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3:  * and only allowed with the written consent of the author (Jelle Spijker)
4:  * This software is proprietary and confidential
5:  * Written by Jelle Spijker <spijker.jelle@gmail.com>, 2015
6:  */
7:
8:  #pragma once
9:
10: #define GENE_MAX 32          /**< maximum number of genes*/
11: #define CROSSOVER 16        /**< crossover location*/
12: #define MUTATIONRATE 0.075f /**< mutation rate*/
13: #define ELITISME 4          /**< total number of the elite bastard*/
14: #define END_ERROR 0.005f    /**< acceptable error between last iteration*/
15:
16: #include <stdint.h>
17: #include <bitset>
18: #include <vector>
19: #include <complex>
20: #include <valarray>
21: #include <array>
22:
23: typedef unsigned char uchar; /**< unsigned char*/
24: typedef unsigned short ushort; /**< unsigned short*/
25:
26: typedef std::complex<double> Complex_t; /**< complex vector of doubles*/
27: typedef std::vector<Complex_t> ComplexVect_t; /**< vector of Complex_t*/
28: typedef std::valarray<Complex_t> ComplexArray_t; /**< valarray of Complex_t*/
29: typedef std::vector<uint32_t> iContour_t; /**< vector of uint32_t*/
30:
31: typedef std::bitset<GENE_MAX> Genome_t; /**< Bitset representing a genome*/
32: typedef std::pair<std::bitset<CROSSOVER>, std::bitset<GENE_MAX - CROSSOVER>>
33:     SplitGenome_t; /**< a matted genome*/
34: typedef std::vector<float> Weight_t; /**< a float vector*/
35: typedef std::vector<Genome_t> GenVect_t; /**< a vector of genomes*/
36: typedef struct PopMemberStruct {
37:     Weight_t weights; /**< the weights the core of a population member*/
38:     GenVect_t weightsGen; /**< the weights as genomes*/
39:     float Calculated = 0.0; /**< the calculated value*/
40:     float Fitness = 0.0; /**< the fitness of the population member*/
41: } PopMember_t; /**< a population member*/
42: typedef std::vector<PopMember_t> Population_t; /**< Vector with PopMember_t*/
43: typedef std::pair<float, float>
44:     MinMaxWeight_t; /**< floating pair weight range*/
45:
46: typedef struct Predict_struct {
47:     uint32_t Category; /**< the category number */
48:     float RealValue; /**< category number as float in order to estimate how
49:         precise to outcome is*/
50:     float Accuracy; /**< the accuracy of the category*/
51:     std::vector<float> OutputNeurons; /**< the output Neurons*/
52: } Predict_t; /**< The prediction results*/
53: typedef Predict_t (*NNfunctionType)(
54:     ComplexVect_t, Weight_t, Weight_t, uint32_t, uint32_t,
55:     uint32_t); /**< The prediction function from the Neural Net*/
56:
57: typedef std::vector<ComplexVect_t>
58:     InputLearnVector_t; /**< Vector of a vector with complex values*/
59: typedef std::vector<Predict_t> OutputLearnVector_t; /**< vector with results*/

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6:  */
7:
8:  #pragma once
9:  #define MAX_UINT8_VALUE 256
10: #define VECTOR_CALC 1
11: #define STATS_VERSION 1
12:
13: #include <stdint.h>
14: #include <utility>
15: #include <vector>
16: #include <cstdlib>
17: #include <cmath>
18: #include <limits>
19: #include <typeinfo>
20: #include <string>
21:
22: #include <fstream>
23:
24: #include <boost/archive/binary_iarchive.hpp>
25: #include <boost/archive/binary_oarchive.hpp>
26: #include <boost/math/distributions/students_t.hpp>
27:
28: #include "MathException.h"
29: #include "SoilMathTypes.h"
30: #include "CommonOperations.h"
31:
32: using namespace std;
33:
34: namespace SoilMath {
35:
36:  /*!
37:   * \brief Stats class
38:   * \details Usage Stats<type1, type2, type3>Stats() type 1, 2 and 3 should be of
39:   * the same value and consecutive in size
40:   */
41:  template <typename T1, typename T2, typename T3> class Stats {
42:  public:
43:      bool isDiscrete = true; /**< indicates if the data is discrete or real*/
44:
45:      T1 *Data;                /**< Pointer the data*/
46:      uint32_t *bins;          /**< the histogram*/
47:      bool Calculated = false; /**< indication if the data has been calculated*/
48:      float Mean = 0.0;        /**< the mean value of the data*/
49:      uint32_t n = 0;           /**< number of data points*/
50:      uint32_t noBins = 0;      /**< number of bins*/
51:      T1 Range = 0;             /**< range of the data*/
52:      T1 min = 0;               /**< minimum value*/
53:      T1 max = 0;               /**< maximum value*/
54:      T1 Startbin = 0;          /**< First bin value*/
55:      T1 EndBin = 0;            /**< End bin value*/
56:      T1 binRange = 0;          /**< the range of a single bin*/
57:      float Std = 0.0;          /**< standard deviation*/
58:      T3 Sum = 0;               /**< total sum of all the data values*/
59:      uint16_t Rows = 0;        /**< number of rows from the data matrix*/
60:      uint16_t Cols = 0;        /**< number of cols from the data matrix*/
61:      bool StartAtZero = true;  /**< indication of the minimum value starts at zero
62:                               or could be less*/
63:
64:      uint32_t *begin() { return &bins[0]; } /**< pointer to the first bin*/
65:      uint32_t *end() { return &bins[noBins]; } /**< pointer to the last + 1 bin*/
66:
67:      /*!
68:       * \brief WelchTest Compare the sample using the Welch's Test
69:       * \details (source:
70:       * http://www.boost.org/doc/libs/1\_57\_0/libs/math/doc/html/math\_toolkit/stat\_tut/weg/st\_eg/two\_sample\_students\_t.html)
71:       * \param statComp Statistics Results of which it should be tested against
72:       * \return
73:       */
74:      bool WelchTest(SoilMath::Stats<T1, T2, T3> &statComp) {
75:          double alpha = 0.05;
76:          // Degrees of freedom:
77:          double v = statComp.Std * statComp.Std / statComp.n +
78:                  this->Std * this->Std / this->n;
79:          v *= v;
80:          double t1 = statComp.Std * statComp.Std / statComp.n;
81:          t1 *= t1;
82:          t1 /= (statComp.n - 1);

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83:     double t2 = this->Std * this->Std / this->n;
84:     t2 *= t2;
85:     t2 /= (this->n - 1);
86:     v /= (t1 + t2);
87:     // t-statistic:
88:     double t_stat = (statComp.Mean - this->Mean) /
89:         sqrt(statComp.Std * statComp.Std / statComp.n +
90:             this->Std * this->Std / this->n);
91:     //
92:     // Define our distribution, and get the probability:
93:     //
94:     boost::math::students_t dist(v);
95:     double q = cdf(complement(dist, fabs(t_stat)));
96:
97:     bool rejected = false;
98:     // Sample 1 Mean == Sample 2 Mean test the NULL hypothesis, the two means
99:     // are the same
100:    if (q < alpha / 2)
101:        rejected = false;
102:    else
103:        rejected = true;
104:    return rejected;
105: }
106:
107: /*!
108:  * \brief Stats Constructor
109:  * \param rhs Right hand side
110:  */
111: Stats(const Stats &rhs)
112:     : Data{new T1[rhs.n]}, bins{new uint32_t[rhs.noBins]} {
113:     this->binRange = rhs.binRange;
114:     this->Calculated = rhs.Calculated;
115:     this->Cols = rhs.Cols;
116:     this->EndBin = rhs.EndBin;
117:     this->isDiscrete = rhs.isDiscrete;
118:     this->max = rhs.max;
119:     this->Mean = rhs.Mean;
120:     this->min = rhs.min;
121:     this->n = rhs.n;
122:     this->noBins = rhs.noBins;
123:     this->n_end = rhs.n_end;
124:     this->Range = rhs.Range;
125:     this->Rows = rhs.Rows;
126:     this->Startbin = rhs.Startbin;
127:     this->Std = rhs.Std;
128:     this->Sum = rhs.Sum;
129:     std::copy(rhs.bins, rhs.bins + rhs.noBins, this->bins);
130:     this->Data = &rhs.Data[0];
131:     this->StartAtZero = rhs.StartAtZero;
132: }
133:
134: /*!
135:  * \brief operator = Assigmmnet operator
136:  * \param rhs right hand side
137:  * \return returns the right hand side
138:  */
139: Stats &operator=(Stats const &rhs) {
140:     if (&rhs != this) {
141:         delete[] bins;
142:         delete[] Data;
143:         bins = new uint32_t[rhs.noBins];
144:         Data = new T1[rhs.n];
145:         this->binRange = rhs.binRange;
146:         this->Calculated = rhs.Calculated;
147:         this->Cols = rhs.Cols;
148:         this->EndBin = rhs.EndBin;
149:         this->isDiscrete = rhs.isDiscrete;
150:         this->max = rhs.max;
151:         this->Mean = rhs.Mean;
152:         this->min = rhs.min;
153:         this->n = rhs.n;
154:         this->noBins = rhs.noBins;
155:         this->n_end = rhs.n_end;
156:         this->Range = rhs.Range;
157:         this->Rows = rhs.Rows;
158:         this->Startbin = rhs.Startbin;
159:         this->Std = rhs.Std;
160:         this->Sum = rhs.Sum;
161:         this->Data = &rhs.Data[0];
162:         std::copy(rhs.bins, rhs.bins + rhs.noBins, this->bins);
163:         this->StartAtZero = rhs.StartAtZero;
164:     }
165:     return *this;

