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LAMPIRAN

Lampiran 1 : Penjabaran Rumus Algoritma *Forward*, *Backward* dan *Viterbi*

1. Algoritma *Forward*

a. Inisialisasi

$$\begin{aligned}\alpha_1(i) &= P(O_1, Q_1 = s_1 | \lambda) \\ &= P(Q_1 = s_{i_1} | \lambda) P(O_1 | Q_1 = s_{i_1}) \\ &= \pi_i b_i(O_1)\end{aligned}$$

b. Induksi

$$\alpha_{t+1}(j) = P(O_1, O_2, \dots, O_{t+1}, Q_{t+1} = s_{j_{t+1}} | \lambda)$$

dengan menambahkan $\sum_{i=1}^N P(Q_t = s_{i_t}) = 1$ yang merupakan kejadian saling lepas

$$\begin{aligned}\alpha_{t+1}(j) &= \sum_{i=1}^N P(O_1, O_2, \dots, O_{t+1}, Q_t = s_{i_t}, Q_{t+1} = s_{j_{t+1}} | \lambda) \\ &= \sum_{i=1}^N P(O_1, O_2, \dots, O_t, Q_t = s_{i_t} | \lambda) P(O_{t+1}, Q_{t+1} = s_{j_{t+1}} | O_1, O_2, \dots, O_t, Q_t = s_{i_t}, \lambda) \\ &= \sum_{i=1}^N \alpha_t(i) P(O_{t+1}, Q_{t+1} = s_{j_{t+1}} | Q_t = s_{i_t}, \lambda) \\ &= \sum_{i=1}^N \alpha_t(i) P(O_{t+1} | Q_{t+1} = s_{j_{t+1}}, Q_t = s_{i_t}, \lambda) P(Q_{t+1} = s_{j_{t+1}} | Q_t = s_{i_t}, \lambda) \\ &= \sum_{i=1}^N \alpha_t(i) a_{ij} P(O_{t+1} | Q_{t+1} = s_{j_{t+1}}, \lambda) \\ &= \left[\sum_{i=1}^N \alpha_t(i) a_{ij} \right] b_j(O_{t+1})\end{aligned}$$

2. Algoritma *Backward*

a. Inisialisasi

$$\beta_T(i) = 1$$

untuk $i = 1, 2, \dots, N$

b. Induksi

$$\beta_t(i) = P(O_{t+1}, \dots, O_T | Q_t = s_{i_t}, \lambda)$$

Dengan menambahkan $\sum_{j=1}^N P(Q_{t+1} = s_{j_{t+1}}) = 1$ yang merupakan kejadian saling lepas

$$\begin{aligned} \beta_t(i) &= P(O_{t+1}, \dots, O_T | Q_t = s_{i_t}, \lambda) \\ &= \sum_{j=1}^N P(O_{t+1}, \dots, O_T, Q_{t+1} = s_{j_{t+1}} | Q_t = s_{i_t}, \lambda) \\ &= \sum_{j=1}^N P(Q_{t+1} = s_{j_{t+1}} | Q_t = s_{i_t}, \lambda) P(O_{t+1}, \dots, O_T | Q_{t+1} = s_{j_{t+1}}, Q_t = s_{i_t}, \lambda) \\ &= \sum_{j=1}^N a_{ij} P(O_{t+1}, \dots, O_T | Q_{t+1} = s_{j_{t+1}}, \lambda) \\ &= \sum_{j=1}^N a_{ij} P(O_{t+1} | O_{t+2}, \dots, O_T, Q_{t+1} = s_{j_{t+1}}, \lambda) P(O_{t+2}, \dots, O_T | Q_{t+1} \\ &\quad = s_{j_{t+1}}, \lambda) \\ &= \sum_{j=1}^N a_{ij} P(O_{t+1} | Q_{t+1} = s_{j_{t+1}}, \lambda) P(O_{t+2}, \dots, O_T | Q_{t+1} = s_{j_{t+1}}, \lambda) \\ &= \sum_{j=1}^N a_{ij} b_j(O_{t+1}) \beta_{t+1} \end{aligned}$$

c. Terminasi

$$P(O|\lambda) = \sum_{i=1}^N b_i(1)\pi(i)\beta_1(i)$$

3. Algoritma Viterbi

a. Inisialisasi

Pada saat $t = 1$,

$$\begin{aligned} \delta_1(i) &= P(Q_1 = s_i, O_1) \\ &= P(O_1 | Q_1 = s_i) P(Q_1 = s_i) \end{aligned}$$

Dengan menyubstitusi asumsi awal pada HMM yaitu $b_i(v_k) = P(O_t = v_k | Q_t = s_i)$ diperoleh:

$$\delta_1(i) = \pi_i b_i(O_1) \text{ untuk setiap } 1 \leq i \leq N$$

Pada tahap ini

$$\psi_t(i) = 0$$

b. Rekursi

Pada tahap rekursi,

$$\begin{aligned} \delta_t(j) &= \max_{Q_1, Q_2, \dots, Q_{t-1}} P(O_1, O_2, \dots, O_{t-1}, O_t, Q_1, Q_2, \dots, Q_{t-1}, Q_t = s_j | \lambda) \\ &= \max_{Q_1, Q_2, \dots, Q_{t-1}} \{P(O_t | O_1, O_2, \dots, O_{t-1}, Q_1, Q_2, \dots, Q_{t-1}, Q_t = s_j, \lambda) \\ &\quad P(O_1, O_2, \dots, O_{t-1}, Q_1, Q_2, \dots, Q_{t-1}, Q_t = s_j, \lambda)\} \\ &= \max_{Q_1, Q_2, \dots, Q_{t-1}} \{P(O_t | Q_t = s_j, \lambda) P(O_1, O_2, \dots, O_{t-1}, Q_1, Q_2, \dots, Q_{t-1}, \\ &\quad Q_t = s_j, \lambda)\} \\ &= P(O_t | Q_t = s_j, \lambda) \max_{Q_1, Q_2, \dots, Q_{t-1}} \max_{1 \leq i \leq N} \{P(O_1, O_2, \dots, O_{t-1}, Q_1, Q_2, \dots, \\ &\quad Q_{t-1} = s_i, Q_t = s_j, \lambda)\} \\ &= b_j(O_t) \max_{Q_1, Q_2, \dots, Q_{t-1}} \max_{1 \leq i \leq N} \{P(Q_t = s_j, | Q_{t-1} = s_i) P(O_1, O_2, \dots, \\ &\quad O_{t-1}, Q_1, Q_2, \dots, Q_{t-2}, Q_{t-1} = s_i, \lambda)\} \\ &= b_j(O_t) \max_{1 \leq i \leq N} \{P(Q_t = s_j, | Q_{t-1} = s_i) \max_{Q_1, Q_2, \dots, Q_{t-1}} P(O_1, O_2, \dots, \\ &\quad O_{t-1}, Q_1, Q_2, \dots, Q_{t-2}, Q_{t-1} = s_i, \lambda)\} \\ &= b_j(O_t) \max_{1 \leq i \leq N} \{P(Q_t = s_j | Q_{t-1} = s_i) \delta_{t-1}(i)\} \\ &= b_j(O_t) \max_{1 \leq i \leq N} \{a_{ij} \delta_{t-1}(i)\} \end{aligned}$$

