1. **MLP**
2. **结果：6个应变在不同飞机型号上的线性拟合误差和拟合系数a (x2=a\*x1+b，x1:P123-P127, x2:P123-P127)**

应变1

(1) 线性拟合的MSE

x2 (P123-P127)

x1 [[3.6003440056258033e-31, 0.22486674909909565, 0.24293464741758486, 0.2477528505821884, 0.24619621872124497],

[0.2261039075196786, 3.571405040020179e-31, 0.298665500972605, 0.3068698166406445, 0.30605632845125474],

[0.19770437436632146, 0.24172916587521184, 2.521049764530629e-32, 0.05204617364246509, 0.07543784964423834],

[0.2019613884253969, 0.24878319153984355, 0.05213287475928729, 0.0, 0.059464919205176756],

[0.2119780078754744, 0.2620764308054773, 0.07981268261228275, 0.06280881121316804, 8.422364024612052e-30]]

(2) 系数矩阵

[[1.0000000000000007, 0.8476659020947664, 0.9646816724735675, 0.9605485613259439, 0.9269594003145485],

[0.8523295396170734, 1.0000000000000007, 0.9311030822326731, 0.9245394315230092, 0.8888798707220934],

[0.7850744574577215, 0.7536015062971314, 0.9999999999999999, 0.9728057740805779, 0.9326498991705828],

[0.7830130738740003, 0.7495356597683142, 0.9744263225505445, 1.0000000000000007, 0.9419478988437563],

[0.7981235783422123, 0.7611489855887190, 0.9867366413799203, 0.9949164741481270, 0.9999999999999970]]

应变2

(1) 线性拟合的MSE

[[7.2406312692526365e-31, 0.338779129357505, 0.4655795556496103, 0.4672930522201875, 0.48472685474509813],

[0.3151232986030192, 7.7888673284259406e-31, 0.5305596575966512, 0.5337792481650252, 0.5200027380683433],

[0.33183672174611073, 0.40653777016059706, 2.6662811571412397e-31, 0.06656732643746613, 0.11637725921107672],

[0.34329013313793644, 0.4215701152309395, 0.06861239339023725, 0.0, 0.11791293993662647],

[0.3341950790040617, 0.38542930658144653, 0.11257463608692865, 0.11066045210706796, 4.0154426780059495e-32]]

(2) 系数矩阵

[[1.0000000000000010, 0.7066593613826765, 0.7822147777776516, 0.7530797235777408, 0.7916533089452340],

[0.6573156657257309, 0.9999999999999989, 0.6829516679389545, 0.6499498816709385, 0.7260809883641318],

[0.5575150034174728, 0.5233071234044680, 0.9999999999999994, 0.9431693840959151, 0.9448937273882612],

[0.5532392089764407, 0.5133197805127904, 0.9721452291764896, 1.0000000000000000, 0.9582985799434605],

[0.5458056171983827, 0.5381758044327414, 0.9140193558659679, 0.8993563740086522, 1.0000000000000002]]

应变3

(1) 线性拟合的MSE

[[9.310940264412034e-31, 0.5159315449228963, 0.6415411655386932, 0.6356117431112501, 0.6797329220166376],

[0.5040156227548911, 4.260208766788069e-31, 0.968010732391901, 0.9425619074549827, 1.013915577461818],

[0.35134746311892645, 0.5426759179447104, 1.887047136319816e-31, 0.0390065708852766, 0.04682092820899104],

[0.3572674728371835, 0.5423248862107839, 0.04003382118411541, 1.8394452847672284e-31, 0.04578962285452325],

[0.35542547883645875, 0.5427003873908813, 0.04470313471012647, 0.042596680168491316, 4.7946416199327634e-32]]

(2) 系数矩阵

[[1.0000000000000013, 0.226270049349895, 0.785333244761094, 0.7622803392136058, 0.7945229550974747],

[0.22104413067223969, 0.99999999999999910, -0.03709148153343468, -0.04963709968348899, -0.03683447545320078],

[0.43009686372670280, -0.02079383328669223, 0.9999999999999996, 0.9664760317046748, 0.9995217467667429],

[0.42846592017203905, -0.02855985821702348, 0.9919284816344357, 1.0000000000000004, 1.0131369368308174],