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166: }
167:
168: /*!
169:  * \brief Stats Constructor
170:  * \param noBins number of bins with which to build the histogram
171:  * \param startBin starting value of the first bin
172:  * \param endBin end value of the second bin
173:  */
174: Stats(int noBins = 256, T1 startBin = 0, T1 endBin = 255) {
175:     min = numeric_limits<T1>::max();
176:     max = numeric_limits<T1>::min();
177:     Range = numeric_limits<T1>::max();
178:     Startbin = startBin;
179:     EndBin = endBin;
180:     this->noBins = noBins;
181:     bins = new uint32_t[noBins]{};
182:
183:     if (typeid(T1) == typeid(float) || typeid(T1) == typeid(double) ||
184:         typeid(T1) == typeid(long double)) {
185:         isDiscrete = false;
186:         binRange = static_cast<T1>((EndBin - Startbin) / noBins);
187:     } else {
188:         isDiscrete = true;
189:         binRange = static_cast<T1>(round((EndBin - Startbin) / noBins));
190:     }
191: }
192:
193: /*!
194:  * \brief Stats constructor
195:  * \param data Pointer to the data
196:  * \param rows Number of rows
197:  * \param cols Number of Columns
198:  * \param noBins Number of bins
199:  * \param startBin Value of the start bin
200:  * \param startatzero bool indicating if the bins should be shifted from zero
201:  */
202: Stats(T1 *data, uint16_t rows, uint16_t cols, int noBins = 256,
203:     T1 startBin = 0, bool startatzero = true) {
204:     min = numeric_limits<T1>::max();
205:     max = numeric_limits<T1>::min();
206:     Range = max - min;
207:
208:     Startbin = startBin;
209:     EndBin = startBin + noBins;
210:     StartAtZero = startatzero;
211:
212:     if (typeid(T1) == typeid(float) || typeid(T1) == typeid(double) ||
213:         typeid(T1) == typeid(long double)) {
214:         isDiscrete = false;
215:     } else {
216:         isDiscrete = true;
217:     }
218:
219:     Data = data;
220:     Rows = rows;
221:     Cols = cols;
222:     bins = new uint32_t[noBins]{};
223:     this->noBins = noBins;
224:     if (isDiscrete) {
225:         BasicCalculate();
226:     } else {
227:         BasicCalculateFloat();
228:     }
229: }
230:
231: /*!
232:  * \brief Stats Constructor
233:  * \param data Pointer the data
234:  * \param rows Number of rows
235:  * \param cols Number of Columns
236:  * \param mask the mask should have the same size as the data a value of zero
237:  * indicates that the data pointer doesn't exist. A 1 indicates that the data
238:  * pointer is to be used
239:  * \param noBins Number of bins
240:  * \param startBin Value of the start bin
241:  * \param startatzero indicating if the bins should be shifted from zero
242:  */
243: Stats(T1 *data, uint16_t rows, uint16_t cols, uchar *mask, int noBins = 256,
244:     T1 startBin = 0, bool startatzero = true) {
245:     min = numeric_limits<T1>::max();
246:     max = numeric_limits<T1>::min();
247:     Range = max - min;
248:
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249:     Startbin = startBin;
250:     EndBin = startBin + noBins;
251:     StartAtZero = startatzero;
252:
253:     if (typeid(T1) == typeid(float) || typeid(T1) == typeid(double) ||
254:         typeid(T1) == typeid(long double)) {
255:         isDiscrete = false;
256:     } else {
257:         isDiscrete = true;
258:     }
259:
260:     Data = data;
261:     Rows = rows;
262:     Cols = cols;
263:     bins = new uint32_t[noBins]{};
264:     this->noBins = noBins;
265:     if (isDiscrete) {
266:         BasicCalculate(mask);
267:     } else {
268:         BasicCalculateFloat(mask);
269:     }
270: }
271:
272: /*!
273:  * \brief Stats Constructor
274:  * \param binData The histogram data
275:  * \param startC start counter
276:  * \param endC end counter
277:  */
278: Stats(T2 *binData, uint16_t startC, uint16_t endC) {
279:     noBins = endC - startC;
280:     Startbin = startC;
281:     EndBin = endC;
282:     uint32_t i = noBins;
283:
284:     if (typeid(T1) == typeid(float) || typeid(T1) == typeid(double) ||
285:         typeid(T1) == typeid(long double)) {
286:         isDiscrete = false;
287:         throw Exception::MathException(
288:             "Calculations using histogram not supported with floating-type!");
289:     } else {
290:         isDiscrete = true;
291:     }
292:
293:     bins = new uint32_t[noBins]{};
294:     while (i-- > 0) {
295:         bins[i] = binData[i];
296:         n += binData[i];
297:     }
298:     BinCalculations(startC, endC);
299: }
300:
301: ~Stats() { delete[] bins; }
302:
303: /*!
304:  * \brief BasicCalculateFloat execute the basic float data calculations
305:  */
306: void BasicCalculateFloat() {
307:     float sum_dev = 0.0;
308:     n = Rows * Cols;
309:     for (uint32_t i = 0; i < n; i++) {
310:         if (Data[i] > max) {
311:             max = Data[i];
312:         }
313:         if (Data[i] < min) {
314:             min = Data[i];
315:         }
316:         Sum += Data[i];
317:     }
318:     binRange = (max - min) / noBins;
319:     uint32_t index = 0;
320:     Mean = Sum / (float)n;
321:     Range = max - min;
322:     if (StartAtZero) {
323:         for (uint32_t i = 0; i < n; i++) {
324:             index = static_cast<uint32_t>(Data[i] / binRange);
325:             if (index == noBins) {
326:                 index -= 1;
327:             }
328:             bins[index]++;
329:             sum_dev += pow((Data[i] - Mean), 2);
330:         }
331:     } else {

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332:     for (uint32_t i = 0; i < n; i++) {
333:         index = static_cast<uint32_t>((Data[i] - min) / binRange);
334:         if (index == noBins) {
335:             index -= 1;
336:         }
337:         bins[index]++;
338:         sum_dev += pow((Data[i] - Mean), 2);
339:     }
340: }
341: Std = sqrt((float)(sum_dev / n));
342: Calculated = true;
343: }
344:
345: /*!
346: * \brief BasicCalculateFloat execute the basic float data calculations with a
347: * mask
348: * \param mask uchar mask type 0 don't calculate, 1 calculate
349: */
350: void BasicCalculateFloat(uchar *mask) {
351:     float sum_dev = 0.0;
352:     n = Rows * Cols;
353:     uint32_t nmask = 0;
354:     for (uint32_t i = 0; i < n; i++) {
355:         if (mask[i] != 0) {
356:             if (Data[i] > max) {
357:                 max = Data[i];
358:             }
359:             if (Data[i] < min) {
360:                 min = Data[i];
361:             }
362:             Sum += Data[i];
363:             nmask++;
364:         }
365:     }
366:     binRange = (max - min) / noBins;
367:     uint32_t index = 0;
368:     Mean = Sum / (float)nmask;
369:     Range = max - min;
370:     if (StartAtZero) {
371:         for (uint32_t i = 0; i < n; i++) {
372:             if (mask[i] != 0) {
373:                 index = static_cast<uint32_t>(Data[i] / binRange);
374:                 if (index == noBins) {
375:                     index -= 1;
376:                 }
377:                 bins[index]++;
378:                 sum_dev += pow((Data[i] - Mean), 2);
379:             }
380:         }
381:     } else {
382:         for (uint32_t i = 0; i < n; i++) {
383:             if (mask[i] != 0) {
384:                 index = static_cast<uint32_t>((Data[i] - min) / binRange);
385:                 if (index == noBins) {
386:                     index -= 1;
387:                 }
388:                 bins[index]++;
389:                 sum_dev += pow((Data[i] - Mean), 2);
390:             }
391:         }
392:     }
393:     Std = sqrt((float)(sum_dev / nmask));
394:     Calculated = true;
395: }
396:
397: /*!
398: * \brief BasicCalculate execute the basic discrete data calculations
399: */
400: void BasicCalculate() {
401:     double sum_dev = 0.0;
402:     n = Rows * Cols;
403:     for (uint32_t i = 0; i < n; i++) {
404:         if (Data[i] > max) {
405:             max = Data[i];
406:         }
407:         if (Data[i] < min) {
408:             min = Data[i];
409:         }
410:         Sum += Data[i];
411:     }
412:     binRange = static_cast<Tl>(ceil((max - min) / static_cast<float>(noBins)));
413:     Mean = Sum / (float)n;
414:     Range = max - min;