Sehingga diperoleh persamaan:

$$\delta_t(j) = b_j(O_t) \max_{1 \leq i \leq N} \{a_{ij} \delta_{t-1}(i)\}$$

$$2 \leq t \leq T, 1 \leq j \leq N$$

$$\psi_t(j) = \arg \max_{1 \leq i \leq N} [\delta_{t-1}(i) a_{ij}]$$

$$2 \leq t \leq T, 1 \leq j \leq N$$

c. Tahap terminasi

$$P^* = \max_{1 \leq i \leq N} [\delta_T(i)]$$

$$X_T^* = \arg \max_{1 \leq i \leq N} [\delta_T(i)]$$

d. Tahap *backtracking*

$$Q_t^* = \psi_{t+1} Q_{t+1}^*$$
$$t = T - 1, T - 2, \dots, 1$$

Lampiran 2 : Data Lengkap Kurs Rupiah terhadap Dolar Amerika Serikat Periode Agustus 2022 - Juli 2023

Tanggal	Kurs Jual	Kurs Beli	Kurs Tengah	State
08/01/2022	14.934,3	14.785,7	14.860	Menguat
08/02/2022	14.948,37	14.799,63	14.874	Menguat
08/03/2022	14.962,44	14.813,56	14.888	Menguat
08/04/2022	14.991,58	14.842,42	14.917	Menguat
08/05/2022	15.003,65	14.854,35	14.929	Menguat
08/08/2022	14.978,52	14.829,48	14.904	Menguat
08/09/2022	14.989,58	14.840,42	14.915	Menguat
08/10/2022	14.936,31	14.787,69	14.862	Menguat
08/11/2022	14.949,38	14.800,63	14.875,005	Menguat
08/12/2022	14.873	14.725	14.799	Menguat
08/15/2022	14.761,44	14.614,56	14.688	Menguat
08/16/2022	14.800,64	14.653,36	14.727	Menguat
08/18/2022	14.840,83	14.693,17	14.767	Menguat
08/19/2022	14.896,11	14.747,89	14.822	Menguat
08/22/2022	14.932,29	14.783,71	14.858	Menguat
08/23/2022	14.956,41	14.807,59	14.882	Menguat
08/24/2022	14.967,47	14.818,53	14.893	Menguat
08/25/2022	14.925,25	14.776,75	14.851	Menguat
08/26/2022	14.901,14	14.752,86	14.827	Menguat

08/29/2022	14.888,07	14.739,93	14.814	Menguat
08/30/2022	14.961,43	14.812,57	14.887	Menguat
08/31/2022	14.949,38	14.800,63	14.875,005	Menguat
09/01/2022	14.927,26	14.778,74	14.853	Menguat
09/02/2022	14.958,42	14.809,58	14.884	Menguat
09/05/2022	14.974,5	14.825,5	14.900	Menguat
09/06/2022	14.994,6	14.845,4	14.920	Menguat
09/07/2022	14.959,42	14.810,58	14.885	Menguat
09/08/2022	15.001,64	14.852,36	14.927	Menguat
09/09/2022	14.979,52	14.830,48	14.905	Menguat
09/12/2022	14.920,23	14.771,77	14.846	Menguat
09/13/2022	14.913,19	14.764,81	14.839	Menguat
09/14/2022	14.935,31	14.786,69	14.861	Menguat
09/15/2022	14.997,61	14.848,39	14.923	Menguat
09/16/2022	14.973,5	14.824,5	14.899	Menguat
09/19/2022	15.013,69	14.864,31	14.939	Menguat
09/20/2022	15.054,9	14.905,1	14.980	Menguat
09/21/2022	15.049,88	14.900,13	14.975,005	Menguat
09/22/2022	15.086,06	14.935,94	15.011	Stabil
09/23/2022	15.108,17	14.957,83	15.033	Stabil
09/26/2022	15.110,17	14.959,83	15.035	Stabil
09/27/2022	15.194,59	15.043,41	15.119	Stabil

09/28/2022	15.230,77	15.079,23	15.155	Stabil
09/29/2022	15.319,22	15.166,78	15.243	Stabil
09/30/2022	15.323,24	15.170,76	15.247	Stabil
10/03/2022	15.308,16	15.155,84	15.232	Stabil
10/04/2022	15.369,47	15.216,53	15.293	Stabil
10/05/2022	15.352,38	15.199,62	15.276	Stabil
10/06/2022	15.271,98	15.120,02	15.196	Stabil
10/07/2022	15.272,99	15.121,01	15.197	Stabil
10/10/2022	15.322,23	15.169,77	15.246	Stabil
10/11/2022	15.375,5	15.222,5	15.299	Stabil
10/12/2022	15.438,81	15.285,19	15.362	Melemah
10/13/2022	15.449,86	15.296,14	15.373	Melemah
10/14/2022	15.433,78	15.280,22	15.357	Stabil
10/17/2022	15.466,95	15.313,05	15.390	Melemah
10/18/2022	15.557,4	15.402,6	15.480	Melemah
10/19/2022	15.546,34	15.391,66	15.469	Melemah
10/20/2022	15.568,45	15.413,55	15.491	Melemah
10/21/2022	15.656,9	15.501,1	15.579	Melemah
10/24/2022	15.688,05	15.531,95	15.610	Melemah
10/25/2022	15.667,95	15.512,05	15.590	Melemah
10/26/2022	15.694,08	15.537,92	15.616	Melemah
10/27/2022	15.673,98	15.518,02	15.596	Melemah

