On Language and Connectionism: Analysis of a PDP Model

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- **Cognitive Theory: *Language: A* crucial *test* case.**
  - **Any alternative model that either eschews symbolic mechanisms altogether, or that is strongly shaped by the restrictive nature of available elementary information processes and unresponsive to the demands of the high-level functions being computed, starts off at a seeming disadvantage.**
  - **connectionism, as a radical restructuring of cognitive theory, will stand or fall depending on its ability to account for human language.**
- **Does knowledge of language consist of mentally-represented rules?**

Parallel Distributed Processing

- **Connectionist Distributed Computation**
- **Models suggested by**
  - **McClelland & Rumelhart , 1981**
  - **Feldman & Ballard , 1982**
- **"Connectionist " models , the hardware mechanisms are networks consisting of large numbers of densely interconnected units , which correspond to concepts**
- ***These units have activation levels and they transmit signals to one another along weighted connections***
- ***Units compute their output signals by comparing the weighted sum of their input signal strengths with a threshold***

- ***Learning consists of adjusting the weights of connections and the threshold values***
- ***Adjustments are made so as to reduce the discrepancy between an actual output in response to some input and a " desired" output provided by an independent set of " teaching " inputs***
- ***The pattern of activation of the output units corresponds to the output of the computation and can be fed into a subsequent network or into response effectors.***
- **A connectionist network does more than match input to output; it responds to regularities in the representation of the data and uses them to accomplish the mapping it is trained on and to generalize to new cases.**

Possible Scenarios for Connectionism

- Implementational connectionism
- Revisionist-symbol-processing connectionism
- Eliminative connectionism

Implementational connectionism

- PDP models occupies an intermediate level between symbol processing and neural hardware
- Neural networks serve as the building blocks of rules or algorithms
- PDP model may would compute the primitive symbol associations : e.g. matching an input against memory, or pairing the input and output of a rule
- Overall output of one network feeds into the input of another similar to the structure of the symbol manipulations captured in the statements of rules.
- In this scenario a well-defined division between rule and hardware would remain, each playing an indispensable role in the explanation of a cognitive process.

