APPENDIX

Electrodiagnosis Support System for Localizing Neural Injury in an Upper Limb

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Design Objectives

As ESS is developed mainly for educational purpose, the primary users of the system will be medical trainees. Nonetheless, the core algorithms of ESS can also be embedded in the medical devices used for neural diagnosis. With both applications in mind, we aim to make ESS interactive, extendible and reliable in its diagnosis. First, for interactivity, ESS provides an intuitive graphical user interface through which users can interact with the system throughout the diagnosis. Its graphical interface can visualize complex neural structures in a simple and easily conceptualizable graph. Second, for extendibility, it allows users to modify the default input file or create their own files reflecting their interpretation of neural structures. ESS then parses the input file and faithfully reproduces the neural structure prescribed in it. Moreover, it has the capacity to deal with different neural structures or myotomes such as lower limb without much change to its core logics. Lastly, for reliability and accuracy of diagnosis, ESS employs localization algorithms that are based on systematic structure analysis and sophisticated clinical heuristics. The diagnosis algorithms are fine-tuned after a rigorous validation process.

Input Data Format

The input data file reflects the expert's own interpretation of the general neural structure and the patient's particular state of health. The format of the input data file is a tab-delineated text file in a markup language. The input data file is separated into two parts: <Header> and <Contents>.

The top of Figure 2 shows the <Header> of the input file. The <Header> contains the metadata for <Contents>, which consists of six elements: <Name>, <Muscle>, <Peripheral nerve>, <Cord>, <Trunk>, and <Segments>. The text of each element is the precise name of the nerve bundle or muscle, and the order of the text reflects the order of the muscles and bundles in the upper limb. If a given muscle is expressed earlier than the others, it means that the muscle is closer to the root than the others. For example, as the serratus anterior (SA) on the long thoracic nerve is closer to the root than the biceps brachii (BB) on the musculocutaneous nerve according to a given interpretation, SA is expressed earlier than BB.

Figure 2 (middle-to-bottom) shows an example of the <Contents> element. The <Contents> element represents the connection structure of the muscles from the root to the peripheral nerve. These elements are expressed in the order of <Muscle>, <Abbreviation>, <Peripheral nerve>, <Cord>, <Trunk>, and <Segments>. For example, line 14 represents a nerve originating from the C5 bundle, passing through the dorsal scapular peripheral nerve, and ending at the rhomboid major muscle. In another example in lines 24-26, the latissimus dorsi muscle is innervated by three spinal nerve roots: C6, C7 and C8. The C6 line (nerve) passes through the upper trunk, the C7 line passes through the middle trunk, and the C8 line passes through the lower trunk. These three nerve lines join in the posterior cord, and continue to the thoracodorsal nerve. The final destination is the latissimus dorsi muscle.

Internal Data Structure

The input data file is parsed by an internal parser object. Figure 3 shows the internal data structure after parsing. This data structure is expressed as a sparse matrix. The rows of the matrix represent individual muscles and the columns represent the paths they pass through. If a muscle passes the specified bundle, its position is 1, otherwise it is 0. Also, the matrix rows reflect the real clinical order (if the muscle is closer to the root, then the muscle rank is higher).

System Validation

A. Test data set

The evaluation was performed using real data of 133 patients from KUAH. There were 90 male patients and 43 female patients. The patients were diagnosed with three types of diseases; radiculopathy, brachial plexopathy, and peripheral neuropathy. The accuracy of the system was measured by comparing the suggestions provided by the system with the diagnosis made by the physicians, per disease. For this reason, a patient with two diseases was counted as two test cases in our evaluation.

Consider the example of a patient with a diagnosis of a lower trunk injury and a C7, C8 radiculopathy. In this case, because a lower trunk injury is a brachial plexopathy and a C7, C8 radiculopathy is a radiculopathy, we regarded this patient as two samples. Consider another case involving a patient with a diagnosis of a C7, C8 radiculopathy and an ulnar neuropathy. Because the injury to the ulnar nerve is a peripheral neuropathy, and a C7, C8 injury means a radiculopathy, we divided this patient's cases into two samples. In accordance with this sample counting policy, 149 samples (100 males and 49 females) were used for the evaluation. Table 1 shows the distribution of patients and their samples across age groups.