[0.41544802762277560, -0.019715728352684044, 0.954311608090553, 0.9424901839042822, 0.9999999999999998]]

应变4

(1) 线性拟合的MSE

[[2.5618943057228625e-31, 0.40609887158519564, 0.2333324231573613, 0.24913394260880112, 0.27008155433357683],

[0.342042931593672, 3.265756019530664e-32, 0.6254141074118351, 0.6421215346136162, 0.6590485808819418],

[0.1408997494689968, 0.44838798397028945, 4.550495046552911e-32, 0.061064529683919, 0.07386287150010892],

[0.14988252721810147, 0.4586553925490299, 0.06083758880829516, 1.2216847307012037e-31, 0.0892618695905145],

[0.15657378236735078, 0.4536205392740168, 0.0709112557547924, 0.0860145637826229, 1.2515595775389046e-30]]

(2) 系数矩阵

[[1.0000000000000007, 0.6989804821650392, 1.1200734007442685, 1.110655214736232, 1.1226161581079523],

[0.5887269085807616, 0.9999999999999998, 0.6989258165087269, 0.6851926852377662, 0.7055593280007368],

[0.6763657592726433, 0.501091891108829, 0.9999999999999998, 0.9696841162860744, 0.9822852205791721],

[0.6681859914769755, 0.4894203092075949, 0.9660803717953281, 0.9999999999999997, 0.9722957464015127],

[0.6508117833347838, 0.48563370310153275, 0.94303236641077, 0.9369240738299882, 1.000000000000001]]

应变5

(1) 线性拟合的MSE

[[9.130581460443793e-33, 0.6325923174801459, 0.8344569438717852, 0.8054910824280266, 0.924666313462179],

[0.046320306453787395, 2.0594417786428656e-31, 0.6417166598574396, 0.6426032456225406, 0.7361250741698244],

[0.046566520309857536, 0.48906395666898417, 3.914401093634747e-32, 0.07947392395908982, 0.10390486001166806],

[0.04653765062883054, 0.507036381211219, 0.08228080295630617, 1.5751163860961242e-31, 0.10172954668837167],

[0.046599202437562666, 0.506637751882668, 0.09383383268332852, 0.08873538513355561, 0.0]]

(2) 系数矩阵

[[1.0000000000000004, -0.28712128369099077, -0.11616371486819276, -0.15413050719549068, -0.032035129337189217],

[-0.021023881388488284, 0.9999999999999994, 0.5512096986651656, 0.5076197060281818, 0.5443541464953248],

[-0.006482467462706298, 0.42008695277350555, 0.9999999999999998, 0.9331227210823472, 0.9914152217431957],

[-0.008904967232519467, 0.40052965889813813, 0.9660789718518402, 1.0000000000000004, 1.0101066692229272],

[-0.0016144326394975025, 0.3746514969883702, 0.8953218360171932, 0.8810832962230731, 1.0000000000000000]]

应变6

(1) 线性拟合的MSE

[[4.0725854860429134e-33, 0.6963844012112458, 0.8330696950143753, 0.792187888814078, 0.9466119632883224],

[0.078326860743797, 3.550562318277338e-32, 0.3536251053777752, 0.3401143684349653, 0.3921343945709361],

[0.08384562415765859, 0.3164320533010065, 1.0287967674918614e-30, 0.09612479624946382, 0.12004885277054443],

[0.08261815627594075, 0.31536289488424646, 0.09960557958543116, 3.8320825274411507e-32, 0.1312749637165468],

[0.08317802572102509, 0.30634434599924765, 0.10480827362846995, 0.11060409985418025, 1.8564291502735371e-31]]

(2) 系数矩阵

[[1.0000000000000002, 0.7855351337370237, 0.195262415440221, 0.4202725155317868, 0.3659761816665975],

[0.08835422063239953, 1.0000000000000002, 0.8031073287271151, 0.7899259170101023, 0.8694976684433187],

[0.019652496297845632, 0.7186393080851063, 0.9999999999999989, 0.9220145641697003, 1.0009308992922503],

[0.043830688220527735, 0.73243987038446, 0.9554017135390706, 0.9999999999999998, 1.012043093145726],

[0.03215803035723401, 0.6792714392691563, 0.8738595759571699, 0.8526844126403227, 0.9999999999999996]]

