Alternatively, Qc, Ql, and Qr may affect the weights Kc, Kl, and Kr in stepwise thresholds.

(35) A numerical example of the embodiment described, using stepwise thresholds is described as follows. For the calculation of y.sub.c, find 3 available data points z as previously described. If the number of valid points is greater than 2 (i.e., Qc≥2), set Kc to 5. If the number of valid points is equal to 2 (i.e., Qc=2), set Kc to 2.5. Otherwise, set Kc to 0. This can be achieved by using a function evaluated at the discrete available number of points Qc, or by evaluating Qc against threshold value 2. For the calculation of yl, find 3 available data points z as previously described. If Ql>2, set Kl to 1. If Ql=2, set Kl to 0.4. Otherwise, since there is insufficient number of points, set Kl to 0. For the calculation of yr, find 3 available data points z as previously described. If Qr>2, set Kr to 1. If Qr=2, set Kr to 0.4. Otherwise, set Kr to 0. In addition, if both yl and yr can be calculated, calculate the mean of both values, ym=[yl+yr]/2. A new weight Km is assigned the value 6 if both can be calculated or 0 otherwise. Finally, an estimate that is robust to data loss and can generate results under partially missing data, yf, can be computed by taking the weighted average:

*yf=[Kc*yc+Kl*yl+Kr*yr+Km*ym]/[Kc+Kl+Kr+Km],*

when at least one of the weights Kc, Kl, Kr, or Km is nonzero. If all of the weights are zero, there is insufficient data to generate a reliable estimate, and no estimate yf is given.

(36) A representation of the combined estimate of the analyte level over time can then be displayed on an output device operatively coupled to the processor (**610**). The representation can be, for example, in the form of a graphical plot, a numerical display, or a combination thereof.

(37) In the manner described above, in certain embodiments of the present disclosure, there is provided a method of estimating an analyte level using sparsely sampled analyte sensor data comprising: determining, using a processor, a composite estimate of an analyte level over time based on a combination of an interpolated estimate of the analyte level and an extrapolated estimate of the analyte level, and displaying a representation of the composite estimate of the analyte level over time on an output device.

(38) In certain embodiments, the interpolated estimate of the analyte level and the extrapolated estimate of the analyte level are computed based on a raw set of sensor data.

(39) In certain embodiments, the raw set of sensor data is received from an on-body device including an in vivo analyte sensor.

(40) In certain embodiments, the interpolated estimate of the analyte level over time is computed based on a least squares fit based calculation of analyte sensor data values within a predefined measurement window, and further, wherein the extrapolated estimate of the analyte level over time is computed based on more than one least squares fit based calculation of analyte sensor data values outside or at the edge of the predefined measurement window.

(41) In certain embodiments, the interpolated estimate of the analyte level over time is computed based on a least squares fit based calculation of analyte sensor data values within a predefined measurement window, and further, wherein the extrapolated estimate of the analyte level over time is computed based on a combination of a first extrapolation using a least squares fit based calculation of analyte sensor data values outside or at the edge of a first predefined measurement window and a second extrapolation using a least squares fit based calculation of analyte sensor data values outside or at the edge of a second predefined measurement window.

(42) In certain embodiments, the first predefined measurement window uses analyte sensor data values from a time before a data point of interest and wherein the second predefined measurement window uses analyte sensor data values from a time after the data point of interest.

(43) A computer-implemented method in certain embodiments includes receiving a raw set of sensor data from an on-body device including an in vivo analyte sensor, determining an interpolation-based estimate of an analyte level over time based on the raw set of sensor data,