B. Injury localization

For analysis we grouped all samples into three clusters, consisting of patients with a radiculopathy (67 samples), brachial plexopathy (19 samples) and peripheral neuropathy (63 samples). The recall and precision were used as evaluation metrics given by

$$Recall = \frac{|\{Doctor's\ diagnosis\} \cap \{ESS's\ diagnosis\}|}{|\{Doctors'\ diagnosis\}|}$$

$$Precision = \frac{|\{Doctor's\ diagnosis\} \cap \{ESS's\ diagnosis\}|}{|\{ESS's\ \ diagnosis\}|}$$

These were computed for each disease and each possibility group (i.e., impression and other possibilities) for the evaluation. To elaborate, consider an example of real patient data involving a male patient who had visited the Department of Rehabilitation at KUAH. He was 66 years old, and had undergone a needle EMG on his left hand. He was given a diagnosis of a lower trunk injury and a C7, C8 radiculopathy. We evaluated this patient's record using ESS, and obtained a diagnosis of a lower trunk injury and a C8 radiculopathy from 'impressions'. For a brachial plexopathy, the doctor's diagnosis indicated that the patient had been damaged in the lower trunk, and ESS also decided that he had sustained an injury to the lower trunk. This was counted as recall = 100%, precision = 100%. On the other hand, for a radiculopathy, he had been given a diagnosis of a C7, C8 injury by the doctor, and ESS said he had a C8 injury. This sample's results are recall = 50%, precision = 100%.

Table 2 shows the results of the evaluation. The diagnosis of a radiculopathy has a high accuracy. The precision and recall of the ESS diagnosis for radiculopathy is 94% and 97% respectively when 'impressions' alone is used. When both 'impressions' and 'other possibilities' are used together, recall improves by 1%, while precision is reduced by 11%. On the other hand, for a brachial plexopathy and peripheral neuropathy, recalls are improved by 12% and 10% respectively, while precisions are reduced by 24% and increased by 2% respectively. Given this result, we can conclude that there is a tradeoff between using 'impressions' alone and using both lists. For higher precision, 'impressions' alone suffices, while for better recall, both lists might be considered.

Note that the accuracy of the tests of brachial plexopathy is somewhat lower compared to the other two cases. The probable cause includes the limited number of samples that might have been skewed, and the lack of NCS results. As we previously mentioned, the EMG examination consists of two tests – needle EMG and NCS. In order to find a nerve injury, both tests are performed together in practice. The current version of ESS, however, does not consider the NCS tests in the diagnosis. Although ESS using needle EMG alone still produces a compelling result, in the future we plan to include NCS in ESS in order to improve the performance further.

C. Lesion diagnosis

For a more detailed evaluation, we validated our result for specific lesions. Especially, we considered nerve injury lesions including C5, C6, C7 and C8 from a radiculopathy, and radial, median, and ulnar nerves from a peripheral neuropathy. In this evaluation, we performed binary classification in order to measure the sensitivity and specificity of our system. The sensitivity and the specificity are defined as follows.

$$Sensitivity = \frac{\#of\ True\ Positives}{\#of\ True\ Positives + \#of\ False\ Negatives}$$

$$Specificity = \frac{\#\ of\ True\ Negatives}{\#of\ True\ Negatives + \#of\ False\ Positives}$$

where True Positive (TP) = injury lesion correctly diagnosed as injury, True Negative (TN) = non-injury lesion correctly diagnosed as non-injury, False Positive (FP)= non-injury lesion incorrectly diagnosed as injury, and False Negative (FN) = injury lesion incorrectly diagnosed as non-injury. A sensitivity of 100% means that the system correctly recognizes all injury lesions. A specificity of 100% means that the system correctly recognizes all non-injury lesions.

Table 3 shows the sensitivity and specificity test results for the seven lesions using the diagnosis in the 'impressions' list alone, while Table 4 shows the results using both 'impressions' and other 'possibilities'. Of the 149 samples, there were 67 samples of C5, C6, C7, and C8 radiculopathy and 63 samples of radial, median, and ulnar neuropathy. As shown in Table 3, the sensitivity of the radiculopathy lesion tests was 97% on average and the specificity was 95% on average. For the neuropathy lesions, the sensitivity was 89% on average while the specificity was 100%.