10/28/2022	15.650,86	15.495,14	15.573	Melemah
10/31/2022	15.619,71	15.464,29	15.542	Melemah
11/01/2022	15.673,98	15.518,02	15.596	Melemah
11/02/2022	15.725,24	15.568,76	15.647	Melemah
11/03/2022	15.730,26	15.573,74	15.652	Melemah
11/04/2022	15.759,41	15.602,59	15.681	Melemah
11/07/2022	15.814,68	15.657,32	15.736	Melemah
11/08/2022	15.770,46	15.613,54	15.692	Melemah
11/09/2022	15.762,42	15.605,58	15.684	Melemah
11/10/2022	15.732,27	15.575,73	15.654	Melemah
11/11/2022	15.779,5	15.622,5	15.701	Melemah
11/14/2022	15.570,47	15.415,53	15.493	Melemah
11/15/2022	15.576,5	15.421,5	15.499	Melemah
11/16/2022	15.641,82	15.486,18	15.564	Melemah
11/17/2022	15.688,05	15.531,95	15.610	Melemah
11/18/2022	15.765,43	15.608,57	15.687	Melemah
11/21/2022	15.770,46	15.613,54	15.692	Melemah
11/22/2022	15.785,53	15.628,47	15.707	Melemah
11/23/2022	15.794,58	15.637,42	15.716	Melemah
11/24/2022	15.778,5	15.621,5	15700	Melemah
11/25/2022	15.725,24	15.568,76	15.647	Melemah
11/28/2022	15.746,34	15.589,66	15.668	Melemah

11/29/2022	15.807,65	15.650,35	15.729	Melemah
11/30/2022	15.815,68	15.658,32	15.737	Melemah
12/01/2022	15.820,71	15.663,29	15.742	Melemah
12/02/2022	15.695,08	15.538,92	15.617	Melemah
12/05/2022	15.506,15	15.351,85	15.429	Melemah
12/06/2022	15.486,05	15.331,95	15.409	Melemah
12/07/2022	15.653,88	15.498,12	15.576	Melemah
12/08/2022	15.697,09	15.540,91	15.619	Melemah
12/09/2022	15.702,12	15.545,88	15.624	Melemah
12/12/2022	15.664,93	15.509,07	15.587	Melemah
12/13/2022	15.720,21	15.563,79	15.642	Melemah
12/14/2022	15.739,31	15.582,69	15.661	Melemah
12/15/2022	15.697,09	15.540,91	15.619	Melemah
12/16/2022	15.708,15	15.551,85	15.630	Melemah
12/19/2022	15.695,08	15.538,92	15.617	Melemah
12/20/2022	15.699,1	15.542,9	15.621	Melemah
12/21/2022	15.686,04	15.529,96	15.608	Melemah
12/22/2022	15.679	15.523	15.601	Melemah
12/23/2022	15.671,97	15.516,03	15.594	Melemah
12/26/2022	15.683,02	15.526,98	15.605	Melemah
12/27/2022	15.714,18	15.557,82	15.636	Melemah
12/28/2022	15.737,3	15.580,7	15.659	Melemah

12/29/2022	15.781,51	15.624,49	15.703	Melemah
12/30/2022	15.809,66	15.652,34	15.731	Melemah
01/02/2023	15.669,96	15.514,04	15.592	Melemah
01/03/2023	15.649,86	15.494,14	15.572	Melemah
01/04/2023	15.667,95	15.512,05	15.590	Melemah
01/05/2023	15.693,08	15.536,92	15.615	Melemah
01/06/2023	15.688,05	15.531,95	15.610	Melemah
01/09/2023	15.713,17	15.556,83	15.635	Melemah
01/10/2023	15.651,87	15.496,13	15.574	Melemah
01/11/2023	15.666,94	15.511,06	15.589	Melemah
01/12/2023	15.604,64	15.449,36	15.527	Melemah
01/13/2023	15.442,83	15.289,17	15.366	Melemah
01/16/2023	15.252,89	15.101,11	15.177	Stabil
01/17/2023	15.094,09	14.943,91	15.019	Stabil
01/18/2023	15.229,77	15.078,23	15.154	Stabil
01/19/2023	15.212,68	15.061,32	15.137	Stabil
01/20/2023	15.188,57	15.037,43	15.113	Stabil
01/24/2023	15.196,6	15.045,4	15.121	Stabil
01/25/2023	15.004,65	14.855,35	14.930	Menguat
01/26/2023	15.032,79	14.883,21	14.958	Menguat
01/27/2023	15.038,82	14.889,18	14.964	Menguat
01/30/2023	15.052,89	14.903,11	14.978	Menguat

01/31/2023	15.053,9	14.904,1	14.979	Menguat
02/01/2023	15.066,96	14.917,04	14.992	Stabil
02/02/2023	15.065,95	14.916,05	14.991	Menguat
02/03/2023	14.942,34	14.793,66	14.868	Menguat
02/06/2023	14.972,49	14.823,51	14.898	Menguat
02/07/2023	15.130,27	14.979,73	15.055	Stabil
02/08/2023	15.214,69	15.063,31	15.139	Stabil
02/09/2023	15.197,61	15.046,39	15.122	Stabil
02/10/2023	15.195,6	15.044,4	15.120	Stabil
02/13/2023	15.215,7	15.064,3	15.140	Stabil
02/14/2023	15.292,08	15.139,92	15.216	Stabil
02/15/2023	15.243,84	15.092,16	15.168	Stabil
02/16/2023	15.269,97	15.118,03	15.194	Stabil
02/17/2023	15.251,88	15.100,12	15.176	Stabil
02/20/2023	15.275	15.123	15.199	Stabil
02/21/2023	15.243,84	15.092,16	15.168	Stabil
02/22/2023	15.254,9	15.103,1	15.179	Stabil
02/23/2023	15.294,09	15.141,91	15.218	Stabil
02/24/2023	15.262,93	15.111,07	15.187	Stabil
02/27/2023	15.292,08	15.139,92	15.216	Stabil
02/28/2023	15.350,37	15.197,63	15.274	Stabil
03/01/2023	15.316,2	15.163,8	15.240	Stabil

03/02/2023	15.326,25	15.173,75	15.250	Stabil
03/03/2023	15.349,36	15.196,64	15.273	Stabil
03/06/2023	15.382,53	15.229,47	15.306	Stabil
03/07/2023	15.377,5	15.224,5	15.301	Stabil
03/08/2023	15.435,8	15.282,2	15.359	Stabil
03/09/2023	15.528,25	15.373,75	15.451	Melemah
03/10/2023	15.515,19	15.360,81	15.438	Melemah
03/13/2023	15.545,34	15.390,66	15.468	Melemah
03/14/2023	15.450,87	15.297,13	15.374	Melemah
03/15/2023	15.456,9	15.303,1	15.380	Melemah
03/16/2023	15.441,83	15.288,17	15.365	Melemah
03/17/2023	15.495,09	15.340,91	15.418	Melemah
03/20/2023	15.440,82	15.287,18	15.364	Melemah
03/21/2023	15.448,86	15.295,14	15.372	Melemah
03/24/2023	15.425,75	15.272,25	15.349	Stabil
03/27/2023	15.264,94	15.113,06	15.189	Stabil
03/28/2023	15.249,87	15.098,13	15.174	Stabil
03/29/2023	15.163,44	15.012,56	15.088	Stabil
03/30/2023	15.169,47	15.018,53	15.094	Stabil
03/31/2023	15.137,31	14.986,69	15.062	Stabil
04/03/2023	15.051,89	14.902,11	14.977	Menguat
04/04/2023	15.064,95	14.915,05	14.990	Menguat