1. **分析：不同来源的飞参使用MLP模型预测的应变的线性拟合系数不同，相似来源的飞参使用MLP模型预测的应变的线性拟合系数相似（以P123和P124的应变1的线性关系为例）**
2. 通过原数据的均值和标准差随机生成5批飞参数据，通过MLP模型预测应变，

所到的线性拟合的MSE分别为：

[0.19734157656582504, 0.23317302210282215, 0.17410987907631736, 0.17876312937263672, 0.20998356908414895]

所到的线性拟合的系数分别为：

[0.6203682665675192, 0.6006976148134849, 0.5561185817320806, 0.579243927332274, 0.5968599708209503]

所到的线性拟合的截距分别为：

[-0.29575382936318006, -0.20173704926880415, -0.46821113672318183, -0.02718975579967226, -0.5433704297689475]

1. 使用P123-P127的原数据作为输入模型的5批飞参数据，过MLP模型预测应变，

所到的线性拟合的MSE分别为：

[0.22513360428270368, 0.25150119002674287, 0.1457802207823446, 0.1689677528752873, 0.189476216993228]

所到的线性拟合的系数分别为：

[0.8970387242441311, 0.8902420972512538, 0.9318993113674418, 0.9361882914549264, 0.8977983742764434]

所到的线性拟合的截距分别为：

[-0.028358677414055504, -0.028307915927542924, -0.04587602027222013, -0.023085612655494296, -0.04351014672852187]