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415:     uint32_t index;
416:     if (StartAtZero) {
417:         for_each(Data, Data + n, [&](T1 &d) {
418:             index = static_cast<uint32_t>(d / binRange);
419:             if (index == noBins) {
420:                 index -= 1;
421:             }
422:             bins[index]++;
423:             sum_dev += pow((d - Mean), 2);
424:         });
425:     } else {
426:         for_each(Data, Data + n, [&](T1 &d) {
427:             index = static_cast<uint32_t>((d - min) / binRange);
428:             if (index == noBins) {
429:                 index -= 1;
430:             }
431:             bins[index]++;
432:             sum_dev += pow((d - Mean), 2);
433:         });
434:     }
435:     Std = sqrt((float)(sum_dev / n));
436:     Calculated = true;
437: }
438:
439: /*
440: * \brief BasicCalculate execute the basic discrete data calculations with
441: * mask
442: * \param mask uchar mask type 0 don't calculate, 1 calculate
443: */
444: void BasicCalculate(uchar *mask) {
445:     double sum_dev = 0.0;
446:     n = Rows * Cols;
447:     uint32_t nmask = 0;
448:     uint32_t i = 0;
449:     for_each(Data, Data + n, [&](T1 &d) {
450:         if (mask[i++] != 0) {
451:             if (d > max) {
452:                 max = d;
453:             }
454:             if (d < min) {
455:                 min = d;
456:             }
457:             Sum += d;
458:             nmask++;
459:         }
460:     });
461:     binRange = static_cast<T1>(ceil((max - min) / static_cast<float>(noBins)));
462:     Mean = Sum / (float)nmask;
463:     Range = max - min;
464:     uint32_t index;
465:     if (StartAtZero) {
466:         i = 0;
467:         for_each(Data, Data + n, [&](T1 &d) {
468:             if (mask[i++] != 0) {
469:                 index = static_cast<uint32_t>(d / binRange);
470:                 if (index == noBins) {
471:                     index -= 1;
472:                 }
473:                 bins[index]++;
474:                 sum_dev += pow((d - Mean), 2);
475:             }
476:         });
477:     } else {
478:         i = 0;
479:         for_each(Data, Data + n, [&](T1 &d) {
480:             if (mask[i++] != 0) {
481:                 index = static_cast<uint32_t>((d - min) / binRange);
482:                 if (index == noBins) {
483:                     index -= 1;
484:                 }
485:                 bins[index]++;
486:                 sum_dev += pow((d - Mean), 2);
487:             }
488:         });
489:     }
490:     Std = sqrt((float)(sum_dev / nmask));
491:     Calculated = true;
492: }
493:
494: /*
495: * \brief BinCalculations excute the cacluations with the histogram
496: * \param startC start counter
497: * \param endC end counter

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498:  */
499:  void BinCalculations(uint16_t startC, uint16_t endC __attribute__((unused))) {
500:      float sum_dev = 0.0;
501:      // Get the Sum
502:      uint32_t i = 0;
503:      for_each(begin(), end(), [&](uint32_t &b) { Sum += b * (startC + i++); });
504:
505:      // Get Mean
506:      Mean = Sum / (float)n;
507:
508:      // Get max
509:      for (int i = noBins - 1; i >= 0; i--) {
510:          if (bins[i] != 0) {
511:              max = i + startC;
512:              break;
513:          }
514:      }
515:
516:      // Get min
517:      for (uint32_t i = 0; i < noBins; i++) {
518:          if (bins[i] != 0) {
519:              min = i + startC;
520:              break;
521:          }
522:      }
523:
524:      // Get Max;
525:      Range = max - min;
526:
527:      // Calculate Standard Deviation
528:      i = 0;
529:      for_each(begin(), end(), [&](uint32_t &b) {
530:          sum_dev += b * pow((i++ + startC) - Mean, 2);
531:      });
532:      Std = sqrt((float)(sum_dev / n));
533:      Calculated = true;
534:  }
535:
536: private:
537:  uint32_t n_end = 0; /**< data end counter used with mask*/
538:  friend class boost::serialization::access; /**< Serialization class*/
539:
540:  /*!
541:   * \brief serialize the object
542:   * \param ar argument
543:   * \param version
544:   */
545:  template <class Archive>
546:  void serialize(Archive &ar, const unsigned int version __attribute__((unused))) {
547:      ar &isDiscrete;
548:      ar &n;
549:      for (size_t dc = 0; dc < n; dc++) {
550:          ar &Data[dc];
551:      }
552:      ar &noBins;
553:      for (size_t dc = 0; dc < noBins; dc++) {
554:          ar &bins[dc];
555:      }
556:      ar &Calculated;
557:      ar &Mean;
558:      ar &Range;
559:      ar &min;
560:      ar &max;
561:      ar &Startbin;
562:      ar &EndBin;
563:      ar &binRange;
564:      ar &Std;
565:      ar &Sum;
566:      ar &Rows;
567:      ar &Cols;
568:      ar &StartAtZero;
569:  }
570: };
571: }
572:
573: typedef SoilMath::Stats<float, double, long double>
574:     floatStat_t; /**< floating Stat type*/
575: typedef SoilMath::Stats<uchar, uint32_t, uint64_t>
576:     ucharStat_t; /**< uchar Stat type*/
577: typedef SoilMath::Stats<uint16_t, uint32_t, uint64_t>
578:     uint16Stat_t; /**< uint16 Stat type*/
579: typedef SoilMath::Stats<uint32_t, uint32_t, uint64_t>
580:     uint32Stat_t; /**< uint32 Stat type*/

```



```
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6:   */
7:
8:  /*! \brief Collection of the public SoilMath headers
9:   *      Commonpractice is to include this header when you want to add
10:   * Soilmath routines
11:   */
12: #pragma once
13:
14: #include "Stats.h"
15: #include "Sort.h"
16: #include "FFT.h"
17: #include "NN.h"
18: #include "GA.h"
19: #include "CommonOperations.h"
20: #include "SoilMathTypes.h"
```

```
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6:  */
7:
8:  #include "NN.h"
9:
10: namespace SoilMath {
11:     NN::NN() { beta = 0.666; }
12:
13:     NN::NN(uint32_t inputneurons, uint32_t hiddenneurons, uint32_t outputneurons) {
14:         // Set the number of neurons in the network
15:         inputNeurons = inputneurons;
16:         hiddenNeurons = hiddenneurons;
17:         outputNeurons = outputneurons;
18:         // Reserve the vector space
19:         iNeurons.reserve(inputNeurons + 1); // input neurons + bias
20:         hNeurons.reserve(hiddenNeurons + 1); // hidden neurons + bias
21:         oNeurons.reserve(outputNeurons); // output neurons
22:
23:         beta = 0.666;
24:     }
25:
26:     NN::~NN() {}
27:
28:     void NN::LoadState(string filename) {
29:         std::ifstream ifs(filename.c_str());
30:         boost::archive::xml_iarchive ia(ifs);
31:         ia >> boost::serialization::make_nvp("NeuralNet", *this);
32:     }
33:
34:     void NN::SaveState(string filename) {
35:         std::ofstream ofs(filename.c_str());
36:         boost::archive::xml_oarchive oa(ofs);
37:         oa << boost::serialization::make_nvp("NeuralNet", *this);
38:     }
39:
40:     Predict_t NN::PredictLearn(ComplexVect_t input, Weight_t inputweights,
41:                               Weight_t hiddenweights, uint32_t inputneurons,
42:                               uint32_t hiddenneurons, uint32_t outputneurons) {
43:         NN neural(inputneurons, hiddenneurons, outputneurons);
44:         neural.SetInputWeights(inputweights);
45:         neural.SetHiddenWeights(hiddenweights);
46:         return neural.Predict(input);
47:     }
48:
49:     Predict_t NN::Predict(ComplexVect_t input) {
50:         if (input.size() != inputNeurons) {
51:             throw Exception::MathException("Size of input Neurons Exception!");
52:         }
53:
54:         iNeurons.clear();
55:         hNeurons.clear();
56:         oNeurons.clear();
57:
58:         // Set the bias in the input and hidden vector to 1 (real number)
59:         iNeurons.push_back(1.0f);
60:         hNeurons.push_back(1.0f);
61:
62:         Predict_t retVal;
63:         uint32_t wCount = 0;
64:
65:         // Init the network
66:         for (uint32_t i = 0; i < inputNeurons; i++) {
67:             iNeurons.push_back(static_cast<float>(abs(input[i])));
68:         }
69:         for (uint32_t i = 0; i < hiddenNeurons; i++) {
70:             hNeurons.push_back(0.0f);
71:         }
72:         for (uint32_t i = 0; i < outputNeurons; i++) {
73:             oNeurons.push_back(0.0f);
74:         }
75:
76:         for (uint32_t i = 1; i < hNeurons.size(); i++) {
77:             wCount = i - 1;
78:             for (uint32_t j = 0; j < iNeurons.size(); j++) {
79:                 hNeurons[i] += iNeurons[j] * iWeights[wCount];
80:                 wCount += hNeurons.size() - 1;
81:             }
82:             hNeurons[i] = 1 / (1 + pow(2.71828f, (-hNeurons[i] * beta)));
83:         }
84:     }
85: }
```