Revisionist-symbol-processing connectionism

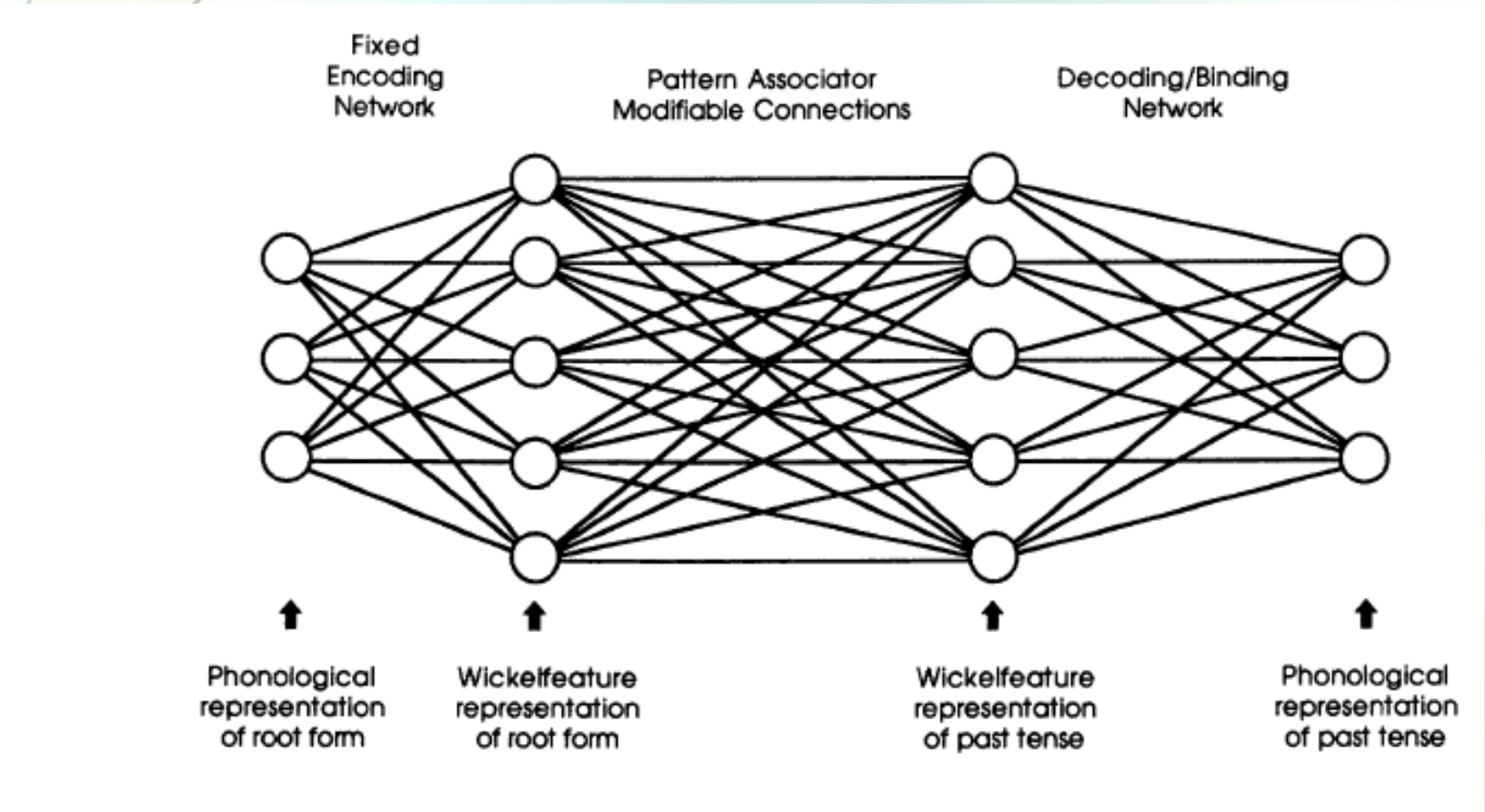
- Intermediate scenario
- PDP theory could lead to fundamental new discoveries about the character of symbol-processing, rather than implying that there was no such thing.
- The primitive information-processing operations made available by the connectionist architecture might force a theorist to posit a radically different set of symbols and operations, which in turn would make different predictions about the functions that could be computed and the patterns of breakdown observable during development, disease, or intermediate stages of processing

Eliminative connectionism

- **Most ambitious scenario**
- **Once fully developed, PDP models will replace symbol-processing models as explanations of cognitive processes.**
- **The entire operation of the model would have to be characterized not in terms of interactions among entities possessing both semantic and physical properties, but in terms of entities that had only physical properties.**
- **The symbolic model:**
  - **Would capture some of the regularities in the domain in an intuitive or easily-communicated way,**
  - **Might allow to make convenient approximate predictions (used as a heuristic).**
- **the symbolic model would not be a literal account at any level of analysis of what is going on in the brain, only an analogy or a rough summary of regularities**

Rumelhart - McClelland Model (1981)

- ***Rumelhart and McClelland*** **described a connectionist model of the acquisition of the past tense in English which successfully maps many stems onto their past tense forms**
- **Both regular (walk/walked) and irregular (go/went) verbs**
- **mimics some of the errors and sequences of development of children.**
- **The model contains no explicit rules**
- **The authors claim eliminative connectionism**



Rumelhart and McClelland, 1986b, p. 222,

Implementation Details of RM Model

- **Requirement: Each datum fed to a network must decompose into an unordered set of properties**
- **To overcome this use Wickelphones. Representing strings as trigrams.**
- **Certain trigram sets are consistent with more than one word, however the sample data does not contain any such words.**
- **Untrained pattern associater is a *"tabula rasa"* (blank slate)**
- **The RM net, following about 200 training cycles of 420 stem-past pairs (a total of about 80,000 trials) is able to produce correct past forms for the stems**
- **Any common property of the input data that participates in a frequently attested pattern of input/output relations will play a major role in the development of the network**