From this result, we can see that with the diagnosis in the 'impressions' list alone we can still achieve a good sensitivity and specificity. As shown in Table 4, when the diagnoses in the 'impressions' and 'other possibilities' lists were used together we could improve the sensitivities, while the specificities were somewhat reduced. For example, for neuropathy lesions, the sensitivity was improved to 100% from 89%, while the specificity was reduced to 94% from 100%.

Algorithms 1 through 3

Algorithm 1 for Injury Diagnosis

Input muscles with normal findings and muscles with abnormal findings

Output diagnosis vector

d = total #of muscles

i = #of normal findings

j = #of abnormal findings

k = #of bundles representing muscle paths

T = *k* x *d* matrix representing upper limb neural structure

$X = [X_1, X_2, \ldots X_i]$ /* *k* x *i* matrix representing muscles with normal findings */

$Y = [Y_1, Y_2, \ldots Y_i]$ /* *k* x *j* matrix representing muscles with abnormal findings */

$D = [0, 0, \ldots 0]$ /* diagnosis vector of size *k* */

$N = [0, 0, \ldots 0]$ /* normal findings summary vector of size *k* */

for $t = 0$ to $t = i$ **do**

  $N = N + X[t]$

end for

$A = [0, 0, \ldots 0]$ /* abnormal findings summary vector of size *k* */

for $t = 0$ to $t = j$ **do**

  $A = A + Y[t]$

end for

```
for t = 0 to t = k do
    if BUNDDLE_NAME(t) =”peripheral nerve”    then
        if A[t] < 0 then D[t] = -1
      else if N[t] = 0 & N[t] > 0    then A[t] = 1
      else if N[t] = 0 & A[t] = 0    then D[t] = 0
      end if
    else then
      if N[t] > 0 then D[t] = 1
      else if N[t] = 0 & A[t] < 0    then D[t] = -1
      else if N[t] = 0 & A[t] = 0    then D[t] = 0
      end if
        end if
end for
```

Algorithm 2 for Selecting ‘Impressions’ and ‘Other Possibilities’

Input normal findings summary vector, abnormal findings summary vector, diagnosis vector

Output ‘impressions’ and ‘other possibilities’(localization of nerve injury)

k = #of bundles representing muscle paths

N = normal findings summary vector of size *k*

M = abnormal findings summary vector of size *k*

D = diagnosis vector of size *k*

for *t = 0* to *t = k* **do**
  if *D[t] = -1* **then**
      p = N[t] + abs(M[t]) / total # of times muscle path t is inspected */*
   if *p > 1* **then**   /* only consider the paths tested more than once */
    if *MEMBER_OF(BUNDDLE_NAME(t), "peripheral nerve")* **then**
      specificInjurySite =
GET_SPECIFIC_INJURY_SITE(*BUNDDLE_NAME(t))*
     if *p >= max(N + abs(M))* **then**
      add BUNDDLE_NAME(t)+ specificInjurySite to "impressions"
     else if
      add BUNDDLE_NAME(t) + specificInjurySite to "other possibilities "
     end if
    else if *MEMBER_OF(BUNDDLE_NAME(t), " root ")* **then**
      add BUNDDLE_NAME(t) to "impressions"
    else if *p >= max(N + M)* **then**

```
            add BUNDDLE_NAME(t) to "impressions"
        else
            add BUNDDLE_NAME(t) to "other possibilities"
        end if
      else
          add BUNDDLE_NAME(t) to "other possibilities "
      end if
    end if
end for
```

Algorithm 3 for Localization of Peripheral Nerve Injury

Input normal findings set, abnormal findings set, target nerve

Output localized injury site

$X = [X_1, X_2, ... X_i]$ /* *k* x *i* matrix representing muscles with normal findings, where k=total #of bundles and i=#of muscles tested normal */

Y=$[Y_1, Y_2, ... Y_i]$ /* *k* x *j* matrix representing muscles with abnormal findings, where k=total #of bundles and j=#of muscles tested abnormal */