04/05/2023	14.987,57	14.838,43	14.913	Menguat
04/06/2023	15.007,67	14.858,33	14.933	Menguat
04/10/2023	15.017,72	14.868,28	14.943	Menguat
04/11/2023	14.979,52	14.830,48	14.905	Menguat
04/12/2023	14.962,44	14.813,56	14.888	Menguat
04/13/2023	14.940,33	14.791,67	14.866	Menguat
04/14/2023	14.865,96	14.718,04	14.792	Menguat
04/17/2023	14.739,33	14.592,67	14.666	Menguat
04/18/2023	14.846,86	14.699,14	14.773	Menguat
04/26/2023	14.929,27	14.780,73	14.855	Menguat
04/27/2023	14.956,41	14.807,59	14.882	Menguat
04/28/2023	14.824,75	14.677,25	14.751	Menguat
05/02/2023	14.734,31	14.587,69	14.661	Menguat
05/03/2023	14.776,51	14.629,49	14.703	Menguat
05/04/2023	14.779,53	14.632,47	14.706	Menguat
05/05/2023	14.705,16	14.558,84	14.632	Menguat
05/08/2023	14.747,37	14.600,63	14.674	Menguat
05/09/2023	14.782,55	14.635,45	14.709	Menguat
05/10/2023	14.830,78	14.683,22	14.757	Menguat
05/11/2023	14.819,73	14.672,27	14.746	Menguat
05/12/2023	14.795,61	14.648,39	14.722	Menguat
05/15/2023	14.825,76	14.678,24	14.752	Menguat

05/16/2023	14.886,06	14.737,94	14.812	Menguat
05/17/2023	14.884,05	14.735,95	14.810	Menguat
05/19/2023	14.949,38	14.800,63	14.875,005	Menguat
05/22/2023	15.010,68	14.861,32	14.936	Menguat
05/23/2023	14.971,49	14.822,51	14.897	Menguat
05/24/2023	14952,39	14.803,61	14.878	Menguat
05/25/2023	14.979,52	14.830,48	14.905	Menguat
05/26/2023	15.026,76	14.877,24	14.952	Menguat
05/29/2023	15.033,8	14.884,2	14.959	Menguat
05/30/2023	15.047,86	14.898,14	14.973	Menguat
05/31/2023	15.043,84	14.894,16	14.969	Menguat
06/05/2023	15.078,01	14.927,99	15.003	Stabil
06/06/2023	14.962,44	14.813,56	14.888	Menguat
06/07/2023	14.913,19	14.764,81	14.839	Menguat
06/08/2023	14.949,38	14.800,63	14.875,005	Menguat
06/09/2023	14.977,51	14.828,49	14.903	Menguat
06/12/2023	14.927,26	14.778,74	14.853	Menguat
06/13/2023	14.948,37	14.799,63	14.874	Menguat
06/14/2023	14.942,34	14.793,66	14.868	Menguat
06/15/2023	14.969,48	14.820,52	14.895	Menguat
06/16/2023	15.017,72	14.868,28	14.943	Menguat
06/19/2023	15.019,73	14.870,27	14.945	Menguat

06/20/2023	15.068,97	14.919,03	14.994	Stabil
06/21/2023	15.115,2	14.964,8	15.040	Stabil
06/22/2023	15.056,91	14.907,09	14.982	Menguat
06/23/2023	14.992,59	14.843,41	14.918	Menguat
06/26/2023	15.072,99	14.923,01	14.998	Stabil
06/27/2023	15.101,13	14.950,87	15.026	Stabil
07/03/2023	15.075	14.925	15.000	Stabil
07/04/2023	15.109,17	14.958,83	15.034	Stabil
07/05/2023	15.093,09	14.942,91	15.018	Stabil
07/06/2023	15.088,07	14.937,93	15.013	Stabil
07/07/2023	15.137,31	14.986,69	15.062	Stabil
07/10/2023	15.211,68	15.060,32	15.136	Stabil
07/11/2023	15.267,96	15.116,04	15.192	Stabil
07/12/2023	15.237,81	15.086,19	15.162	Stabil
07/13/2023	15.159,42	15.008,58	15.084	Stabil
07/14/2023	15.052,89	14.903,11	14.978	Menguat
07/17/2023	15.019,73	14.870,27	14.945	Menguat
07/18/2023	15.082,03	14.931,97	15.007	Stabil
07/20/2023	15.068,97	14.919,03	14.994	Stabil
07/21/2023	15.065,95	14.916,05	14.991	Menguat
07/24/2023	15.101,13	14.950,87	15.026	Stabil
07/25/2023	15.103,14	14.952,86	15.028	Stabil

07/26/2023	15.082,03	14.931,97	15.007	Stabil
07/27/2023	15.107,16	14.956,84	15.032	Stabil
07/28/2023	15.078,01	14.927,99	15.003	Stabil
07/31/2023	15.158,42	15.007,58	15.083	Stabil

Lampiran 3 : Hasil Prediksi *State* Kurs Rupiah terhadap Dolar Amerika Serikat
Periode Agustus 2023 – Juli 2024

No.	Tanggal Prediksi	Hasil Prediksi
1	01/08/2023	Menguat
2	02/08/2023	Menguat
3	03/08/2023	Menguat
4	04/08/2023	Menguat
5	05/08/2023	Menguat
6	08/08/2023	Menguat
7	09/08/2023	Menguat
8	10/08/2023	Menguat
9	11/08/2023	Menguat
10	12/08/2023	Menguat
11	15/08/2023	Menguat
12	16/08/2023	Menguat
13	18/08/2023	Menguat
14	19/08/2023	Menguat
15	22/08/2023	Menguat
16	23/08/2023	Menguat
17	24/08/2023	Menguat
18	25/08/2023	Menguat
19	26/08/2023	Menguat
20	29/08/2023	Menguat
21	30/08/2023	Menguat

22	31/08/2023	Menguat
23	01/09/2023	Menguat
24	02/09/2023	Menguat
25	05/09/2023	Menguat
26	06/09/2023	Menguat
27	07/09/2023	Menguat
28	08/09/2023	Menguat
29	09/09/2023	Menguat
30	12/09/2023	Menguat
31	13/09/2023	Menguat
32	14/09/2023	Menguat
33	15/09/2023	Menguat
34	16/09/2023	Menguat
35	19/09/2023	Menguat
36	20/09/2023	Menguat
37	21/09/2023	Menguat
38	22/09/2023	Menguat
39	23/09/2023	Menguat
40	26/09/2023	Menguat
41	27/09/2023	Menguat
42	28/09/2023	Menguat
43	29/09/2023	Menguat
44	30/09/2023	Menguat
45	03/10/2023	Menguat