```
84:
85:   for (uint32_t i = 0; i < oNeurons.size(); i++) {
86:       wCount = i;
87:       for (uint32_t j = 0; j < hNeurons.size(); j++) {
88:           oNeurons[i] += hNeurons[j] * hWeights[wCount];
89:           wCount += oNeurons.size();
90:       }
91:       oNeurons[i] =
92:           (2 / (1.0f + pow(2.71828f, (-oNeurons[i] * beta)))) -
93:           1; // Shift plus scale so the learning function can be calculated
94:   }
95:
96:   retVal.OutputNeurons = oNeurons;
97:   return retVal;
98: }
99:
100: void NN::Learn(InputLearnVector_t input, OutputLearnVector_t cat,
101:               uint32_t noOfDescriptorsUsed __attribute__((unused))) {
102:     SoilMath::GA optim(PredictLearn, inputNeurons, hiddenNeurons, outputNeurons);
103:     ComplexVect_t inputTest;
104:     std::vector<Weight_t> weights;
105:     Weight_t weight(((inputNeurons + 1) * hiddenNeurons) +
106:                     ((hiddenNeurons + 1) * outputNeurons),
107:                     0);
108:     // loop through each case and adjust the weights
109:     optim.Evolve(input, weight, MinMaxWeight_t(-50, 50), cat, 1000, 50);
110:
111:     this->iWeights = Weight_t(
112:         weight.begin(), weight.begin() + ((inputNeurons + 1) * hiddenNeurons));
113:     this->hWeights = Weight_t(
114:         weight.begin() + ((inputNeurons + 1) * hiddenNeurons), weight.end());
115:     studied = true;
116: }
117: }
```

```

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6:  */
7:
8:  #include "GA.h"
9:
10: namespace SoilMath {
11:     GA::GA() {}
12:
13:     GA::GA(NNfunctionType nnfunction, uint32_t inputneurons, uint32_t hiddenneurons,
14:           uint32_t outputneurons) {
15:         this->NNfunction = nnfunction;
16:         this->inputneurons = inputneurons;
17:         this->hiddenneurons = hiddenneurons;
18:         this->outputneurons = outputneurons;
19:     }
20:
21:     GA::~GA() {}
22:
23:     void GA::Evolve(const ComplexVect_t &inputValues, Weight_t &weights,
24:                    std::vector<Weight_t> &prevWeights, MinMaxWeight_t rangeweights,
25:                    Predict_t goal, uint32_t maxGenerations, uint32_t popSize) {
26:         // Create the population
27:         uint32_t NOprevPopUsed =
28:             prevWeights.size() < popSize ? prevWeights.size() : popSize;
29:         Population_t pop = Genesis(weights, rangeweights, popSize - NOprevPopUsed);
30:         for (uint32_t i = 0; i < NOprevPopUsed; i++) {
31:             PopMember_t newMember;
32:             newMember.weights = prevWeights[i];
33:             for (uint32_t j = 0; j < newMember.weights.size(); j++) {
34:                 newMember.weightsGen.push_back(
35:                     ConvertToGenome<float>(newMember.weights[j], rangeweights));
36:             }
37:             pop.push_back(newMember);
38:         }
39:         float totalFitness = 0.0;
40:         for (uint32_t i = 0; i < maxGenerations; i++) {
41:             CrossOver(pop);
42:             Mutate(pop);
43:             totalFitness = 0.0;
44:             GrowToAdulthood(pop, inputValues, rangeweights, goal, totalFitness);
45:             if (SurvivalOfTheFittest(pop, totalFitness)) {
46:                 break;
47:             }
48:         }
49:
50:         weights = pop[0].weights;
51:     }
52:
53:     void GA::Evolve(const InputLearnVector_t &inputValues, Weight_t &weights,
54:                    MinMaxWeight_t rangeweights, OutputLearnVector_t &goal,
55:                    uint32_t maxGenerations, uint32_t popSize) {
56:         // Create the population
57:         Population_t pop = Genesis(weights, rangeweights, popSize);
58:         float totalFitness = 0.0;
59:         for (uint32_t i = 0; i < maxGenerations; i++) {
60:             CrossOver(pop);
61:             Mutate(pop);
62:             totalFitness = 0.0;
63:             GrowToAdulthood(pop, inputValues, rangeweights, goal, totalFitness);
64:             if (SurvivalOfTheFittest(pop, totalFitness)) {
65:                 break;
66:             }
67:         }
68:         weights = pop[0].weights;
69:     }
70:
71:     Population_t GA::Genesis(const Weight_t &weights, MinMaxWeight_t rangeweights,
72:                             uint32_t popSize) {
73:         if (popSize < 1)
74:             return Population_t();
75:
76:         Population_t pop;
77:         unsigned seed = std::chrono::system_clock::now().time_since_epoch().count();
78:         std::default_random_engine gen(seed);
79:         std::uniform_real_distribution<float> dis(rangeweights.first,
80:                                                  rangeweights.second);
81:
82:         for (uint32_t i = 0; i < popSize; i++) {
83:             PopMember_t I;

```

```

84:     for (uint32_t j = 0; j < weights.size(); j++) {
85:         I.weights.push_back(dis(gen));
86:         I.weightsGen.push_back(
87:             ConvertToGenome<float>(I.weights[j], rangeweights));
88:     }
89:     pop.push_back(I);
90: }
91: return pop;
92: }
93:
94: void GA::CrossOver(Population_t &pop) {
95:     Population_t newPop; // create a new population
96:     PopMember_t newPopMembers[2];
97:     SplitGenome_t Split[2];
98:
99:     for (uint32_t i = 0; i < pop.size(); i += 2) {
100:
101:         for (uint32_t j = 0; j < pop[i].weights.size(); j++) {
102:             // Split A
103:             Split[0].first = bitset<CROSSOVER>(
104:                 pop[i].weightsGen[j].to_string().substr(0, CROSSOVER));
105:             Split[0].second =
106:                 bitset<GENE_MAX - CROSSOVER>(pop[i].weightsGen[j].to_string().substr(
107:                     CROSSOVER, GENE_MAX - CROSSOVER));
108:
109:             // Split B
110:             Split[1].first = bitset<CROSSOVER>(
111:                 pop[i + 1].weightsGen[j].to_string().substr(0, CROSSOVER));
112:             Split[1].second = bitset<GENE_MAX - CROSSOVER>(
113:                 pop[i + 1].weightsGen[j].to_string().substr(CROSSOVER,
114:                     GENE_MAX - CROSSOVER));
115:
116:             // Mate A and B to AB and BA
117:             newPopMembers[0].weightsGen.push_back(
118:                 Genome_t(Split[0].first.to_string() + Split[1].second.to_string()));
119:             newPopMembers[1].weightsGen.push_back(
120:                 Genome_t(Split[1].first.to_string() + Split[0].second.to_string()));
121:         }
122:         newPop.push_back(newPopMembers[0]);
123:         newPop.push_back(newPopMembers[1]);
124:         newPopMembers[0].weightsGen.clear();
125:         newPopMembers[1].weightsGen.clear();
126:     }
127:
128:     // Allow the top tiers population partners to mate again
129:     uint32_t halfN = pop.size() / 2;
130:     for (uint32_t i = 0; i < halfN; i++) {
131:         for (uint32_t j = 0; j < pop[i].weights.size(); j++) {
132:             Split[0].first = bitset<CROSSOVER>(
133:                 pop[i].weightsGen[j].to_string().substr(0, CROSSOVER));
134:             Split[0].second =
135:                 bitset<GENE_MAX - CROSSOVER>(pop[i].weightsGen[j].to_string().substr(
136:                     CROSSOVER, GENE_MAX - CROSSOVER));
137:
138:             Split[1].first = bitset<CROSSOVER>(
139:                 pop[i + 2].weightsGen[j].to_string().substr(0, CROSSOVER));
140:             Split[1].second = bitset<GENE_MAX - CROSSOVER>(
141:                 pop[i + 2].weightsGen[j].to_string().substr(CROSSOVER,
142:                     GENE_MAX - CROSSOVER));
143:
144:             newPopMembers[0].weightsGen.push_back(
145:                 Genome_t(Split[0].first.to_string() + Split[1].second.to_string()));
146:             newPopMembers[1].weightsGen.push_back(
147:                 Genome_t(Split[1].first.to_string() + Split[0].second.to_string()));
148:         }
149:         newPop.push_back(newPopMembers[0]);
150:         newPop.push_back(newPopMembers[1]);
151:         newPopMembers[0].weightsGen.clear();
152:         newPopMembers[1].weightsGen.clear();
153:     }
154:     pop = newPop;
155: }
156:
157: void GA::Mutate(Population_t &pop) {
158:     unsigned seed = std::chrono::system_clock::now().time_since_epoch().count();
159:
160:     std::default_random_engine gen(seed);
161:     std::uniform_real_distribution<float> dis(0, 1);
162:
163:     std::default_random_engine genGen(seed);
164:     std::uniform_int_distribution<int> disGen(0, (GENE_MAX - 1));
165:
166:     for (uint32_t i = 0; i < pop.size(); i++) {

```