determining an extrapolation-based estimate of the analyte level over time based on the raw set of sensor data, determining a combined estimate of the analyte level over time based on the interpolation-based estimate and the extrapolation-based estimate, and displaying a representation of the combined estimate of the analyte level over time on an output device.
(44) In certain embodiments, the interpolation-based estimate of the analyte level over time based on the raw set of sensor data is computed based on a least squares fit based calculation of analyte sensor data values within a predefined measurement window.
(45) In certain embodiments, the extrapolation-based estimate of the analyte level over time based on the raw set of sensor data is computed based on more than one least squares fit based calculation of analyte sensor data values outside or at the edge of a predefined measurement window.
(46) In certain embodiments, the extrapolation-based estimate of the analyte level over time based on the raw set of sensor data is computed based on a combination of a first extrapolation using a least squares fit based calculation of analyte sensor data values outside or at the edge of a first predefined measurement window and a second extrapolation using a least squares fit based calculation of analyte sensor data values outside or at the edge of a second predefined measurement window.
(47) In certain embodiments, the first predefined measurement window uses analyte sensor data values from a time before a data point of interest and wherein the second predefined measurement window uses analyte sensor data values from a time after the data point of interest.
(48) In certain embodiments, the raw set of sensor data includes data sampled at a rate less than once per ten minutes.
(49) In certain embodiments, the representation of the combined estimate of the analyte level over time includes at least one of a graph and a numeric display.
(50) A system for monitoring analyte concentration in certain embodiments includes a processor, and a memory coupled to the processor, the memory storing processor executable instructions to: receive a raw set of sensor data from an on-body device including an in vivo analyte sensor, determine an interpolation-based estimate of an analyte level over time based on the raw set of sensor data, determine an extrapolation-based estimate of the analyte level over time based on the raw set of sensor data, determine a combined estimate of the analyte level over time based on the interpolation-based estimate and the extrapolation-based estimate, display a representation of the combined estimate of the analyte level over time on an output device operatively coupled to the processor.
(51) In certain embodiments, the instruction to determine the interpolation-based estimate of the analyte level over time based on the raw set of sensor data includes an instruction to determine the interpolation-based estimate based on a least squares fit based calculation of analyte sensor data values within a predefined measurement window.
(52) In certain embodiments, the instruction to determine the extrapolation-based estimate of the analyte level over time based on the raw set of sensor data includes an instruction to determine the extrapolation-based estimate based on more than one least squares fit based calculation of analyte sensor data values outside or at the edge of a predefined measurement window.
(53) In certain embodiments, the instruction to determine the extrapolation-based estimate of the analyte level over time based on the raw set of sensor data includes an instruction to determine the extrapolation-based estimate based on a combination of a first extrapolation using a least squares fit based calculation of analyte sensor data values outside or at the edge of a first predefined measurement window and a second extrapolation using a least squares fit based calculation of analyte sensor data values outside or at the edge of a second predefined measurement window.
(54) In certain embodiments, the first predefined measurement window uses analyte sensor data values from a time before a data point of interest and wherein the second predefined measurement window uses analyte sensor data values from a time after the data point of interest.
(55) In certain embodiments, the raw set of sensor data includes data sampled at a rate less than

once per ten minutes.
(56) In certain embodiments, the instruction to display the representation of the combined estimate of the analyte level over time on the output device includes an instruction to display at least one of a graph and a numeric display.
(57) A computer-implemented method in certain embodiments includes receiving a raw set of sensor data from an on-body device including an in vivo analyte sensor, determining an interpolation-based estimate of an analyte level over time based on the raw set of sensor data, determining an extrapolation-based estimate of the analyte level over time based on the raw set of sensor data, determining weights of each estimate based on the number of available sensor data used to compute each estimate, determining a combined estimate of the analyte level over time based on the weighted average of the interpolation-based estimate and the extrapolation-based estimate, displaying a representation of the combined estimate of the analyte level over time on an output device.
(58) Various other modifications and alterations in the structure and method of operation of the embodiments of the present disclosure will be apparent to those skilled in the art without departing from the scope and spirit of the present disclosure. Although the present disclosure has been described in connection with certain embodiments, it should be understood that the present disclosure as claimed should not be unduly limited to such embodiments. It is intended that the following claims define the scope of the present disclosure and that structures and methods within the scope of these claims and their equivalents be covered thereby.

Claims

1. A method of monitoring a glucose concentration using a glucose sensor having a processor configured to be positioned in contact with a fluid under a skin layer of a subject, the method comprising: receiving a plurality of data points within a period of time, the plurality of data points corresponding to a glucose level of the subject; determining, based on the plurality of data points, interpolated estimates of the glucose level of the subject; determining, based on a first portion of the plurality of data points, a first set of extrapolated estimates of the glucose level of the subject; determining, based on a second portion of the plurality of data points, a second set of extrapolated estimates of the glucose level of the subject, wherein the second portion of the plurality of data points correspond to time points associated with later time points than the first portion of the plurality of data points; determining, using the processor of the glucose sensor, composite estimates of the glucose level of the subject based on a combination of the interpolated estimates, the first set of extrapolated estimates, and the second set of extrapolated estimates, wherein determining the composite estimates comprises applying weights to the interpolated estimates and the first and second sets of extrapolated estimates, the weights being determined based on a function of a number of the plurality of data points; and providing, to a display associated with the glucose sensor, the composite estimate of the glucose level of the subject.
2. The method of claim 1, wherein the plurality of data points within the period of time are sparsely sampled data generated by the glucose sensor.
3. The method of claim 1, wherein the interpolated estimates of the glucose level and the first set and the second set of extrapolated estimates of the glucose level are computed based on a raw set of data from the glucose sensor.
4. The method of claim 3, wherein the raw set of data from the glucose sensor includes data sampled at a rate less than once per minute.
5. The method of claim 1, wherein glucose sensor is an in vivo analyte sensor.
6. The method of claim 1, wherein the interpolated estimates of the glucose level are based on a least squares fit based calculation.
7. The method of claim 1, wherein each of the first set and the second set of extrapolated estimates