由(1)(2)可知，线性拟合系数在相似来源的数据所得到的线性系数基本一致。

1. **图片展示**

**应变1在飞机P123和P124、P125、P126、P127之间的线性关系**

**图表, 散点图

描述已自动生成图表, 散点图

描述已自动生成图表, 散点图

描述已自动生成图表, 散点图

描述已自动生成**

1. **LightGBM**

**c**oef：系数，intercept：截距

{('P124', 'P123'): {'coef': [0.8514, 0.6243, 0.1649, 0.5762, -0.0019, 0.0793],

'intercept': [0.0267, -0.0366, 0.0016, -0.001, 0.0278, 0.0011],

'mse': [0.0224, 0.1264, 0.583, 0.1598, 0.7734, 0.6591]},

('P125', 'P123'): {'coef': [0.8592, 0.718, 0.5215, 0.7537, 0.0208, 0.025],

'intercept': [0.0357, -0.0348, 0.0016, 0.0055, 0.0284, 0.0028],

'mse': [0.0222, 0.0697, 0.2164, 0.059, 0.7265, 0.6573]},

('P125', 'P124'): {'coef': [0.8095, 0.5906, -0.0165, 0.5748, 0.5677, 0.7939],

'intercept': [0.0168, -0.0279, 0.0293, 0.0321, -0.0448, 0.0105],

'mse': [0.0389, 0.1461, 0.9768, 0.1763, 0.1424, 0.0294]},

('P126', 'P123'): {'coef': [0.8756, 0.6798, 0.5151, 0.7548, 0.0194, 0.0346],

'intercept': [0.0299, -0.0473, 0.0011, 0.0048, 0.0281, 0.0026],

'mse': [0.0163, 0.0921, 0.2276, 0.0595, 0.7237, 0.6725]},

('P126', 'P124'): {'coef': [0.8275, 0.5603, -0.0229, 0.5716, 0.5563, 0.7806],

'intercept': [0.0112, -0.0381, 0.0294, 0.0317, -0.0523, 0.0115],

'mse': [0.0302, 0.1718, 1.0128, 0.1821, 0.1503, 0.0348]},

('P126', 'P125'): {'coef': [1.0143, 0.9605, 0.9835, 0.9767, 0.9569, 0.9399],

'intercept': [-0.0066, -0.0168, -0.0009, -0.0001, -0.0132, 0.0022],

'mse': [0.0002, 0.0016, 0.0003, 0.0005, 0.0016, 0.0026]},

('P127', 'P123'): {'coef': [0.8519, 0.7337, 0.516, 0.7476, 0.0204, 0.0345],

'intercept': [0.034, -0.0601, 0.0087, 0.0147, 0.028, 0.0039],

'mse': [0.0244, 0.062, 0.2236, 0.0622, 0.7586, 0.719]},

('P127', 'P124'): {'coef': [0.7909, 0.6031, -0.0154, 0.5784, 0.5024, 0.7293],

'intercept': [0.0156, -0.0488, 0.0291, 0.039, -0.0552, 0.0402],

'mse': [0.047, 0.1327, 0.9849, 0.1741, 0.1984, 0.0584]},

('P127', 'P125'): {'coef': [0.9803, 0.9791, 0.9884, 0.9788, 0.9241, 0.8898],

'intercept': [-0.0017, -0.0361, 0.0136, 0.0125, -0.018, 0.0369],

'mse': [0.0004, 0.0016, 0.0003, 0.0006, 0.0049, 0.0108]},

('P127', 'P126'): {'coef': [0.9582, 0.9723, 1.0, 0.9815, 0.9246, 0.9206],

'intercept': [0.0051, -0.021, 0.0148, 0.0133, -0.0052, 0.0365],

'mse': [0.0019, 0.0011, 0.0002, 0.0005, 0.0045, 0.0063]}}

**分段系数标定**

（1）随机取5个飞参center，按照str\*random(-0.1,0.1)+center,在每个center周围获取100个样本点，生成的飞参样本使用t-sne展示：

**图表, 散点图

描述已自动生成**

以P123和P124的应变1的系数标定为例：将生成的飞参代入P123和P124的MLP模型，对应变1进行线性拟合，基于5个cluster数据的拟合结果：

MSE: [0.012206176278440995, 0.00877490810221498, 0.024946954563310794, 0.008373810470632358, 0.004967852595492866]

拟合系数： [0.039413019755085446, 0.04482742226888147, 0.040242380083879158, 0.039676867398897257, -0.033330090535241684]

截距:[-0.08557107575590564, -0.09324344565739637, -0.5400135555968143, 0.2712899546087166, -0.03423394527572344]

结论：系数差不多，大致在0.04，截距不同。也有例外，如系数为-0.033，与随机生成的数据有关。因此数据的划分需要进一步考虑。

（1）随机取20个飞参center，按照str\*random(-0.1,0.1)+center,在每个center周围获取100个样本点，生成的飞参样本使用t-sne展示：

图表, 散点图

描述已自动生成

红色圈和加粗是异常系数。

应变1的P123和P124的系数:

[0.15072880579135506, 0.12189606001855375, 0.1547201325283544, 0.130168959519975697, 0.1106233610431902, 0.12623309153033815, 0.10482941744580414, 0.08384345444987937, 0.10597499752682459, 0.10794432457510407, **-0.17521633178093846**, **-0.08666866772355891**, 0.1150076252392193, 0.12993950159668225, **-0.12560987615383904**, **0.05177710603825663, -0.2133857029381744**, 0.12500935728134535, -**0.06456188950378332**, 0.101173979691166]

截距:

[-0.06907563692915622, 0.34943800415310056, -0.59787705976352, -1.4269189775769315, 0.02769703296630488, -0.007037123817293892, -0.06365275967063241, -0.5426003214650411, 0.35900519570531064, 0.23096250424921763, -0.33825262177300774, 0.12051596591109158, 0.2440791712845581, -0.075712387103248, 0.7458091486740526, 0.021929657242508775, 0.09644976218869332, 0.32405378452558964, -0.4812277822175386, 0.023518151471058367]

结论：

系数差不多，大致在0.1左右，与之前的0.04又不同。还是和生成的数据有关，需要探索更合适的聚类/分类的方法。

即使在0.1左右，但也有0.8-0.15的波动，所以可能模型还不是太好，需要尝试新的数据，提高准确度/降低过拟合。

Random 0.2

图表, 散点图

描述已自动生成

系数:

[0.05300069186898071, 0.13039966661571897, 0.043447691933309235, 0.08111086337372164, -0.01206716677128423, 0.046685188237581565, 0.12239379213163387, 0.06410825080655712, 0.09230540458827959, 0.04269898678375062]

截距:

[-0.21568420614525424, -0.3315898178887218, 0.19855245032739838, 0.03771886696507486, 1.1008779245723623, -0.30592741376315, -1.0732827322230205, 0.5142550284051273, -0.9179465333275103, -0.7879487831190728]

Random 0.3

图表, 散点图

描述已自动生成

系数:

[0.09765661076585379, 0.1252793040050144, 0.06050989527006487, 0.03473169459116926, 0.06535322097164032, 0.07532161803809743, 0.032538009920781963, 0.044517228523297486, 0.037484853877023633, 0.041800316920440485]