```

167:     for (uint32_t j = 0; j < pop[i].weightsGen.size(); j++) {
168:         if (dis(gen) < MUTATIONRATE) {
169:             pop[i].weightsGen[j][disGen(genGen)].flip();
170:         }
171:     }
172: }
173: }
174:
175: void GA::GrowToAdulthood(Population_t &pop, const ComplexVect_t &inputValues,
176:                          MinMaxWeight_t rangeweights, Predict_t goal,
177:                          float &totalFitness) {
178:     for (uint32_t i = 0; i < pop.size(); i++) {
179:         for (uint32_t j = 0; j < pop[i].weightsGen.size(); j++) {
180:             pop[i].weights.push_back(
181:                 ConvertToValue<float>(pop[i].weightsGen[j], rangeweights));
182:         }
183:         Weight_t iWeight(pop[i].weights.begin(),
184:                          pop[i].weights.begin() +
185:                          ((inputneurons + 1) * hiddenneurons));
186:         Weight_t hWeight(pop[i].weights.begin() +
187:                          ((inputneurons + 1) * hiddenneurons),
188:                          pop[i].weights.end());
189:         Predict_t results = NNfuction(inputValues, iWeight, hWeight, inputneurons,
190:                                       hiddenneurons, outputneurons);
191:         for (uint32_t j = 0; j < results.OutputNeurons.size(); j++) {
192:             pop[i].Fitness -= results.OutputNeurons[j] / goal.OutputNeurons[j];
193:         }
194:         pop[i].Fitness += results.OutputNeurons.size();
195:         totalFitness += pop[i].Fitness;
196:     }
197: }
198:
199: void GA::GrowToAdulthood(Population_t &pop,
200:                          const InputLearnVector_t &inputValues,
201:                          MinMaxWeight_t rangeweights, OutputLearnVector_t &goal,
202:                          float &totalFitness) {
203:     for (uint32_t i = 0; i < pop.size(); i++) {
204:         for (uint32_t j = 0; j < pop[i].weightsGen.size(); j++) {
205:             pop[i].weights.push_back(
206:                 ConvertToValue<float>(pop[i].weightsGen[j], rangeweights));
207:         }
208:         Weight_t iWeight(pop[i].weights.begin(),
209:                          pop[i].weights.begin() +
210:                          ((inputneurons + 1) * hiddenneurons));
211:         Weight_t hWeight(pop[i].weights.begin() +
212:                          ((inputneurons + 1) * hiddenneurons),
213:                          pop[i].weights.end());
214:         for (uint32_t j = 0; j < inputValues.size(); j++) {
215:             Predict_t results = NNfuction(inputValues[j], iWeight, hWeight,
216:                                           inputneurons, hiddenneurons, outputneurons);
217:             for (uint32_t k = 0; k < results.OutputNeurons.size(); k++) {
218:                 pop[i].Fitness -= results.OutputNeurons[k] / goal[j].OutputNeurons[k];
219:             }
220:             pop[i].Fitness += results.OutputNeurons.size();
221:         }
222:         pop[i].Fitness /= inputValues.size();
223:         totalFitness += pop[i].Fitness;
224:     }
225: }
226:
227: bool GA::SurvivalOfTheFittest(Population_t &pop, float &totalFitness) {
228:     bool retVal = false;
229:     uint32_t decimationCount = pop.size() / 2;
230:
231:     unsigned seed = std::chrono::system_clock::now().time_since_epoch().count();
232:     std::default_random_engine gen(seed);
233:
234:     std::sort(pop.begin(), pop.end(), PopMemberSort);
235:
236:     uint32_t i = ELITISME;
237:     while (pop.size() > decimationCount) {
238:         if (i >= pop.size()) {
239:             i = ELITISME;
240:         }
241:         std::uniform_real_distribution<float> dis(0, totalFitness);
242:         if (dis(gen) < pop[i].Fitness) {
243:             pop.erase(pop.begin() + i--);
244:             totalFitness -= pop[i].Fitness;
245:         }
246:         i++;
247:     }
248:
249:     if (pop[0].Fitness < END_ERROR) {

```

```
250:     retVal = true;
251: }
252: return retVal;
253: }
254: }
```

```

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6:  */
7:
8:  #pragma once
9:
10: #include <vector>
11: #include <complex>
12: #include <cmath>
13: #include <valarray>
14: #include <array>
15: #include <deque>
16: #include <queue>
17: #include <iterator>
18: #include <algorithm>
19: #include <stdint.h>
20: #include <opencv2/core.hpp>
21: #include "SoilMathTypes.h"
22: #include "MathException.h"
23:
24: namespace SoilMath {
25:  /*!
26:  * \brief Fast Fourier Transform class
27:  * \details Use this class to transform a black and white blob presented as a
28:  * cv::Mat with values 0 or 1 to a vector of complex values representing the Fourier
29:  * Descriptors.
30:  */
31:  class FFT {
32:  public:
33:    /*!
34:    * \brief Standard constructor
35:    */
36:    FFT();
37:
38:    /*!
39:    * \brief Standard destructor
40:    */
41:    ~FFT();
42:
43:    /*!
44:    * \brief Transforming the img to the frequency domain and returning the
45:    * Fourier Descriptors
46:    * \param img contour in the form of a cv::Mat type CV_8UC1. Which should
47:    * consist of a continous contour.  $\{ \text{img} \in \mathbb{Z} \mid 0 \leq \text{img} \leq$ 
48:    *  $1 \}$ 
49:    * \return a vector with complex values, represing the contour in the
50:    * frequency domain, expressed as Fourier Descriptors
51:    */
52:    ComplexVect_t GetDescriptors(const cv::Mat &img);
53:
54:  private:
55:    ComplexVect_t
56:      fftDescriptors; /**< Vector with complex values which represent the
57:                        descriptors*/
58:    ComplexVect_t
59:      complexcontour; /**< Vector with complex values which represent the
60:                       contour*/
61:    cv::Mat Img;      /**< Img which will be analysed*/
62:
63:    /*!
64:    * \brief Contour2Complex a private function which translates a continous
65:    * contour image
66:    * to a vector of complex values. The contour is found using a depth first
67:    * search with
68:    * extension list. The algorithm is based upon <a
69:    * href="http://ocw.mit.edu/courses/electrical-engineering-and-computer-science/6-034-artificial-intellig
ence-fall-2010/lecture-videos/lecture-4-search-depth-first-hill-climbing-beam/">MIT
70:    * opencourseware
71:    * 6-034-artificial-intelligence lecture 4</a>
72:    * \param img contour in the form of a cv::Mat type CV_8UC1. Which should
73:    * consist of a continous contour.  $\{ \text{img} \in \mathbb{Z} \mid 0 \leq \text{img} \leq$ 
74:    *  $1 \}$ 
75:    * \param centerCol centre of the contour X value
76:    * \param centerRow centre of the contour Y value
77:    * \return a vector with complex values, represing the contour as a function
78:    */
79:    ComplexVect_t Contour2Complex(const cv::Mat &img, float centerCol,
80:                                float centerRow);
81:
82:    /*!
    * \brief Neighbors a private function returning the neighboring pixels which

```



```
83:  * belong to a contour
84:  * \param O uchar pointer to the data
85:  * \param pixel current counter
86:  * \param columns total number of columns
87:  * \param rows total number of rows
88:  * \return
89:  */
90: iContour_t Neighbors(uchar *O, int pixel, uint32_t columns, uint32_t rows);
91:
92: /*!
93:  * \brief fft a private function calculating the Fast Fourier Transform
94:  * let  $m$  be an integer and let  $N=2^m$  also
95:  *  $CA=[x_0, \dots, x_{N-1}]$  is an  $N$  dimensional complex vector
96:  * let  $\omega = \exp(\{-2\pi i \text{ over } N\})$ 
97:  * then  $c_k = \{\frac{1}{N}\} \sum_{j=0}^{N-1} CA_j \omega^{jk}$ 
98:  * \param CA a  $CA=[x_0, \dots, x_{N-1}]$  is an  $N$  dimensional
99:  * complex vector
100:  */
101: void fft(ComplexArray_t &CA);
102:
103: /*!
104:  * \brief ifft
105:  * \param CA
106:  */
107: void ifft(ComplexArray_t &CA);
108: };
109: }
```