46	04/10/2023	Menguat
47	05/10/2023	Menguat
48	06/10/2023	Menguat
49	07/10/2023	Menguat
50	10/10/2023	Menguat
51	11/10/2023	Menguat
52	12/10/2023	Menguat
53	13/10/2023	Menguat
54	14/10/2023	Menguat
55	17/10/2023	Menguat
56	18/10/2023	Menguat
57	19/10/2023	Menguat
58	20/10/2023	Menguat
59	21/10/2023	Menguat
60	24/10/2023	Menguat
61	25/10/2023	Menguat
62	26/10/2023	Menguat
63	27/10/2023	Menguat
64	28/10/2023	Menguat
65	31/10/2023	Menguat
66	01/11/2023	Menguat
67	02/11/2023	Menguat
68	03/11/2023	Menguat
69	04/11/2023	Menguat

70	07/11/2023	Menguat
71	08/11/2023	Menguat
72	09/11/2023	Menguat
73	10/11/2023	Menguat
74	11/11/2023	Menguat
75	14/11/2023	Menguat
76	15/11/2023	Menguat
77	16/11/2023	Menguat
78	17/11/2023	Menguat
79	18/11/2023	Menguat
80	21/11/2023	Menguat
81	22/11/2023	Menguat
82	23/11/2023	Menguat
83	24/11/2023	Menguat
84	25/11/2023	Menguat
85	28/11/2023	Menguat
86	29/11/2023	Menguat
87	30/11/2023	Menguat
88	01/12/2023	Menguat
89	02/12/2023	Menguat
90	05/12/2023	Menguat
91	06/12/2023	Menguat
92	07/12/2023	Menguat
93	08/12/2023	Menguat

94	09/12/2023	Menguat
95	12/12/2023	Menguat
96	13/12/2023	Menguat
97	14/12/2023	Menguat
98	15/12/2023	Menguat
99	16/12/2023	Menguat
100	19/12/2023	Menguat
101	20/12/2023	Menguat
102	21/12/2023	Menguat
103	22/12/2023	Menguat
104	23/12/2023	Menguat
105	26/12/2023	Menguat
106	27/12/2023	Menguat
107	28/12/2023	Menguat
108	29/12/2023	Menguat
109	30/12/2023	Menguat
110	02/01/2024	Menguat
111	03/01/2024	Menguat
112	04/01/2024	Menguat
113	05/01/2024	Menguat
114	06/01/2024	Menguat
115	09/01/2024	Menguat
116	10/01/2024	Menguat
117	11/01/2024	Menguat

118	12/01/2024	Menguat
119	13/01/2024	Menguat
120	16/01/2024	Menguat
121	17/01/2024	Menguat
122	18/01/2024	Menguat
123	19/01/2024	Menguat
124	20/01/2024	Menguat
125	24/01/2024	Menguat
126	25/01/2024	Menguat
127	26/01/2024	Menguat
128	27/01/2024	Menguat
129	30/01/2024	Menguat
130	31/01/2024	Menguat
131	01/02/2024	Menguat
132	02/02/2024	Menguat
133	03/02/2024	Menguat
134	06/02/2024	Menguat
135	07/02/2024	Menguat
136	08/02/2024	Menguat
137	09/02/2024	Menguat
138	10/02/2024	Menguat
139	13/02/2024	Menguat
140	14/02/2024	Menguat
141	15/02/2024	Menguat

142	16/02/2024	Menguat
143	17/02/2024	Menguat
144	20/02/2024	Menguat
145	21/02/2024	Menguat
146	22/02/2024	Menguat
147	23/02/2024	Menguat
148	24/02/2024	Menguat
149	27/02/2024	Menguat
150	28/02/2024	Menguat
151	01/03/2024	Menguat
152	02/03/2024	Menguat
153	03/03/2024	Menguat
154	06/03/2024	Menguat
155	07/03/2024	Menguat
156	08/03/2024	Menguat
157	09/03/2024	Menguat
158	10/03/2024	Menguat
159	13/03/2024	Menguat
160	14/03/2024	Menguat
161	15/03/2024	Menguat
162	16/03/2024	Menguat
163	17/03/2024	Menguat
164	20/03/2024	Menguat
165	21/03/2024	Menguat

166	24/03/2024	Menguat
167	27/03/2024	Menguat
168	28/03/2024	Menguat
169	29/03/2024	Menguat
170	30/03/2024	Menguat
171	31/03/2024	Menguat
172	03/04/2024	Menguat
173	04/04/2024	Menguat
174	05/04/2024	Menguat
175	06/04/2024	Menguat
176	10/04/2024	Menguat
177	11/04/2024	Menguat
178	12/04/2024	Menguat
179	13/04/2024	Menguat
180	14/04/2024	Menguat
181	17/04/2024	Menguat
182	18/04/2024	Menguat
183	26/04/2024	Menguat
184	27/04/2024	Menguat
185	28/04/2024	Menguat
186	02/05/2024	Melemah
187	03/05/2024	Melemah
188	04/05/2024	Melemah
189	05/05/2024	Melemah

190	08/05/2024	Melemah
191	09/05/2024	Melemah
192	10/05/2024	Melemah
193	11/05/2024	Melemah
194	12/05/2024	Melemah
195	15/05/2024	Melemah
196	16/05/2024	Melemah
197	17/05/2024	Melemah
198	19/05/2024	Melemah
199	22/05/2024	Melemah
200	23/05/2024	Melemah
201	24/05/2024	Melemah
202	25/05/2024	Melemah
203	26/05/2024	Melemah
204	29/05/2024	Melemah
205	30/05/2024	Melemah
206	31/05/2024	Melemah
207	05/06/2024	Melemah
208	06/06/2024	Melemah
209	07/06/2024	Melemah
210	08/06/2024	Melemah
211	09/06/2024	Melemah
212	12/06/2024	Melemah
213	13/06/2024	Melemah

214	14/06/2024	Melemah
215	15/06/2024	Melemah
216	16/06/2024	Melemah
217	19/06/2024	Melemah
218	20/06/2024	Melemah
219	21/06/2024	Melemah
220	22/06/2024	Melemah
221	23/06/2024	Melemah
222	26/06/2024	Melemah
223	27/06/2024	Melemah
224	03/07/2024	Menguat
225	04/07/2024	Menguat
226	05/07/2024	Menguat
227	06/07/2024	Menguat
228	07/07/2024	Menguat
229	10/07/2024	Menguat
230	11/07/2024	Menguat
231	12/07/2024	Menguat
232	13/07/2024	Menguat
233	14/07/2024	Menguat
234	17/07/2024	Menguat
235	18/07/2024	Menguat
236	20/07/2024	Menguat
237	21/07/2024	Menguat