Z=$[Z_1,Z_2, ... Z_h]$ /* *k* x *h* matrix representing the union of X and Y, where *h* = #of muscles passing through the target nerve(peripheral nerve) */

current =state of the muscle currently examined

next =state of the next muscle

distalMuscle = muscle far from the root

proximalMuscle=muscle close to the root

for *t =1* to *t =h* **do**

current = -1

next = -1

if *t=h* **then** *break*

end if

if *MEMBER_OF(Z[t], X)* **then**

current =1

end if

if *MEMBER_OF(Z[t+1],X)* **then**

```
            next =1
        end if

      if current =-1 & next=1 then
            distalMuscle =Z[t]
          proximalMuscle =Z[t+1]
        else if current=-1 & next =-1 then
                    proximalMuscle=Z[t+1]
                    distalMuscle =null
          else if current =1 & next=-1 then
                    return null
          end if
end for

if distalMuscle != null & proximalMuscle != null then
        injurySite = between distalMuscle and proximalMuscle
else
        injurySite =before proximalMuscle
end if

return injurySite
```

Tables 1 through 4

Age	*~9*	*10~19*	*20~29*	*30~39*	*40~49*	*50~59*	*60~*	*Sum*
M	1/1	5/5	23/22	19/17	17/15	22/19	13/11	100/90
F	1/1	1/1	6/6	6/5	8/7	11/10	16/13	49/43

(Number of samples) / (Number of patients)

Table 1. Patients who had visited the Department of Rehabilitation of Korea University Anam Hospital. The distribution of patients and their samples are shown for different age groups. The first row represents male patients and the second row represents female patients.

	Impression		*Imp. + Others*		*# of patients*
	recall	precision	recall	precision	
Radiculopathy	97%	94%	98%	83%	67
Brachial Plexopathy	71%	79%	83%	55%	19
Peripheral Neuropathy	90%	92%	100%	94%	63

Table 2. Precision and recall. We tested 149 samples, and grouped these samples into three clusters – radiculopathy, brachial plexopathy, and peripheral neuropathy.

	Impression						
	TP	FN.	FP.	TN.	Sum	*Sens.*	*Spec.*
C5 lesion	20	0	8	39	67	100%	83%
C6 lesion	32	0	0	35		100%	100%
C7 lesion	49	4	0	14		92.3%	100%
C8 lesion	19	1	2	45		95%	95.7%
Radial N.	16	1	0	46	63	94.1%	100%
Median N.	13	2	0	48		86.7%	100%
Ulnar N.	27	4	0	32		87.1%	100%

Table 3. Sensitivity and specificity from impressions.

	Impression + Other possibilities						
	TP	FN.	FP.	TN.	Sum	Sens.	Spec.
C5 lesion	20	0	11	36	67	100%	76.6%
C6 lesion	32	0	1	34		100%	97.1%
C7 lesion	49	4	2	12		92.5%	85.7%
C8 lesion	19	1	3	44		95%	93.6%
Radial N.	17	0	5	41	63	100%	89.1%
Median N.	15	0	4	44		100%	91.7%
Ulnar N.	31	0	0	32		100%	100%

Table 4. Sensitivity and specificity from impressions and other possibilities.