```
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6:  */
7:
8: #pragma once
9: #define COMMONOPERATIONS_VERSION 1
10:
11: #include <algorithm>
12: #include <stdint.h>
13:
14: namespace SoilMath {
15:     inline uint16_t MinNotZero(uint16_t a, uint16_t b) {
16:         if (a != 0 && b != 0) {
17:             return (a < b) ? a : b;
18:         } else {
19:             return (a > b) ? a : b;
20:         }
21:     }
22:
23:     inline uint16_t Max(uint16_t a, uint16_t b) { return (a > b) ? a : b; }
24:
25:     inline uint16_t Max(uint16_t a, uint16_t b, uint16_t c, uint16_t d) {
26:         return (Max(a, b) > Max(c, d)) ? Max(a, b) : Max(c, d);
27:     }
28:
29:     inline uint16_t Min(uint16_t a, uint16_t b) { return (a < b) ? a : b; }
30:
31:     inline uint16_t Min(uint16_t a, uint16_t b, uint16_t c, uint16_t d) {
32:         return (Min(a, b) > Min(c, d)) ? Min(a, b) : Min(c, d);
33:     }
34:
35:     static inline double quick_pow10(int n) {
36:         static double pow10[19] = {1, 10, 100, 1000, 10000, 100000, 1000000, 10000000,
37:                                     100000000, 1000000000, 10000000000, 100000000000,
38:                                     1000000000000, 10000000000000, 100000000000000,
39:                                     1000000000000000, 10000000000000000,
40:                                     100000000000000000, 1000000000000000000};
41:         return pow10[n];
42:     }
43:
44:
45: // Source:
46: // http://martin.ankerl.com/2012/01/25/optimized-approximative-pow-in-c-and-cpp/
47: static inline double fastPow(double a, double b) {
48:     union {
49:         double d;
50:         int x[2];
51:     } u = {a};
52:     u.x[1] = (int)(b * (u.x[1] - 1072632447) + 1072632447);
53:     u.x[0] = 0;
54:     return u.d;
55: }
56:
57: static inline double quick_pow2(int n) {
58:     static double pow2[256] = {
59:         0, 1, 4, 9, 16, 25, 36, 49, 64, 81,
60:         100, 121, 144, 169, 196, 225, 256, 289, 324, 361,
61:         400, 441, 484, 529, 576, 625, 676, 729, 784, 841,
62:         900, 961, 1024, 1089, 1156, 1225, 1296, 1369, 1444, 1521,
63:         1600, 1681, 1764, 1849, 1936, 2025, 2116, 2209, 2304, 2401,
64:         2500, 2601, 2704, 2809, 2916, 3025, 3136, 3249, 3364, 3481,
65:         3600, 3721, 3844, 3969, 4096, 4225, 4356, 4489, 4624, 4761,
66:         4900, 5041, 5184, 5329, 5476, 5625, 5776, 5929, 6084, 6241,
67:         6400, 6561, 6724, 6889, 7056, 7225, 7396, 7569, 7744, 7921,
68:         8100, 8281, 8464, 8649, 8836, 9025, 9216, 9409, 9604, 9801,
69:         10000, 10201, 10404, 10609, 10816, 11025, 11236, 11449, 11664, 11881,
70:         12100, 12321, 12544, 12769, 12996, 13225, 13456, 13689, 13924, 14161,
71:         14400, 14641, 14884, 15129, 15376, 15625, 15876, 16129, 16384, 16641,
72:         16900, 17161, 17424, 17689, 17956, 18225, 18496, 18769, 19044, 19321,
73:         19600, 19881, 20164, 20449, 20736, 21025, 21316, 21609, 21904, 22201,
74:         22500, 22801, 23104, 23409, 23716, 24025, 24336, 24649, 24964, 25281,
75:         25600, 25921, 26244, 26569, 26896, 27225, 27556, 27889, 28224, 28561,
76:         28900, 29241, 29584, 29929, 30276, 30625, 30976, 31329, 31684, 32041,
77:         32400, 32761, 33124, 33489, 33856, 34225, 34596, 34969, 35344, 35721,
78:         36100, 36481, 36864, 37249, 37636, 38025, 38416, 38809, 39204, 39601,
79:         40000, 40401, 40804, 41209, 41616, 42025, 42436, 42849, 43264, 43681,
80:         44100, 44521, 44944, 45369, 45796, 46225, 46656, 47089, 47524, 47961,
81:         48400, 48841, 49284, 49729, 50176, 50625, 51076, 51529, 51984, 52441,
82:         52900, 53361, 53824, 54289, 54756, 55225, 55696, 56169, 56644, 57121,
83:         57600, 58081, 58564, 59049, 59536, 60025, 60516, 61009, 61504, 62001,
```

```
84:      62500, 63001, 63504, 64009, 64516, 65025};
85:  return pow2[(n >= 0) ? n : -n];
86: }
87:
88: static inline long float2intRound(double d) {
89:     d += 6755399441055744.0;
90:     return reinterpret_cast<int> &>(d);
91: }
92: }
```

```
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6:  */
7:
8:  #include "FFT.h"
9:
10: namespace SoilMath {
11:     FFT::FFT() {}
12:
13:     FFT::~FFT() {}
14:
15:     ComplexVect_t FFT::GetDescriptors(const cv::Mat &img) {
16:         if (!fftDescriptors.empty()) {
17:             return fftDescriptors;
18:         }
19:
20:         complexcontour = Contour2Complex(img, img.cols / 2, img.rows / 2);
21:
22:         // Supplement the vector of complex numbers so that N = 2^m
23:         uint32_t N = complexcontour.size();
24:         double logN = log(static_cast<double>(N)) / log(2.0);
25:         if (floor(logN) != logN) {
26:             // Get the next power of 2
27:             double nextLogN = floor(logN + 1.0);
28:             N = static_cast<uint32_t>(pow(2, nextLogN));
29:
30:             uint32_t i = complexcontour.size();
31:             // Append the vector with zeros
32:             while (i++ < N) {
33:                 complexcontour.push_back(Complex_t(0.0, 0.0));
34:             }
35:         }
36:
37:         ComplexArray_t ca(complexcontour.data(), complexcontour.size());
38:         fft(ca);
39:         fftDescriptors.assign(std::begin(ca), std::end(ca));
40:         return fftDescriptors;
41:     }
42:
43:     iContour_t FFT::Neighbors(uchar *O, int pixel, uint32_t columns,
44:                             uint32_t rows) {
45:         long int LUT_nBore[8] = {-columns + 1, -columns, -columns - 1, -1,
46:                                 columns - 1, columns, 1 + columns, 1};
47:         iContour_t neighbors;
48:         uint32_t pEnd = rows * columns;
49:         uint32_t count = 0;
50:         for (uint32_t i = 0; i < 8; i++) {
51:             count = pixel + LUT_nBore[i];
52:             while (count >= pEnd && i < 8) {
53:                 count = pixel + LUT_nBore[++i];
54:             }
55:             if (i >= 8) {
56:                 break;
57:             }
58:             if (O[count] == 1)
59:                 neighbors.push_back(count);
60:         }
61:         return neighbors;
62:     }
63:
64:     ComplexVect_t FFT::Contour2Complex(const cv::Mat &img, float centerCol,
65:                                       float centerRow) {
66:         uchar *O = img.data;
67:         uint32_t pEnd = img.cols * img.rows;
68:
69:         std::deque<std::deque<uint32_t>> sCont;
70:         std::deque<uint32_t> eList;
71:
72:         // Initialize the queue
73:         for (uint32_t i = 0; i < pEnd; i++) {
74:             if (O[i] == 1) {
75:                 std::deque<uint32_t> tmpQ;
76:                 tmpQ.push_back(i);
77:                 sCont.push_back(tmpQ);
78:                 break;
79:             }
80:         }
81:
82:         if (sCont.front().size() < 1) {
83:             throw Exception::MathException("No contour found in image!");
84:         }
85:     }
86: }
```

```

84:  } // Exception handling
85:
86:  uint32_t prev = -1;
87:
88:  // Extend path on queue
89:  for (uint32_t i = sCont.front().front(); i < pEnd; i) {
90:      iContour_t nBors =
91:          Neighbors(0, i, img.cols, img.rows); // find neighboring pixels
92:      std::deque<uint32_t> cQ = sCont.front(); // store first queue;
93:      sCont.erase(sCont.begin()); // erase first queue from beginning
94:      if (cQ.size() > 1) {
95:          prev = cQ.size() - 2;
96:      } else {
97:          prev = 0;
98:      }
99:      // Loop through each neighbor
100:     for (uint32_t j = 0; j < nBors.size(); j++) {
101:         if (nBors[j] != cQ[prev]) // No backtracking
102:         {
103:             if (nBors[j] == cQ.front() && cQ.size() > 8) {
104:                 i = pEnd;
105:             } // Back at first node
106:             if (std::find(eList.begin(), eList.end(), nBors[j]) ==
107:                 eList.end()) // Check if this current route is extended elsewhere
108:             {
109:                 std::deque<uint32_t> nQ = cQ;
110:                 nQ.push_back(nBors[j]); // Add the neighbor to the queue
111:                 sCont.push_front(nQ); // add the sequence to the front of the queue
112:             }
113:         }
114:     }
115:     if (nBors.size() > 2) {
116:         eList.push_back(i);
117:     } // if there are multiple choices put current node in extension List
118:     if (i != pEnd) {
119:         i = sCont.front().back();
120:     } // If it isn't the end set i to the last node of the first queue
121:     if (sCont.size() == 0) {
122:         throw Exception::MathException(
123:             "No continuous contour found, or less then 8 pixels long!");
124:     }
125: }
126:
127: // convert the first queue to a complex normalized vector
128: Complex_t cPoint;
129: ComplexVect_t contour;
130: float col = 0.0;
131: // Normalize and convert the complex function
132: for_each(
133:     sCont.front().begin(), sCont.front().end(),
134:     [&img, &cPoint, &contour, &centerCol, &centerRow, &col](uint32_t &e) {
135:         col = (float)((e % img.cols) - centerCol);
136:         if (col == 0.0) {
137:             cPoint.real(1.0);
138:         } else {
139:             cPoint.real((float)(col / centerCol));
140:         }
141:         cPoint.imag((float)((floorf(e / img.cols) - centerRow) / centerRow));
142:         contour.push_back(cPoint);
143:     });
144:
145: return contour;
146: }
147:
148: void FFT::fft(ComplexArray_t &CA) {
149:     const size_t N = CA.size();
150:     if (N <= 1) {
151:         return;
152:     }
153:
154:     ///< Divide and conquer
155:     ComplexArray_t even = CA[std::slice(0, N / 2, 2)];
156:     ComplexArray_t odd = CA[std::slice(1, N / 2, 2)];
157:
158:     fft(even);
159:     fft(odd);
160:
161:     for (size_t k = 0; k < N / 2; ++k) {
162:         Complex_t ct = std::polar(1.0, -2 * M_PI * k / N) * odd[k];
163:         CA[k] = even[k] + ct;
164:         CA[k + N / 2] = even[k] - ct;
165:     }
166: }

```