238	24/07/2024	Menguat
239	25/07/2024	Menguat
240	26/07/2024	Menguat
241	27/07/2024	Menguat
242	28/07/2024	Menguat
243	31/07/2024	Menguat

Lampiran 4 : Kode Lengkap RStudio

```

library(xts)
library(markovchain)
library(HMM)
library(gtools)

# Langkah 1: Pengumpulan Data Sekunder
# Membaca data kurs jual dari file CSV
data <- read.csv("D:/eja/Kurs Transaksi USD.csv")
View(data)

# Langkah 2: Preprocessing Data
# Atur Format Tiap Variabel
data$Tanggal <- as.Date(gsub('/', '-', data$Tanggal), format = "%m-%d-%Y")
data$Kurs_Jual <- as.numeric(gsub(',', '.', data$Kurs_Jual))
data$Kurs_Beli <- as.numeric(gsub(',', '.', data$Kurs_Beli))
data$Tingkat_Inflasi_ID <- as.numeric(gsub(',', '.', gsub('%', '', data$Tingkat_Inflasi_ID)))
data$Tingkat_Inflasi_AS <- as.numeric(gsub(',', '.', gsub('%', '', data$Tingkat_Inflasi_AS)))

#Definisikan Kurs Tengah
data$Kurs_Tengah <- (data$Kurs_Jual + data$Kurs_Beli)/2

# Mengubah data menjadi time series
data_ts <- xts(data[, c("Kurs_Jual", "Kurs_Beli", "Kurs_Tengah", "Tingkat_Inflasi_ID", "Tingkat_Inflasi_AS")], order.by = data$Tanggal)
View(data_ts)

# Visualisasi Kurs Jual dan Kurs Beli

```

```

plot(data$Tanggal, data$Kurs_Jual, col = "blue", ylab = "Kurs", main =
"Visualisasi Kurs Jual, Kurs Beli dan Kurs Tengah", xlab="Tanggal",
type="l")
lines(data$Tanggal, data$Kurs_Beli, col = "red")
lines(data$Tanggal, data$Kurs_Tengah, col = "orange")
legend("topright", legend = c("Kurs Jual", "Kurs Beli", "Kurs Tengah"),
col = c("blue", "red", "orange"), lty = 1)

```

Visualisasi Tingkat Inflasi

```

plot(data$Tanggal, data$Tingkat_Inflasi_AS, col = "blue", ylab =
"Tingkat Inflasi", main = "Visualisasi Tingkat Inflasi Indonesia dan
Amerika Serikat", xlab="Tanggal", type="l")
lines(data$Tanggal, data$Tingkat_Inflasi_ID, col = "red")
legend("topright", legend = c("Tingkat Inflasi Indonesia", "Tingkat
Inflasi Amerika Serikat"), col = c("red", "blue"), lty = 1)

```

Membagi data Kurs Tengah berdasarkan 3 state

Rata-rata, nilai terkecil, dan nilai terbesar

```

mean_kurs <- mean(data_ts$Kurs_Tengah)
min_kurs <- min(data_ts$Kurs_Tengah)
max_kurs <- max(data_ts$Kurs_Tengah)

```

Menentukan batas untuk kelompok

```

threshold_low <- mean_kurs - (mean_kurs - min_kurs) / 3
threshold_high <- mean_kurs + (max_kurs - mean_kurs) / 3

```

Mengelompokkan data kurs menjadi 3 state

```

State_Kurs <- data.frame(Kurs = data_ts$Kurs_Tengah)
State_Kurs$State <- ifelse(State_Kurs$Kurs_Tengah < threshold_low,
'Menguat',
ifelse(State_Kurs$Kurs_Tengah <= threshold_high,
'Stabil', 'Melemah'))

```

```

#Observasi Inflasi
State_Kurs$inflasi <- ifelse(data_ts$Tingkat_Inflasi_ID <
data_ts$Tingkat_Inflasi_AS, "Rendah",
                           ifelse(data_ts$Tingkat_Inflasi_ID <=
data_ts$Tingkat_Inflasi_AS, "Sedang", "Tinggi"))

# Menampilkan hasil kelompok state
print(State_Kurs)

# Langkah 3 : Definisikan Struktur HMM
# Mendefinisikan Hidden State
S <- c("Melemah", "Stabil", "Menguat")

# Menentukan matriks probabilitas transisi menggunakan library
markovchain
transisi <- markovchainFit(State_Kurs$State)
transisi$estimate
A <- rbind(c(transisi$estimate[1]), (transisi$estimate[2]),
(transisi$estimate[3]))

# Mengecek bahwa jumlah setiap barisnya = 1
apply(A, 1, sum)

# Menentukan Urutan Observasi
V_labels <- c('Rendah','Sedang','Tinggi')
V <- State_Kurs$inflasi
# Membuat tabel kontingensi untuk menentukan probabilitas observasi
e_table <- table(State_Kurs$State, State_Kurs$inflasi)
e_table

# Menentukan probabilitas observasi

```



```

Melemah <- e_table[1,]/sum(e_table[1,])
Menguat <- e_table[2,]/sum(e_table[2,])
Stabil <- e_table[3,]/sum(e_table[3,])

# Pastikan urutannya sama dengan S di atas
B <- rbind(Melemah, Stabil, Menguat)
B

# Menentukan Distribusi Probabilitas Inisial
table(State_Kurs$State)/length(State_Kurs$inflasi)
pi <- rbind(c(0.3127572, 0.3909465, 0.2962963))
pi

# Menjalankan Model HMM
# Initialise HMM
hmm = initHMM(S, V_labels, startProbs = pi, transProbs = A,
emissionProbs = B)
print(hmm)

# Langkah 4 : Evaluation Problem
# Mengambil 3 observasi
State_Kurs$inflasi[1:3]
State_Kurs$State [1:3]
V_sample <- c("Rendah", "Rendah", "Rendah")

# Fungsi forward
forward = function(v, a, b, initial_distribution){

  T = length(v)
  m = nrow(a)
  alpha = matrix(0, T, m)

```

```

alpha[1, ] = initial_distribution*b[, v[1]]

for(t in 2:T){
  tmp = alpha[t-1, ] %*% a
  alpha[t, ] = tmp * b[, v[t]]
}
return(alpha)
}

# Menghitung Probabilitas dengan algoritma forward
answer <- forward(V_sample,A,B,pi)
answer

# Menjumlahkan probabilitas di waktu ke 3
sum(answer[3,])

# Terdapat 3^3 urutan yang mungkin
# Untuk semua Urutan yang mungkin
test <- permutations(3, 3,V_labels, repeats.allowed = TRUE)
test

# Iterasi melalui semua urutan dan menghitung probabilitas di waktu ke-
3
total <- 0
for (i in 1:27){
  x <- (test[i,])
  print(sum(forward(x,A,B,pi)[3,]))
  total <- total + sum(forward(x,A,B,pi)[3,])
}
# Total probabilitas harus = 1
total