Figures 1 through 3

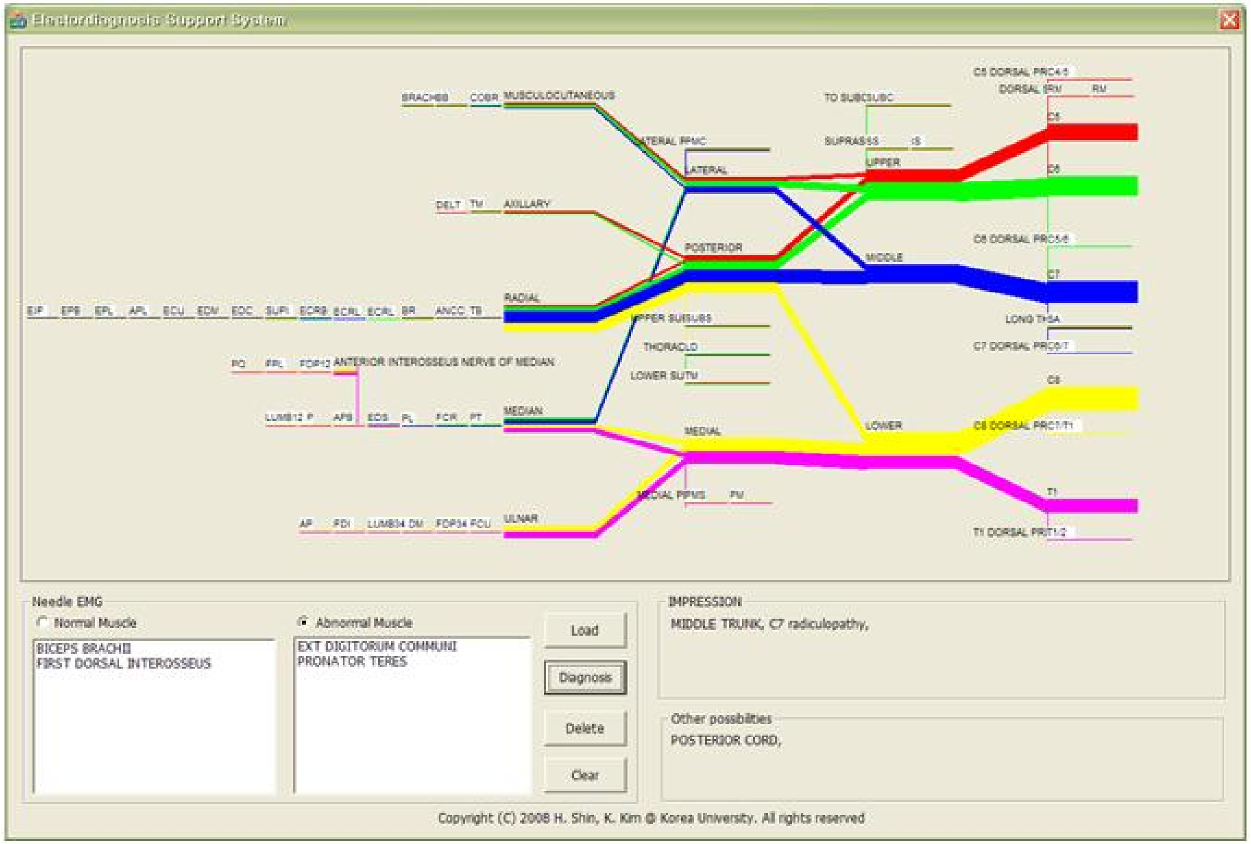

Figure 1. User interface of Electrodiagnosis Support System. Users can load input data file describing the neural structures using the “Load” button, and insert normal and abnormal findings. Users can obtain diagnosis results at any point in time during the inspection by clicking the “Diagnosis” button.

```
<HEADER>
<Name>Brachial Plexus</NAME>
<Muscle>Serratus anterior,Rhomboid major,Rhomboid minor,Supraspinatus,Infraspinatus
<Peripheral  nerve>Long thoracic,Dorsal scapular,Suprascapular,To subclavius,Upper
<Cord>Lateral,Posterior,Medial</Cord>
<Trunk>Upper,Middle,Lower</Trunk>
<Segments>C5,C6,C7,C8,T1</Segments>
</HEADER>
<CONTENTS>
<Muscle>        <Abbreviation>  <Peripheral  nerve>    <Cord>  <Trunk> <Segments>
Serratus anterior       SA      Long thoracic   NULL    NULL    C5
Serratus anterior       SA      Long thoracic   NULL    NULL    C6
Serratus anterior       SA      Long thoracic   NULL    NULL    C7
Rhomboid major  RM      Dorsal scapular NULL    NULL    C5
Rhomboid minor  Rm      Dorsal scapular NULL    NULL    C5
Supraspinatus   SS      Suprascapular   NULL    Upper   C5
Supraspinatus   SS      Suprascapular   NULL    Upper   C6
Infraspinatus   IS      Suprascapular   NULL    Upper   C5
Infraspinatus   IS      Suprascapular   NULL    Upper   C6
Subclavius      Subc    To subclavius   NULL    Upper   C5
Subclavius      Subc    To subclavius   NULL    Upper   C6
Subscapularis   Subs    Upper subscapular       Posterior       Upper   C5
Subscapularis   Subs    Upper subscapular       Posterior       Upper   C6
Latissimus dorsi        LD      Thoracodorsal   Posterior       Upper   C6
Latissimus dorsi        LD      Thoracodorsal   Posterior       Middle  C7
Latissimus dorsi        LD      Thoracodorsal   Posterior       Lower   C8
Teres major     TM      Lower subscapular       Posterior       Upper   C5
......
......
C7/T1 Paravertebral muscle      C7/T1   C8 dorsal primary ramus NULL    NULL    C8
T1/T2 Paravertebral muscle      T1/2    T1 dorsal primary ramus NULL    NULL    T1
</CONTENTS>
```

