Part 1 Coding

1. Index of each split

Spilt 1, train fold:

[1, 2, 3, 4, 5, 6, 7, 8, 11, 12, 13, 17, 18,
19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 31, 33,
34, 35, 36, 39, 40, 41, 42, 44, 46, 47, 48, 49, 50,
51, 52, 53, 54, 55, 56, 59, 60, 61, 62, 64, 65, 66,
67, 68, 71, 72, 73, 74, 75, 76, 77, 78, 79, 81, 84,
85, 87, 88, 89, 90, 91, 92, 94, 96, 97, 98, 99, 101,
102, 103, 106, 108, 109, 110, 113, 114, 115, 116, 117, 118, 119,
120, 121, 122, 123, 124, 126, 127, 128, 129, 130, 132, 133, 136,
137, 138, 140, 141, 142, 143, 144, 145, 146, 147, 148, 149, 150,
151, 152, 153, 155, 156, 157, 158, 160, 161, 163, 165, 166, 167,
168, 169, 170, 172, 173, 174, 176, 177, 178, 179, 181, 182, 183,
185, 186, 187, 188, 189, 190, 192, 194, 195, 196, 197, 198, 199,
200, 201, 202, 204, 205, 208, 210, 212, 213, 214, 215, 216, 218,
219, 220, 221, 222, 223, 224, 225, 226, 227, 228, 229, 230, 232,
234, 235, 236, 237, 239, 240, 241, 242, 243, 244, 245, 246, 247,
249, 250, 251, 252, 254, 257, 259, 260, 261, 262, 263, 264, 267,
268, 269, 270, 271, 272, 274, 275, 276, 277, 279, 280, 281, 282,
283, 284, 286, 287, 288, 290, 291, 292, 293, 295, 296, 297, 298,
299, 300, 301, 302, 303, 304, 305, 306, 307, 308, 309, 310, 312,
313, 314, 315, 316, 317, 318, 319, 320, 321, 322, 323, 325, 326,
327, 328, 329, 330, 332, 333, 334, 335, 336, 338, 339, 340, 341,
344, 345, 346, 350, 351, 352, 353, 354, 356, 357, 358, 359, 360,
361, 362, 363, 364, 365, 366, 367, 368, 369, 370, 372, 373, 374,
376, 378, 379, 380, 381, 383, 384, 385, 386, 388, 389, 390, 391,
393, 394, 395, 396, 397, 398, 400, 402, 403, 404, 405, 407, 409,
411, 412, 413, 414, 415, 416, 417, 418, 419, 420, 422, 425, 427,
428, 429, 430, 431, 432, 433, 434, 436, 437, 438, 439, 440, 441,
442, 443, 444, 445, 447, 448, 449, 450, 451, 452, 453, 454, 455,
456, 458, 459, 460, 462, 463, 464, 465, 466, 467, 468, 469, 470,
471, 474, 475, 476, 477, 478, 479, 480, 481, 482, 483, 484, 485,
486, 487, 488, 489, 490, 491, 492, 494, 495, 496, 498, 499, 501,

502, 503, 505, 507, 508, 509, 510, 511, 513, 514, 515, 516, 517,
518, 519, 520, 521, 522, 523, 524, 525, 527, 528, 529, 531, 532,
533, 535, 538, 539, 540, 541, 542, 543, 545, 546, 547]

Spilt 1, validation fold:

[0, 9, 10, 14, 15, 16, 30, 32, 37, 38, 43, 45, 57,
58, 63, 69, 70, 80, 82, 83, 86, 93, 95, 100, 104, 105,
107, 111, 112, 125, 131, 134, 135, 139, 154, 159, 162, 164, 171,
175, 180, 184, 191, 193, 203, 206, 207, 209, 211, 217, 231, 233,
238, 248, 253, 255, 256, 258, 265, 266, 273, 278, 285, 289, 294,
311, 324, 331, 337, 342, 343, 347, 348, 349, 355, 371, 375, 377,
382, 387, 392, 399, 401, 406, 408, 410, 421, 423, 424, 426, 435,
446, 457, 461, 472, 473, 493, 497, 500, 504, 506, 512, 526, 530,
534, 536, 537, 544, 548, 549]

Spilt 2, train fold:

[0, 2, 3, 4, 6, 7, 8, 9, 10, 11, 12, 14, 15,
16, 18, 19, 20, 21, 23, 26, 27, 28, 29, 30, 31, 32,
33, 36, 37, 38, 39, 40, 42, 43, 44, 45, 46, 47, 49,
50, 51, 54, 55, 56, 57, 58, 59, 61, 62, 63, 64, 65,
66, 68, 69, 70, 71, 72, 73, 74, 75, 76, 78, 79, 80,
81, 82, 83, 84, 86, 87, 88, 89, 90, 91, 92, 93, 95,
97, 99, 100, 102, 104, 105, 106, 107, 108, 109, 110, 111, 112,
113, 114, 116, 117, 119, 121, 122, 125, 126, 128, 129, 130, 131,
132, 134, 135, 137, 139, 140, 141, 142, 143, 145, 146, 147, 148,
149, 150, 151, 152, 154, 155, 156, 157, 158, 159, 160, 162, 163,
164, 166, 167, 168, 169, 170, 171, 172, 173, 174, 175, 177, 178,
180, 181, 182, 184, 185, 186, 187, 188, 189, 190, 191, 192, 193,
194, 195, 196, 197, 198, 199, 200, 201, 203, 204, 205, 206, 207,
208, 209, 210, 211, 213, 214, 215, 216, 217, 219, 221, 222, 224,
225, 227, 228, 229, 231, 232, 233, 234, 236, 238, 239, 242, 243,
244, 245, 246, 248, 249, 251, 252, 253, 254, 255, 256, 258, 260,
261, 262, 263, 264, 265, 266, 267, 268, 269, 272, 273, 274, 275,
276, 278, 279, 280, 281, 282, 283, 284, 285, 286, 287, 288, 289,
290, 291, 292, 293, 294, 297, 300, 301, 302, 303, 306, 307, 308,

309, 311, 313, 315, 316, 317, 318, 319, 320, 321, 322, 323, 324,
325, 326, 327, 329, 331, 332, 333, 334, 335, 336, 337, 338, 339,
340, 341, 342, 343, 344, 345, 346, 347, 348, 349, 350, 352, 353,
354, 355, 356, 357, 358, 359, 360, 362, 363, 364, 367, 368, 369,
370, 371, 372, 374, 375, 376, 377, 378, 380, 381, 382, 383, 384,
386, 387, 388, 389, 390, 392, 393, 394, 395, 397, 398, 399, 400,
401, 403, 404, 406, 408, 409, 410, 412, 413, 414, 415, 416, 417,
418, 419, 420, 421, 422, 423, 424, 426, 427, 428, 429, 430, 431,
432, 433, 434, 435, 436, 437, 438, 439, 440, 441, 442, 443, 444,
445, 446, 448, 449, 451, 455, 456, 457, 459, 460, 461, 462, 464,
465, 466, 467, 468, 469, 470, 472, 473, 476, 480, 481, 482, 483,
484, 485, 486, 487, 488, 489, 490, 491, 493, 494, 497, 498, 499,
500, 503, 504, 505, 506, 509, 512, 513, 514, 515, 516, 518, 519,
520, 521, 522, 523, 526, 528, 529, 530, 531, 532, 533, 534, 535,
536, 537, 538, 539, 542, 543, 544, 545, 547, 548, 549]

Spilt 2, validation fold:

[1, 5, 13, 17, 22, 24, 25, 34, 35, 41, 48, 52, 53,
60, 67, 77, 85, 94, 96, 98, 101, 103, 115, 118, 120, 123,
124, 127, 133, 136, 138, 144, 153, 161, 165, 176, 179, 183, 202,
212, 218, 220, 223, 226, 230, 235, 237, 240, 241, 247, 250, 257,
259, 270, 271, 277, 295, 296, 298, 299, 304, 305, 310, 312, 314,
328, 330, 351, 361, 365, 366, 373, 379, 385, 391, 396, 402, 405,
407, 411, 425, 447, 450, 452, 453, 454, 458, 463, 471, 474, 475,
477, 478, 479, 492, 495, 496, 501, 502, 507, 508, 510, 511, 517,
524, 525, 527, 540, 541, 546]

Spilt 3, train fold:

[0, 1, 4, 5, 7, 8, 9, 10, 12, 13, 14, 15, 16,
17, 18, 20, 22, 23, 24, 25, 26, 27, 28, 29, 30, 32,
34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 47,
48, 49, 50, 52, 53, 54, 55, 56, 57, 58, 60, 61, 63,
64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 77, 78,
79, 80, 81, 82, 83, 84, 85, 86, 88, 89, 90, 93, 94,
95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 107, 108,

109, 110, 111, 112, 113, 114, 115, 117, 118, 119, 120, 121, 123,
124, 125, 126, 127, 128, 130, 131, 132, 133, 134, 135, 136, 137,
138, 139, 140, 141, 143, 144, 145, 146, 147, 148, 151, 152, 153,
154, 155, 156, 157, 159, 160, 161, 162, 164, 165, 166, 168, 169,
171, 173, 174, 175, 176, 177, 178, 179, 180, 181, 182, 183, 184,
185, 186, 187, 189, 190, 191, 192, 193, 194, 195, 196, 198, 199,
200, 201, 202, 203, 206, 207, 208, 209, 210, 211, 212, 214, 216,
217, 218, 219, 220, 222, 223, 224, 225, 226, 227, 229, 230, 231,
232, 233, 235, 236, 237, 238, 240, 241, 242, 245, 247, 248, 249,
250, 253, 255, 256, 257, 258, 259, 261, 262, 264, 265, 266, 267,
268, 270, 271, 273, 276, 277, 278, 280, 282, 283, 284, 285, 287,
288, 289, 290, 291, 292, 294, 295, 296, 297, 298, 299, 301, 302,
303, 304, 305, 306, 310, 311, 312, 314, 316, 318, 319, 320, 321,
322, 323, 324, 325, 326, 327, 328, 329, 330, 331, 333, 334, 335,
336, 337, 340, 342, 343, 344, 345, 347, 348, 349, 350, 351, 352,
353, 354, 355, 356, 357, 358, 360, 361, 362, 363, 364, 365, 366,
367, 368, 369, 370, 371, 372, 373, 374, 375, 376, 377, 379, 381,
382, 384, 385, 386, 387, 389, 390, 391, 392, 393, 395, 396, 397,
398, 399, 400, 401, 402, 403, 404, 405, 406, 407, 408, 410, 411,
414, 418, 419, 421, 422, 423, 424, 425, 426, 428, 430, 431, 434,
435, 437, 438, 440, 442, 443, 446, 447, 448, 449, 450, 451, 452,
453, 454, 456, 457, 458, 459, 460, 461, 462, 463, 464, 465, 466,
467, 468, 471, 472, 473, 474, 475, 477, 478, 479, 481, 487, 488,
489, 490, 491, 492, 493, 494, 495, 496, 497, 499, 500, 501, 502,
503, 504, 505, 506, 507, 508, 510, 511, 512, 513, 514, 517, 519,
520, 521, 522, 523, 524, 525, 526, 527, 528, 529, 530, 531, 534,
536, 537, 538, 539, 540, 541, 543, 544, 546, 548, 549]

Spilt 3, validation fold:

[2, 3, 6, 11, 19, 21, 31, 33, 46, 51, 59, 62, 75,
76, 87, 91, 92, 106, 116, 122, 129, 142, 149, 150, 158, 163,
167, 170, 172, 188, 197, 204, 205, 213, 215, 221, 228, 234, 239,
243, 244, 246, 251, 252, 254, 260, 263, 269, 272, 274, 275, 279,
281, 286, 293, 300, 307, 308, 309, 313, 315, 317, 332, 338, 339,
341, 346, 359, 378, 380, 383, 388, 394, 409, 412, 413, 415, 416,
417, 420, 427, 429, 432, 433, 436, 439, 441, 444, 445, 455, 469,

470, 476, 480, 482, 483, 484, 485, 486, 498, 509, 515, 516, 518,
532, 533, 535, 542, 545, 547])

Spilt 4, train fold:

[0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 13,
14, 15, 16, 17, 19, 20, 21, 22, 24, 25, 26, 28, 29,
30, 31, 32, 33, 34, 35, 37, 38, 39, 40, 41, 43, 45,
46, 47, 48, 50, 51, 52, 53, 55, 56, 57, 58, 59, 60,
61, 62, 63, 65, 67, 69, 70, 72, 73, 74, 75, 76, 77,
78, 80, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92,
93, 94, 95, 96, 98, 99, 100, 101, 102, 103, 104, 105, 106,
107, 108, 111, 112, 113, 114, 115, 116, 118, 120, 122, 123, 124,
125, 127, 128, 129, 130, 131, 132, 133, 134, 135, 136, 137, 138,
139, 141, 142, 143, 144, 145, 147, 149, 150, 151, 153, 154, 157,
158, 159, 160, 161, 162, 163, 164, 165, 166, 167, 169, 170, 171,
172, 173, 175, 176, 177, 178, 179, 180, 183, 184, 188, 189, 191,
192, 193, 195, 197, 198, 199, 200, 201, 202, 203, 204, 205, 206,
207, 209, 211, 212, 213, 215, 216, 217, 218, 220, 221, 223, 225,
226, 227, 228, 229, 230, 231, 232, 233, 234, 235, 237, 238, 239,
240, 241, 242, 243, 244, 246, 247, 248, 249, 250, 251, 252, 253,
254, 255, 256, 257, 258, 259, 260, 263, 264, 265, 266, 267, 268,
269, 270, 271, 272, 273, 274, 275, 276, 277, 278, 279, 281, 282,
284, 285, 286, 287, 289, 290, 293, 294, 295, 296, 297, 298, 299,
300, 302, 304, 305, 307, 308, 309, 310, 311, 312, 313, 314, 315,
316, 317, 318, 319, 320, 324, 326, 327, 328, 329, 330, 331, 332,
333, 337, 338, 339, 340, 341, 342, 343, 346, 347, 348, 349, 350,
351, 353, 354, 355, 356, 359, 361, 365, 366, 367, 370, 371, 373,
374, 375, 376, 377, 378, 379, 380, 382, 383, 384, 385, 387, 388,
390, 391, 392, 393, 394, 396, 397, 399, 401, 402, 403, 404, 405,
406, 407, 408, 409, 410, 411, 412, 413, 414, 415, 416, 417, 420,
421, 422, 423, 424, 425, 426, 427, 428, 429, 431, 432, 433, 434,
435, 436, 438, 439, 441, 442, 443, 444, 445, 446, 447, 450, 451,
452, 453, 454, 455, 456, 457, 458, 459, 461, 463, 467, 469, 470,
471, 472, 473, 474, 475, 476, 477, 478, 479, 480, 481, 482, 483,
484, 485, 486, 487, 491, 492, 493, 495, 496, 497, 498, 499, 500,
501, 502, 503, 504, 506, 507, 508, 509, 510, 511, 512, 515, 516,

517, 518, 522, 524, 525, 526, 527, 529, 530, 532, 533, 534, 535,
536, 537, 540, 541, 542, 544, 545, 546, 547, 548, 549]

Spilt 4, validation fold:

[12, 18, 23, 27, 36, 42, 44, 49, 54, 64, 66, 68, 71,
79, 81, 97, 109, 110, 117, 119, 121, 126, 140, 146, 148, 152,
155, 156, 168, 174, 181, 182, 185, 186, 187, 190, 194, 196, 208,
210, 214, 219, 222, 224, 236, 245, 261, 262, 280, 283, 288, 291,
292, 301, 303, 306, 321, 322, 323, 325, 334, 335, 336, 344, 345,
352, 357, 358, 360, 362, 363, 364, 368, 369, 372, 381, 386, 389,
395, 398, 400, 418, 419, 430, 437, 440, 448, 449, 460, 462, 464,
465, 466, 468, 488, 489, 490, 494, 505, 513, 514, 519, 520, 521,
523, 528, 531, 538, 539, 543]

Spilt 5, train fold:

[0, 1, 2, 3, 5, 6, 9, 10, 11, 12, 13, 14, 15,
16, 17, 18, 19, 21, 22, 23, 24, 25, 27, 30, 31, 32,
33, 34, 35, 36, 37, 38, 41, 42, 43, 44, 45, 46, 48,
49, 51, 52, 53, 54, 57, 58, 59, 60, 62, 63, 64, 66,
67, 68, 69, 70, 71, 75, 76, 77, 79, 80, 81, 82, 83,
85, 86, 87, 91, 92, 93, 94, 95, 96, 97, 98, 100, 101,
103, 104, 105, 106, 107, 109, 110, 111, 112, 115, 116, 117, 118,
119, 120, 121, 122, 123, 124, 125, 126, 127, 129, 131, 133, 134,
135, 136, 138, 139, 140, 142, 144, 146, 148, 149, 150, 152, 153,
154, 155, 156, 158, 159, 161, 162, 163, 164, 165, 167, 168, 170,
171, 172, 174, 175, 176, 179, 180, 181, 182, 183, 184, 185, 186,
187, 188, 190, 191, 193, 194, 196, 197, 202, 203, 204, 205, 206,
207, 208, 209, 210, 211, 212, 213, 214, 215, 217, 218, 219, 220,
221, 222, 223, 224, 226, 228, 230, 231, 233, 234, 235, 236, 237,
238, 239, 240, 241, 243, 244, 245, 246, 247, 248, 250, 251, 252,
253, 254, 255, 256, 257, 258, 259, 260, 261, 262, 263, 265, 266,
269, 270, 271, 272, 273, 274, 275, 277, 278, 279, 280, 281, 283,
285, 286, 288, 289, 291, 292, 293, 294, 295, 296, 298, 299, 300,
301, 303, 304, 305, 306, 307, 308, 309, 310, 311, 312, 313, 314,
315, 317, 321, 322, 323, 324, 325, 328, 330, 331, 332, 334, 335,
336, 337, 338, 339, 341, 342, 343, 344, 345, 346, 347, 348, 349,

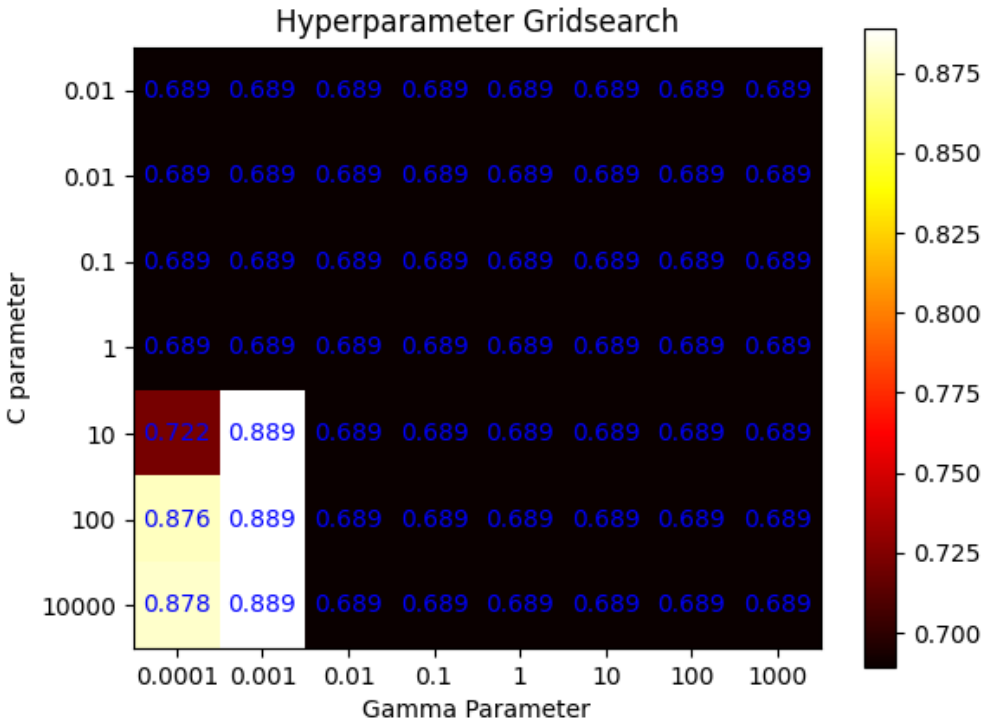
351, 352, 355, 357, 358, 359, 360, 361, 362, 363, 364, 365, 366,
368, 369, 371, 372, 373, 375, 377, 378, 379, 380, 381, 382, 383,
385, 386, 387, 388, 389, 391, 392, 394, 395, 396, 398, 399, 400,
401, 402, 405, 406, 407, 408, 409, 410, 411, 412, 413, 415, 416,
417, 418, 419, 420, 421, 423, 424, 425, 426, 427, 429, 430, 432,
433, 435, 436, 437, 439, 440, 441, 444, 445, 446, 447, 448, 449,
450, 452, 453, 454, 455, 457, 458, 460, 461, 462, 463, 464, 465,
466, 468, 469, 470, 471, 472, 473, 474, 475, 476, 477, 478, 479,
480, 482, 483, 484, 485, 486, 488, 489, 490, 492, 493, 494, 495,
496, 497, 498, 500, 501, 502, 504, 505, 506, 507, 508, 509, 510,
511, 512, 513, 514, 515, 516, 517, 518, 519, 520, 521, 523, 524,
525, 526, 527, 528, 530, 531, 532, 533, 534, 535, 536, 537, 538,
539, 540, 541, 542, 543, 544, 545, 546, 547, 548, 549]