```

```

# Urutan ke-26 memiliki observasi "Tinggi", "Tinggi", "Sedang"
test[26,]

# Langkah 5 : Decoding Problem
# viterbi
# Urutan State Terbaik
HMM_states <- viterbi(hmm, V)
HMM_states

# Membandingkan Model dengan data
cbind(HMM_states, State_Kurs$State)[1:15]

# Persentase state sesuai dengan data
sum(HMM_states == State_Kurs$State)/length(State_Kurs$State)

plot(HMM_states == State_Kurs$State)

# Langkah 6 : Learning Problem
# Fungsi untuk algoritma backward
backward = function(V, A, B){
  T = length(V) # Mendapatkan panjang urutan observasi
  m = nrow(A) # Jumlah state dalam model HMM
  beta = matrix(1, T, m) # Matriks untuk menyimpan nilai beta

  # Iterasi mundur untuk menghitung nilai beta
  for(t in (T-1):1){
    # Menghitung komponen beta untuk waktu t
    tmp = as.matrix(beta[t+1, ] * B[, V[t+1]])
    # Menghitung nilai beta menggunakan transpose dari matriks transisi
    A
    beta[t, ] = t(A %*% tmp)
  }
}

```

```

}

# Mengembalikan matriks beta sebagai output
return(beta)
}

# Menggunakan fungsi backward untuk urutan observasi tertentu
backward(V_sample,A,B)

# Mengupdate state observasi
State_Kurs$inflasi <- ifelse(data_ts$Tingkat_Inflasi_ID <
data_ts$Tingkat_Inflasi_AS, "1",
                           ifelse(data_ts$Tingkat_Inflasi_ID <=
data_ts$Tingkat_Inflasi_AS, "2", "3"))

# BaumWelch
BaumWelch = function(v, a, b, initial_distribution, n.iter = 100){

  for(i in 1:n.iter){
    T = length(v)
    M = nrow(a)
    K=ncol(b)
    alpha = forward(v, a, b, initial_distribution)
    beta = backward(v, a, b)
    xi = array(0, dim=c(M, M, T-1))

    for(t in 1:T-1){
      denominator = ((alpha[t,] %*% a) * b[,v[t+1]]) %*%
matrix(beta[t+1,])
      for(s in 1:M){
        numerator = alpha[t,s] * a[s,] * b[,v[t+1]] * beta[t+1,]
        xi[s,,t]=numerator/as.vector(denominator)
      }
    }
  }
}

```

```

    }
  }

  xi.all.t = rowSums(xi, dims = 2)
  a = xi.all.t/rowSums(xi.all.t)

  gamma = apply(xi, c(1, 3), sum)
  gamma = cbind(gamma, colSums(xi[, , T-1]))
  for(l in 1:K){
    b[, l] = rowSums(gamma[, which(v==l)])
  }
  b = b/rowSums(b)

}
return(list(a = a, b = b, initial_distribution = initial_distribution))
}

M=3; K=3
A = matrix(1, M, M)
A = A/rowSums(A)
B = matrix(1:9, M, K)
B = B/rowSums(B)
initial_distribution = c(1/3,1/3, 1/3)

State_Kurs$inflasi <- as.numeric(State_Kurs$inflasi)
(myout = BaumWelch(State_Kurs$inflasi, A, B, initial_distribution,
n.iter = 100))

pi <- c(1/3,1/3,1/3)
S <- c("Melemah", "Stabil","Menguat")

```

```

hmm2 = initHMM(S, V_labels, startProbs = pi, transProbs = myout$a,
emissionProbs = myout$b)
print(hmm2)

HMM_states2 <- viterbi(hmm2, V)

# Bandingkan model dengan data
cbind(HMM_states2, State_Kurs$State)[1:15]

# Persentase state sesuai dengan data
sum(HMM_states2 == State_Kurs$State)/length(State_Kurs$State)
plot(HMM_states2 == State_Kurs$State)

# Menyimpan data prediksi untuk satu tahun ke depan
predicted_states <- HMM_states2

# Menggabungkan hasil prediksi dengan tanggal prediksi
Hasil_Prediksi <- data.frame(
  Tanggal = data$Tanggal + lubridate::years(1),
  Kurs_Prediksi = predicted_states)

# Tampilkan hasil prediksi
print(Hasil_Prediksi)

# Plot menggunakan ggplot2
ggplot(Hasil_Prediksi, aes(x = Tanggal, y = Kurs_Prediksi, group = 1))
+
  geom_line(color = "blue") +
  labs(title = "Visualisasi Kurs Hasil Prediksi",
    x = "Tanggal",
    y = "Kurs Prediksi") +
  theme_minimal()