Figure 2. Input data file format. Part of the default input file provided with the system. The input file describes the neural structure of the brachial plexus, which is constructed based on the description of (Rubin and Safdieh, 2007).

	p.n.																cord			trunk			root				
	Anteri	Axillar	Dorsa	Dorsa	Latera	Long	Lower	Media	Media	Musc	Radial	Supra	Thora	To sul	Ulnar	Upper	Poster	Latera	Media	upper	middl	lower	c5	c6	c7	c8	t1
Abductor digiti minimi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	1	0	0	0	1	1
Abductor pollicis brevis	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	1	1
Abductor pollicis longus	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	1	1	0	0	1	1	0
Adductor pollicis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	1	0	0	0	1	1
Anconeus	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	1	1	0	0	1	1	0
Biceps brachii	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	1	0	0	1	1	0	0	0
Brachialis	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	1	0	0	1	1	0	0	0
Brachioradialis	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	1	0	0	1	1	0	0	0
C4/5 Paravertebral muscle	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
C5/6 Paravertebral muscle	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
C6/7 Paravertebral muscle	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
C7/T1 Paravertebral muscle	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Coracobrachialis	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	1	1	0	0	1	1	0	0
Deltoid	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	1	1	0	0	0
Ext carpi ulnaris	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	1	1	0	0	1	1	0
Ext digiti minimi	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	1	1	0	0	1	1	0
Ext digitorum communi	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	1	1	0	0	1	1	0
Ext indicis	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	1	1	0	0	1	1	0
Extensor carpi rad, brev	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	1	1	0	0	1	1	0	0
Extensor carpi rad, long	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	1	1	0	0	1	1	0	0
Extensor pollicis longus/bre	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	1	1	0	0	1	1	0
First dorsal interosseus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	1	0	0	0	1	1
Flexor carpi radialis	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	1	1	0	0	1	1	0	0
Flexor carpi ulnaris	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	1	0	0	0	1	1
Flexor digitorum profundus	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	1	1
Flexor digitorum profundus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	1	0	0	0	1	1
Flexor digitorum superficial	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	1	0	1	1	0	0	1	1	1
Flexor pollicis longus	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	1	1
Infraspinatus	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0
Latissimus dorsi	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	1	1	1	0	1	1	1	0
Lumbrical I/II	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	1	1
Lumbrical III/IV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	1	0	0	0	1	1
Opponens pollicis	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	1	1
Palmaris longus	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	1	0	1	1	0	0	1	1	1
Pectoralis major(clavicular)	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0	1	1	1	0	0
Pectoralis major(sternocost	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	1	1
Pectoralis minor	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	1	1
Pronator quadratus	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	1	1
Pronator teres	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	1	1	0	0	1	1	0	0
Rhomboid major/minor	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Serratus anterior	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0
Subclavius	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	1	1	0	0	0
Subscapularis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	0	0	1	1	0	0	0

Figure 3. Example of internal data structure. Once the input data file is loaded, ESS constructs the internal data structure shown above from the input file in order to represent the complex neural structures. This structure is not only used to visualize the brachial plexus graph in the user interface, but also to localize the injury sites. The rows and columns represent muscles and bundles, respectively. The order of each row and column reflects the clinical order in the neural system.