截距:

[0.1968501930649868, 0.32063625410234875, 0.5166693734606553, 1.1281057251463875, 0.0285155001235117, -0.18186468972750003, -0.12123047209656101, 0.13116244168310193, 0.23209055376934756, 0.29134956549495433]

Random 0.4:

图表, 散点图

描述已自动生成

系数:

[0.11869856642051362, 0.12116991124151548, -0.09469420968976965, 0.0977998413778447, 0.1563696672540367, 0.06680965525268172, 0.04749836952623037, 0.041101069387873, 0.047537201875087783, 0.13868775967184048]

截距:

[0.6239081686041458, 0.26351730273695567, -0.01587274987504024, -0.17136935513461057, -0.03757332971112047, 0.013000897426027502, -0.0442478735995054, -0.34127390082971976, 0.12375117498605058, -0.10866743877392934]

Random 0.5:

图表, 散点图

描述已自动生成

系数:

[0.30199395715342066, 0.03799780684960962, 0.049171910487731735, 0.0476712030946377, -0.039576475670801636, 0.041230885851372906, 0.831954724197974, 0.13358433869110073, 0.05660781565779492, 0.016950603347438278]

截距:

[0.09527493698300189, 1.090149315174932, 0.5463029489025466, 0.18196325086359094, -0.11462811104668089, 0.4583545349205368, -0.12934288319108495, 1.183699425654857, 0.11962852012733569, 0.24147480420892675]

结论：看来大部分在0.04-0.13之间

图表, 散点图

描述已自动生成

Random 0.3，30 clusters，斜率0.04固定

截距

[0.29845168668275796, -0.1988669686840574, -0.13293369550223508, -0.7379937384858283, 0.008091064260736629, -0.30927187058900907, 2.125444053839881, -0.09156084774103966, -0.13212927295246701, -0.6470701558242685, -1.151563076584419, 0.14009249041414296, -0.3557715771768079, -0.09482400608503037, -1.5934689591946907, 0.2152130143322642, -1.1310700497986086, -0.7451306480591694, 0.03310879757705816, -0.04147784831406331, 0.16633388146885225, -0.18178459501213184, -0.07667791338161625, -0.5080430278230611, -0.7934135820125005, 0.13859119118922308, -0.2732940233197764, 0.4045336294944461, -0.39205030127836865, 0.19197306798895863]

MSE

[0.08476823080070517, 0.0469685609750144, 0.052805534742283805, 0.06425242150629319, 0.06985837818894834, 0.3098900479108673, 0.14989405180030974, 0.023353727569210187, 0.029528833197985417, 0.10872017498510629, 0.08138771096144234, 0.05458941456919606, 0.0699676437179719, 0.0924831212409983, 0.3154008297934019, 0.015081115738645528, 0.1968924517457021, 0.26585019237897195, 0.03511724913057392, 0.03959588258654506, 0.027190239811425338, 0.04894037280768788, 0.04902571272841039, 0.03809405341649555, 0.168190809241504, 0.04726249940194295, 0.0632616510181151, 0.0394571168971801, 0.2296844012916817, 0.03530096572625977]

R2

[-0.045485903189787, -0.921757545360032, 0.31774604122537, 0.019504391949114, 0.725995380774695, 0.138291531138666, 0.33443018378772, -0.912104275299158, 0.8385467982380277, 0.147628421822766, 0661413195719696, -0.1900806841904, -3.934138961992378, 0.843702471282, 0.22344569781546, 0.384636465377291, 0.717107356843666, -0.772416843074618, 0.142420410562108, 0.63781800087664, 0.952397494105718, 0.238465557562066, -0.66470805640785, 0.437028436008559, -0.33319788755097, 0.745067231923272, -0.95625305869265, 0.032010653849932, 0.838462143074, 0.0596570467187]

R2\_score = 1，样本中预测值和真实值完全相等，没有任何误差，表示回归分析中自变量对因变量的解释越好。

R2\_score = 0。此时分子等于分母，样本的每项预测值都等于均值。

R2\_score不是r的平方，也可能为负数(分子>分母)，模型等于盲猜，还不如直接计算目标变量的平均值。

结论：0.4时效果参差不齐