```
167:
168: void FFT::ifft(ComplexArray_t &CA) {
169:     CA = CA.apply(std::conj);
170:     fft(CA);
171:     CA = CA.apply(std::conj);
172:     CA /= CA.size();
173: }
174: }
```

```
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6:  */
7:
8:  ///! Genetic Algorithmes used for optimization problems
9:  /*!
10:   * Use this class for optimization problems. It's currently optimized for
11:   * Neural Network optimzation
12:   */
13: #pragma once
14:
15: #include <bitset>
16: #include <random>
17: #include <string>
18: #include <algorithm>
19: #include <chrono>
20:
21: #include "NN.h"
22: #include "SoilMathTypes.h"
23: #include "MathException.h"
24:
25: namespace SoilMath {
26:
27: class GA {
28: public:
29:     /*!
30:     * \brief GA Standard constructor
31:     */
32:     GA();
33:
34:     /*!
35:     * \brief GA Construction with a Neural Network initializers
36:     * \param nnfunction the Neural Network prediction function which results will
37:     * be optimized
38:     * \param inputneurons the number of input neurons in the Neural Network don't
39:     * count the bias
40:     * \param hiddenneurons the number of hidden neurons in the Neural Network
41:     * don't count the bias
42:     * \param outputneurons the number of output neurons in the Neural Network
43:     */
44:     GA(NNfunctionType nnfunction, uint32_t inputneurons, uint32_t hiddenneurons,
45:        uint32_t outputneurons);
46:
47:     /*!
48:     * \brief GA standard de constructor
49:     */
50:     ~GA();
51:
52:     /*!
53:     * \brief Evolve Darwin would be proud!!! This function creates a population
54:     * and itterates
55:     * through the generation till the maximum number off itterations has been
56:     * reached of the
57:     * error is acceptable
58:     * \param inputValues complex vector with a reference to the inputvalues
59:     * \param weights reference to the vector of weights which will be optimized
60:     * \param prevWeights pointer to the pevious weight results
61:     * \param rangeweights pointer to the range of weights, currently it doesn't
62:     * support indivudal ranges
63:     * this is because of the crossing
64:     * \param goal target value towards the Neural Network prediction function
65:     * will be optimized
66:     * \param maxGenerations maximum number of itterations default value is 200
67:     * \param popSize maximum number of population, this should be an even number
68:     */
69:     void Evolve(const ComplexVect_t &inputValues, Weight_t &weights,
70:                std::vector<Weight_t> &prevWeights, MinMaxWeight_t rangeweights,
71:                Predict_t goal, uint32_t maxGenerations = 200,
72:                uint32_t popSize = 30);
73:
74:     /*!
75:     * \brief Evolve Darwin would be proud!!! This function creates a population
76:     * and itterates
77:     * through the generation till the maximum number off itterations has been
78:     * reached of the
79:     * error is acceptable
80:     * \param inputValues complex vector with a reference to the inputvalues
81:     * \param weights reference to the vector of weights which will be optimized
82:     * \param rangeweights reference to the range of weights, currently it doesn't
83:     * support indivudal ranges
```

```
84:  * this is because of the crossing
85:  * \param goal target value towards the Neural Network prediction function
86:  * will be optimized
87:  * \param maxGenerations maximum number of iterations default value is 200
88:  * \param popSize maximum number of population, this should be an even number
89:  */
90: void Evolve(const InputLearnVector_t &inputValues, Weight_t &weights,
91:             MinMaxWeight_t rangeweights, OutputLearnVector_t &goal,
92:             uint32_t maxGenerations = 200, uint32_t popSize = 30);
93:
94: private:
95:     NNfunctionType NNfunction; /**< The Neural Net work function*/
96:     uint32_t inputneurons; /**< the total number of input neurons*/
97:     uint32_t hiddenneurons; /**< the total number of hidden neurons*/
98:     uint32_t outputneurons; /**< the total number of output neurons*/
99:
100:  /*!
101:  * \brief Genesis private function which is the spark of live, using a random
102:  * seed
103:  * \param weights a reference to the used Weight_t vector
104:  * \param rangeweights pointer to the range of weights, currently it doesn't
105:  * support individual ranges
106:  * \param popSize maximum number of population, this should be an even number
107:  * \return
108:  */
109: Population_t Genesis(const Weight_t &weights, MinMaxWeight_t rangeweights,
110:                      uint32_t popSize);
111:
112:  /*!
113:  * \brief CrossOver a private function where the partners mate with each other
114:  * The values or PopMember_t are expressed as bits or are cut at the point CROSSOVER
115:  * the population members are paired with the nearest neighbor and new members are
116:  * created pairing the Genome_t of each other at the CROSSOVER point. Afterwards all
117:  * the top tiers partners are allowed to mate again.
118:  * \param pop reference to the population
119:  */
120: void CrossOver(Population_t &pop);
121:
122:  /*!
123:  * \brief Mutate a private function where individual bits from the Genome_t are mutated
124:  * at a random uniform distribution event defined by the MUTATIONRATE
125:  * \param pop reference to the population
126:  */
127: void Mutate(Population_t &pop);
128:
129:  /*!
130:  * \brief GrowToAdulthood a private function where the new population members serve as the
131:  * the input for the Neural Network prediction function. The results are weight against
132:  * the goal and this weight determine the fitness of the population member
133:  * \param pop reference to the population
134:  * \param inputValues complex vector with a reference to the inputvalues
135:  * \param rangeweights pointer to the range of weights, currently it doesn't
136:  * support individual ranges
137:  * \param goal a Predict_t type with the expected value
138:  * \param totalFitness a reference to the total population fitness
139:  */
140: void GrowToAdulthood(Population_t &pop, const ComplexVect_t &inputValues,
141:                      MinMaxWeight_t rangeweights, Predict_t goal,
142:                      float &totalFitness);
143:
144:  /*!
145:  * \brief GrowToAdulthood a private function where the new population members serve as the
146:  * the input for the Neural Network prediction function. The results are weight against
147:  * the goal and this weight determine the fitness of the population member
148:  * \param pop reference to the population
149:  * \param inputValues a InputLearnVector_t with a reference to the inputvalues
150:  * \param rangeweights pointer to the range of weights, currently it doesn't
151:  * support individual ranges
152:  * \param goal a Predict_t type with the expected value
153:  * \param totalFitness a reference to the total population fitness
154:  */
155: void GrowToAdulthood(Population_t &pop, const InputLearnVector_t &inputValues,
156:                      MinMaxWeight_t rangeweights, OutputLearnVector_t &goal,
157:                      float &totalFitness);
158:
159:  /*!
160:  * \brief SurvivalOfTheFittest a private function where a battle to the death commences
161:  * The fittest population members have the best chance of survival. Death is instigated
162:  * with a random uniform distribution. The elite members don't partake in this destruction
163:  * The ELITISME rate indicate how many top tier members survive this catastrophic event.
164:  * \param inputValues a InputLearnVector_t with a reference to the inputvalues
165:  * \param totalFitness a reference to the total population fitness
166:  * \return
```