```


Lampiran 5 : Hasil Program Rstudio

```
> transisi <- markovchainFit(State_Kurs$State)
> transisi$estimate
MLE Fit
A 3 - dimensional discrete Markov chain defined by the following states:
Melemah, Menguat, stabil
The transition matrix (by rows) is defined as follows:
      Melemah  Menguat  stabil
Melemah 0.96052632 0.00000000 0.03947368
Menguat 0.00000000 0.91578947 0.08421053
stabil  0.04225352 0.09859155 0.85915493
```

```
> # Mengecek bahwa jumlah setiap barisnya = 1
> apply(A, 1, sum)
[1] 1 1 1
```

```
> B <- rbind(Melemah, stabil, Menguat)
> B
      Rendah  Sedang  Tinggi
Melemah 1.0000000 0.0000000 0.0000000
stabil  0.9305556 0.0000000 0.06944444
Menguat 0.6526316 0.2210526 0.12631579
```

```
> # Menentukan Distribusi Probabilitas Inisial
> table(State_Kurs$State)/length(State_Kurs$inflasi)

Melemah  Menguat  stabil
0.3127572 0.3909465 0.2962963
```

```
> # Menjalankan Model HMM
> # Initialise HMM
> hmm = inithMM(S, v_labels, startProbs = pi, transProbs = A, emissionProbs = B)
> print(hmm)
$states
[1] "Melemah" "stabil" "Menguat"

$symbols
[1] "Rendah" "Sedang" "Tinggi"

$startProbs
  Melemah  stabil  Menguat
0.3127572 0.3909465 0.2962963

$transProbs
      to
from   Melemah  stabil  Menguat
Melemah 0.96052632 0.00000000 0.03947368
stabil  0.00000000 0.91578947 0.08421053
Menguat 0.04225352 0.09859155 0.85915493

$emissionProbs
      symbols
states  Rendah  Sedang  Tinggi
Melemah 1.0000000 0.0000000 0.0000000
stabil  0.9305556 0.0000000 0.06944444
Menguat 0.6526316 0.2210526 0.12631579
```



```
> state_kurs$inflasi[1:3]
      [,1]
2022-08-01 Rendah
2022-08-02 Rendah
2022-08-03 Rendah
> state_kurs$State [1:3]
[1] "Menguat" "Menguat" "Menguat"
```

```
> answer <- forward(v_sample,A,B,pi)
> answer
      [,1]      [,2]      [,3]
[1,] 0.3127572 0.3637974 0.1933723
[2,] 0.3085822 0.3277666 0.1364770
[3,] 0.3021679 0.2918414 0.1024874
>
```

```
> # Menjumlahkan probabilitas di waktu ke 3
> sum(answer[3,])
[1] 0.6964968
```

```
> # Terdapat 3^3 urutan yang mungkin
> # Untuk semua urutan yang mungkin
> test <- permutations(3, 3,v_labels, repeats.allowed = TRUE)
> test
      [,1]      [,2]      [,3]
[1,] "Rendah" "Rendah" "Rendah"
[2,] "Rendah" "Rendah" "Sedang"
[3,] "Rendah" "Rendah" "Tinggi"
[4,] "Rendah" "Sedang" "Rendah"
[5,] "Rendah" "Sedang" "Sedang"
[6,] "Rendah" "Sedang" "Tinggi"
[7,] "Rendah" "Tinggi" "Rendah"
[8,] "Rendah" "Tinggi" "Sedang"
[9,] "Rendah" "Tinggi" "Tinggi"
[10,] "Sedang" "Rendah" "Rendah"
[11,] "Sedang" "Rendah" "Sedang"
[12,] "Sedang" "Rendah" "Tinggi"
[13,] "Sedang" "Sedang" "Rendah"
[14,] "Sedang" "Sedang" "Sedang"
[15,] "Sedang" "Sedang" "Tinggi"
[16,] "Sedang" "Tinggi" "Rendah"
[17,] "Sedang" "Tinggi" "Sedang"
[18,] "Sedang" "Tinggi" "Tinggi"
[19,] "Tinggi" "Rendah" "Rendah"
[20,] "Tinggi" "Rendah" "Sedang"
[21,] "Tinggi" "Rendah" "Tinggi"
[22,] "Tinggi" "Sedang" "Rendah"
[23,] "Tinggi" "Sedang" "Sedang"
[24,] "Tinggi" "Sedang" "Tinggi"
[25,] "Tinggi" "Tinggi" "Rendah"
[26,] "Tinggi" "Tinggi" "Sedang"
[27,] "Tinggi" "Tinggi" "Tinggi"
```

```

> # Iterasi melalui semua urutan dan menghitung probabilitas di waktu ke-3
> total <- 0
> for (i in 1:27){
+   x <- (test[i,])
+   print(sum(forward(x,A,B,pi)[3,]))
+   total <- total + sum(forward(x,A,B,pi)[3,])
+ }
[1] 0.6964968
[1] 0.03471348
[1] 0.04161549
[1] 0.03211373
[1] 0.008779188
[1] 0.005333172
[1] 0.0405398
[1] 0.005472004
[1] 0.004863295
[1] 0.03369384
[1] 0.007110756
[1] 0.004696885
[1] 0.008641571
[1] 0.002362415
[1] 0.001435118
[1] 0.005344839
[1] 0.001358299
[1] 0.0008533562
[1] 0.04127825
[1] 0.004777341
[1] 0.004573563
[1] 0.005289132
[1] 0.001445932
[1] 0.0008783735
[1] 0.004821091
[1] 0.0008631575
[1] 0.0006491206

```

```

> # Total probabilitas harus = 1
> total
[1] 1

```

```

> # Membandingkan Model dengan data
> cbind(HMM_states, state_kurs$state)[1:15]
[1] "Melemah" "Melemah" "Melemah" "Melemah" "Melemah" "Melemah" "Melemah" "Melemah"
[9] "Melemah" "Melemah" "Melemah" "Melemah" "Melemah" "Melemah" "Melemah"

```

```

> # Persentase state sesuai dengan data
> sum(HMM_states == state_kurs$state)/length(state_kurs$state)
[1] 0.4485597

```

```

> backward(v_sample,A,B)
      [,1]      [,2]      [,3]
[1,] 0.9652526 0.8112483 0.5144327
[2,] 0.9862881 0.9071514 0.6947101
[3,] 1.0000000 1.0000000 1.0000000

```

```
> (myout = BaumWelch(State_Kurs$inflasi, A, B, initial_distribution, n.iter = 100))
$a
      [,1]      [,2]      [,3]
[1,] 0.973684211 0.01253684 0.01377895
[2,] 0.005203524 0.39897553 0.59582095
[3,] 0.004709031 0.37979461 0.61549636

$b
      [,1]      [,2]      [,3]
[1,] 2.321397e-115 5.526316e-01 4.473684e-01
[2,] 1.000000e+00 1.557499e-179 2.691245e-169
[3,] 1.000000e+00 1.169050e-191 6.949314e-186

$initial_distribution
[1] 0.3333333 0.3333333 0.3333333
```

```
> hmm2 = initHMM(S, v_labels, startProbs = pi, transProbs = myout$a, emissionProbs = myout$b)
> print(hmm2)
$states
[1] "Melemah" "stabil" "Menguat"

$symbols
[1] "Rendah" "Sedang" "Tinggi"

$startProbs
  Melemah  stabil  Menguat
0.3333333 0.3333333 0.3333333

$transProbs
      to
from    Melemah  stabil  Menguat
Melemah 0.973684211 0.01253684 0.01377895
stabil  0.005203524 0.39897553 0.59582095
Menguat 0.004709031 0.37979461 0.61549636

$emissionProbs
      symbols
states  Rendah      sedang      Tinggi
Melemah 2.321397e-115 5.526316e-01 4.473684e-01
stabil  1.000000e+00 1.557499e-179 2.691245e-169
Menguat 1.000000e+00 1.169050e-191 6.949314e-186
```

```
> #compare model to actual
> cbind(HMM_states2, State_Kurs$State)[1:15]
[1] "Menguat" "Menguat" "Menguat" "Menguat" "Menguat" "Menguat" "Menguat" "Menguat"
[9] "Menguat" "Menguat" "Menguat" "Menguat" "Menguat" "Menguat" "Menguat"
```

```
> # Persentase state sesuai dengan data
> sum(HMM_states2 == State_Kurs$State)/length(State_Kurs$State)
[1] 0.255144
```