of the glucose level are based on a more than one least squares fit based calculation.
8. The method of claim 1, wherein each of the first set and the second set of extrapolated estimates of the glucose level are based on a combination of a first extrapolation based on a least squares fit based calculation and a second extrapolation based on a least squares fit based calculation.
9. The method of claim 1, wherein the display associated with the glucose sensor is configured to display the first set of extrapolated estimates or the second set of extrapolated estimates based at least an estimated glucose value outside the period of time.
10. A system for monitoring glucose concentration, the system comprising: a processor; and memory coupled to the processor, the memory storing instructions to: receive a plurality of data points within a period of time, the plurality of data points corresponding to a glucose level of a subject; determine, based on the plurality of data points, interpolated estimates of the glucose level of the subject; determine, based on a first portion of the plurality of data points, a first set of extrapolated estimates of the glucose level of the subject; determine, based on a second portion of the plurality of data points, a second set of extrapolated estimates of the glucose level of the subject, wherein the second portion of the plurality of data points correspond to time points associated with later time points than the first portion of the plurality of data points; and determine composite estimates of a glucose level of the subject based on a combination of the interpolated estimates, the first set of extrapolated estimates, and the second set of extrapolated estimates, wherein the composite estimates of the glucose level are determined based on data sampled by a glucose sensor that is configured to be positioned in contact with a fluid under a skin layer of the subject, wherein determining the composite estimates comprises applying weights to the interpolated estimates and the first and second sets of extrapolated estimates, the weights being determined based on a function of a number of the plurality of data points.
11. The system of claim 10, wherein the instructions are further configured to cause the system to display a representation of the composite estimates of the glucose level.
12. The system of claim 10, wherein the plurality of data points within the period of time are sparsely sampled analyte sensor data generated by the glucose sensor.
13. The system of claim 10, wherein the interpolated estimates of the glucose level and the first set and the second set of extrapolated estimates of the glucose level are computed based on a raw set of data from the glucose sensor.
14. The system of claim 13, wherein the raw set of data from the glucose sensor includes data sampled at a rate less than once per minute.
15. The system of claim 10, wherein glucose sensor is an in vivo glucose sensor.
16. The system of claim 10, wherein the interpolated estimates of the glucose level are based on a least squares fit based calculation.
17. The system of claim 10, wherein each of the first set and the second set of extrapolated estimates of the glucose level are based on a more than one least squares fit based calculation.
18. The system of claim 10, wherein the instructions are further configured to cause the system to display the first set of extrapolated estimates or the second set of extrapolated estimates based at least an estimated glucose value outside the period of time.
19. An apparatus for monitoring analyte concentration, the apparatus comprising: an on-body device including an in vivo glucose sensor that is configured to be positioned in contact with a fluid under a skin layer of a subject, wherein the apparatus is configured to: receive a plurality of data points within a period of time, the plurality of data points corresponding to a glucose level of a subject; determine, based on the plurality of data points, interpolated estimates of the glucose level of the subject; determine, based on a first portion of the plurality of data points, a first set of extrapolated estimates of the glucose level of the subject; determine, based on a second portion of the plurality of data points, a second set of extrapolated estimates of the glucose level of the subject, wherein the second portion of the plurality of data points correspond to time points associated with later time points than the first portion of the plurality of data points; and determine

composite estimates of a glucose level based on a combination of the interpolated estimates, the first set of extrapolated estimates, and the second set of extrapolated estimates, wherein determining the composite estimates comprises applying weights to the interpolated estimates and the first and second sets of extrapolated estimates, the weights being determined based on a function of a number of the plurality of data points.

20. The apparatus of claim 19, wherein the apparatus is further configured to send instructions to an associated display for displaying the first set of extrapolated estimates or the second set of extrapolated estimates based at least an estimated glucose value outside the period of time.