```
167:  */
168:  bool SurvivalOfTheFittest(Population_t &pop, float &totalFitness);
169:
170:  /*!
171:   * \brief PopMemberSort a private function where the members are sorted according to
172:   * there fitness ranking
173:   * \param i left hand population member
174:   * \param j right hand population member
175:   * \return true if the left member is closser to the goal as the right member.
176:   */
177:  static bool PopMemberSort(PopMember_t i, PopMember_t j) {
178:      return (i.Fitness < j.Fitness);
179:  }
180:
181:  /*!
182:   * \brief Conversion of the value of type T to Genome_t
183:   * \details Usage: Use <tt>ConvertToGenome<Type>(type, range)</tt>
184:   * \param value The current value wich should be converted to a Genome_t
185:   * \param range the range in which the value should fall, this is to have a Genome_t
186:   * which utilizes the complete range 0000...n till 1111...n
187:   */
188:  template <typename T>
189:  inline Genome_t ConvertToGenome(T value, std::pair<T, T> range) {
190:      uint32_t intVal = static_cast<uint32_t>(
191:          (UINT32_MAX * (range.first + value)) / (range.second - range.first));
192:      Genome_t retVal(intVal);
193:      return retVal;
194:  }
195:
196:  /*!
197:   * \brief Conversion of the Genome to a value
198:   * \details Usage: use <tt>ConvertToValue<Type>(genome, range)
199:   * \param gen is the Genome which is to be converted
200:   * \param range is the range in which the value should fall
201:   */
202:  template <typename T>
203:  inline T ConvertToValue(Genome_t gen, std::pair<T, T> range) {
204:      T retVal =
205:          range.first +
206:          (((range.second - range.first) * static_cast<T>(gen.to_ulong())) /
207:           UINT32_MAX);
208:      return retVal;
209:  }
210: };
211: }
```

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6:  */
7:
8:  #pragma once
9:  #include <exception>
10: #include <string>
11:
12: using namespace std;
13:
14: namespace SoilMath {
15: namespace Exception {
16: class MathException : public std::exception {
17: public:
18:     MathException(string m = "Math Exception!") : msg(m){};
19:     ~MathException() _GLIBCXX_USE_NOEXCEPT{};
20:     const char *what() const _GLIBCXX_USE_NOEXCEPT { return msg.c_str(); };
21:
22: private:
23:     string msg;
24: };
25: }
26: }
```

```
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6:  */
7:
8:  #pragma once
9:  #include <stdint.h>
10:
11: namespace SoilMath {
12:  /*!
13:   * \brief The Sort template class
14:   */
15:  class Sort {
16:  public:
17:      Sort() {}
18:      ~Sort() {}
19:
20:  /*!
21:   * \brief QuickSort a static sort a Type T array with i values
22:   * \details Usage: QuickSort<type>(*type , i)
23:   * \param arr an array of Type T
24:   * \param i the number of elements
25:   */
26:  template <typename T> static void QuickSort(T *arr, int i) {
27:      if (i < 2)
28:          return;
29:
30:      T p = arr[i / 2];
31:      T *l = arr;
32:      T *r = arr + i - 1;
33:      while (l <= r) {
34:          if (*l < p) {
35:              l++;
36:          } else if (*r > p) {
37:              r--;
38:          } else {
39:              T t = *l;
40:              *l = *r;
41:              *r = t;
42:              l++;
43:              r--;
44:          }
45:      }
46:      Sort::QuickSort<T>(arr, r - arr + 1);
47:      Sort::QuickSort<T>(l, arr + i - 1);
48:  }
49:
50:  /*!
51:   * \brief QuickSort a static sort a Type T array with i values where the key
52:   * are also changed accordingly
53:   * \details Usage: QuickSort<type>(*type *type , i)
54:   * \param arr an array of Type T
55:   * \param key an array of 0..i-1 representing the index
56:   * \param i the number of elements
57:   */
58:  template <typename T> static void QuickSort(T *arr, T *key, int i) {
59:      if (i < 2)
60:          return;
61:
62:      T p = arr[i / 2];
63:
64:      T *l = arr;
65:      T *r = arr + i - 1;
66:
67:      T *lkey = key;
68:      T *rkey = key + i - 1;
69:
70:      while (l <= r) {
71:          if (*l < p) {
72:              l++;
73:              lkey++;
74:          } else if (*r > p) {
75:              r--;
76:              rkey--;
77:          } else {
78:              if (*l != *r) {
79:                  T t = *l;
80:                  *l = *r;
81:                  *r = t;
82:
83:                  T tkey = *lkey;
```

```
84:         *lkey = *rkey;
85:         *rkey = tkey;
86:     }
87:
88:     l++;
89:     r--;
90:
91:     lkey++;
92:     rkey--;
93: }
94: }
95: Sort::QuickSort<T>(arr, key, r - arr + 1);
96: Sort::QuickSort<T>(l, lkey, arr + i - 1);
97: }
98: };
99: }
```

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6:  */
7:
8:  #pragma once
9:
10: #include <stdint.h>
11: #include <vector>
12: #include <string>
13: #include <fstream>
14:
15: #include <boost/archive/xml_iarchive.hpp>
16: #include <boost/archive/xml_oarchive.hpp>
17: #include <boost/serialization/vector.hpp>
18:
19: #include "GA.h"
20: #include "MathException.h"
21: #include "SoilMathTypes.h"
22: #include "FFT.h"
23:
24: namespace SoilMath {
25:  /*!
26:  * \brief The Neural Network class
27:  * \details This class is used to make prediction on large data set. Using self
28:  * learning algoritmes
29:  */
30:  class NN {
31:  public:
32:    /*!
33:    * \brief NN constructor for the Neural Net
34:    * \param inputneurons number of input neurons
35:    * \param hiddenneurons number of hidden neurons
36:    * \param outputneurons number of output neurons
37:    */
38:    NN(uint32_t inputneurons, uint32_t hiddenneurons, uint32_t outputneurons);
39:
40:    /*!
41:    * \brief NN constructor for the Neural Net
42:    */
43:    NN();
44:
45:    /*!
46:    * \brief ~NN virtual destructor for the Neural Net
47:    */
48:    virtual ~NN();
49:
50:    /*!
51:    * \brief Predict The prediction function.
52:    * \details In this function the neural net is setup and the input which are
53:    * the complex values describing the contour in the frequency domein serve as
54:    * input. The absolute value of these im. number because I'm not interested
55:    * in the orrientation of the particle but more in the degree of variations.
56:    * \param input vector of complex input values, these're the Fourier
57:    * descriptors
58:    * \return a real valued vector of the output neurons
59:    */
60:    Predict_t Predict(ComplexVect_t input);
61:
62:    /*!
63:    * \brief PredictLearn a static function used in learning of the weights
64:    * \details It starts a new Neural Network object and passes all the
65:    * paramaters in to this newly created object. After this the predict function
66:    * is called and the value is returned. This work around was needed to pass
67:    * the neural network to the Genetic Algorithm class.
68:    * \param input a complex vector of input values
69:    * \param inputweights the input weights
70:    * \param hiddenweights the hidden weights
71:    * \param inputneurons the input neurons
72:    * \param hiddenneurons the hidden neurons
73:    * \param outputneurons the output neurons
74:    * \return
75:    */
76:    static Predict_t PredictLearn(ComplexVect_t input, Weight_t inputweights,
77:                                   Weight_t hiddenweights, uint32_t inputneurons,
78:                                   uint32_t hiddenneurons, uint32_t outputneurons);
79:
80:    /*!
81:    * \brief SetInputWeights a function to set the input weights
82:    * \param value the real valued vector with the values
83:    */
```

```

84: void SetInputWeights(Weight_t value) { iWeights = value; }
85:
86: /*!
87: * \brief SetHiddenWeights a function to set the hidden weights
88: * \param value the real valued vector with the values
89: */
90: void SetHiddenWeights(Weight_t value) { hWeights = value; }
91:
92: /*!
93: * \brief SetBeta a function to set the beta value
94: * \param value a floating value usually between 0.5 and 1.5
95: */
96: void SetBeta(float value) { beta = value; }
97:
98: /*!
99: * \brief Learn the learning function
100: * \param input a vector of vectors with complex input values
101: * \param cat a vector of vectors with the know output values
102: * \param noOfDescriptorsUsed the total number of descriptors which should be
103: * used
104: */
105: void Learn(InputLearnVector_t input, OutputLearnVector_t cat,
106:            uint32_t noOfDescriptorsUsed);
107:
108: /*!
109: * \brief SaveState Serialize and save the values of the Neural Net to disk
110: * \details Save the Neural Net in XML valued text file to disk so that a
111: * object can
112: * be reconstructed on a latter stadia.
113: * \param filename a string indicating the file location and name
114: */
115: void SaveState(string filename);
116:
117: /*!
118: * \brief LoadState Loads the previous saved Neural Net from disk
119: * \param filename a string indicating the file location and name
120: */
121: void LoadState(string filename);
122:
123: Weight_t iWeights; /**< a vector of real valued floating point input weights*/
124: Weight_t hWeights; /**< a vector of real valued floating point hidden weight*/
125:
126: private:
127:     std::vector<float> iNeurons; /**< a vector of input values, the bias is
128:                                included, the bias is included and
129:                                is the first value*/
130:     std::vector<float>
131:         hNeurons; /**< a vector of hidden values, the bias is included and
132:                   is the first value*/
133:     std::vector<float> oNeurons; /**< a vector of output values*/
134:
135:     uint32_t hiddenNeurons; /**< number of hidden neurons minus bias*/
136:     uint32_t inputNeurons; /**< number of input neurons minus bias*/
137:     uint32_t outputNeurons; /**< number of output neurons*/
138:     float beta; /**< the beta value, this indicates the steepness of the sigmoid
139:                 function*/
140:
141:     bool studied =
142:         false; /**< a value indicating if the weights are a results of a
143:                 learning curve*/
144:     friend class boost::serialization::access; /**< a private friend class so the
145:                                                serialization can access all
146:                                                the needed functions*/
147:
148: /*!
149: * \brief serialization function
150: * \param ar the object
151: * \param version the version of the class
152: */
153: template <class Archive>
154: void serialize(Archive &ar, const unsigned int version __attribute__((unused))) {
155:     ar &BOOST_SERIALIZATION_NVP(inputNeurons);
156:     ar &BOOST_SERIALIZATION_NVP(hiddenNeurons);
157:     ar &BOOST_SERIALIZATION_NVP(outputNeurons);
158:     ar &BOOST_SERIALIZATION_NVP(iWeights);
159:     ar &BOOST_SERIALIZATION_NVP(hWeights);
160:     ar &BOOST_SERIALIZATION_NVP(beta);
161:     ar &BOOST_SERIALIZATION_NVP(studied);
162: }
163: };

```