Spilt 5, validation fold:

[4, 7, 8, 20, 26, 28, 29, 39, 40, 47, 50, 55, 56,
61, 65, 72, 73, 74, 78, 84, 88, 89, 90, 99, 102, 108,
113, 114, 128, 130, 132, 137, 141, 143, 145, 147, 151, 157, 160,
166, 169, 173, 177, 178, 189, 192, 195, 198, 199, 200, 201, 216,
225, 227, 229, 232, 242, 249, 264, 267, 268, 276, 282, 284, 287,
290, 297, 302, 316, 318, 319, 320, 326, 327, 329, 333, 340, 350,
353, 354, 356, 367, 370, 374, 376, 384, 390, 393, 397, 403, 404,
414, 422, 428, 431, 434, 438, 442, 443, 451, 456, 459, 467, 481,
487, 491, 499, 503, 522, 529]

2. Best parameter : c=10, gamma=0.001

3. Grid search image

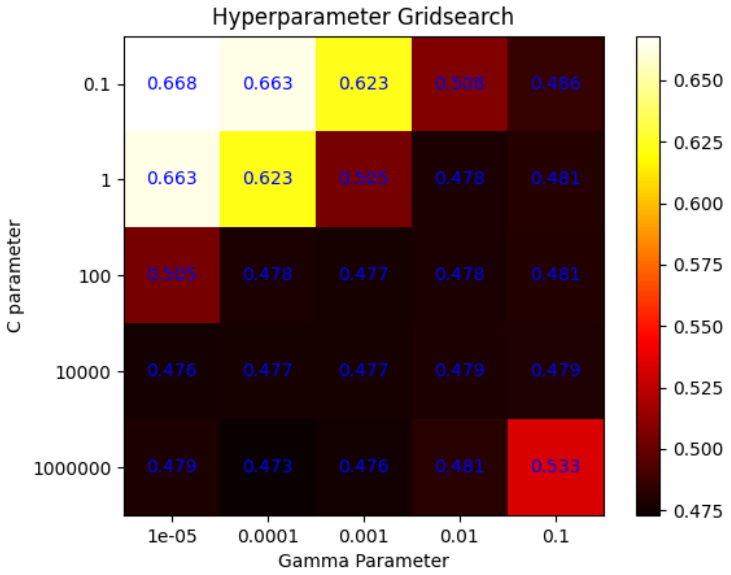


4. Accuracy score: 0.8958333333333334

5.

Best parameter : c=1000000, gamma=0.0001

Grid search image



Accuracy:

Square error of SVM regresssion model: 0.4905700546339396

Square error of Linear regression: 0.49090256

Part 2 Questions

1.

$k(x,x') = c\,k_1(x,x')$, $c>0$.

∵ k_1 是 kernel ⇒ $a^T k_1 a \geq 0$, $\forall a \in \mathbb{R}^n$

∴ $aka = a^T c k_1 a = c a^T k_1 a \geq 0$, $\forall a \in \mathbb{R}^n$ and $c>0$.

⇒ $a^T k a \geq 0$ ⇒ K is a valid kernel.

2.

$k(x,x') = f(x)\,k_1(x,x_1')\,f(x')$

∵ k_1 is a kernel , k_1可以寫成 $k_1 = \phi(x)^T\phi(x')$

∴ $k(x,x') = f(x)(\phi(x)^T\phi(x'))f(x')$, $f(x)$ is real valued function

$= (\phi(x)f(x))^T(\phi(x')f(x'))$.

$= \phi_{new}(x)^T\phi_{new}(x')$

⇒ $k(x,x')$ is a valid kernel.