Assumptions of the RM model

These are the fundamental linguistic assumptions of the RM model:

- That the Wickelphone/ Wickelfeature provides an adequate basis for phonological generalization, circumventing the need to deal with strings.
- That the past tense is formed by direct modification of the phonetics of the root, so that there is no need to recognize a more abstract level of morphological structure.
- That the formation of strong (irregular) pasts is determined by purely phonetic considerations, so that there is no need to recognize the notion ' lexical item ' to serve as a locus of idiosyncrasy .
- That the regular system is qualitatively the same as the irregular, differing only in the number and uniformity of their populations of exemplars , so that it is appropriate to handle the whole stem/past relation in a single, indissoluble facility.

Immediate Reactions

- The model really does contain rules
- Past tense acquisition is an unrepresentatively easy problem
- There is some reason in principle why PDP models are incapable of being extended to language as a whole
- Rumelhart and McClelland are modeling performance and saying little about competence or are modeling implementation and saying little about algorithms

Goal of the paper

- To take the model at face value as a theory of the psychology of the child and examine the claims of the model in detail.
- Attempt to seek whether the RM model is viable as a theory of human language acquisition
- “There is no question that it is a valuable demonstration of some of the surprising things that PDP models are capable of”
- The concern is whether it is an accurate model of children

Problems in the Model

Analysis of the linguistic and the developmental assumptions of the model in detail reveal the following:

- Rumelhart and McClelland's actual explanation of children's stages of regularization of the past tense morpheme is demonstrably incorrect (pg.65)
  - Observations:
    - The U –shaped curve representing the over regularization of strong verbs whose regular pasts the child had previously used properly
    - The fact that verbs ending in t or d (e.g. hit) are regularized less often than other verbs
    - The order of acquisition of the different classes of irregular verbs manifesting different sub regularities
    - The appearance during the course of development of [past + ed] errors such as ated in addition to [stem + ed] errors such as eated .

Problems …

- Their explanation for one striking type of childhood speech error is also incorrect
  - Doubly marked words: ated
    - Reason for children making error: assumes wrong root
    - Reason for model making error: blending
- Their other apparent successes in accounting for developmental phenomena either have nothing to do with the model's parallel distributed processing architecture, and can easily be duplicated by symbolic models, or involve major confounds and hence do not provide clear support for the model

Problems …

- The model is incapable of representing certain kinds of words
  - E.g. unable to differentiate between forms of read [rid] and [rɛd]
  - Words with closed cyclic permutation. E.g. algal and algalgal
- It is incapable of explaining patterns of psychological similarity among words
  - E.g.: slit/silt ←no common trigrams
  - Wickelfeatures better than wickelphones
    - Both sil and sli are Voiceless-Voiced-Voiced
    - But bird and brid no common trigrams again.

Problems …

- It easily models many kinds of rules that are not found in any human language
  - Because of overgeneralization/ overfitting
  - Blending response: activation of two or more features to learn a possibly incorrect rule.
    - E.g. Meet →met, play →played ➔ flee →fled
    - Eat →ate, play →played ➔ ated
- It fails to capture central generalizations about English sound patterns
  - E.g. letter i is implicated in the spellings of both [ay] and [I]
    - wr*i*te –wr*i*tten, b*i*te – b*i*t, ign*i*te –ign*i*tion, sen*i*le-sen*i*lity, der*i*ve - der*i*vative
- It makes false predictions about derivational morphology, compounding, and novel words
- It cannot handle the elementary problem of homophony .
  - E.g.. Wring (wrung) and ring (ringed/rang) ← Identical Wickelfeatures

Problems …

- It makes errors in computing the past tense forms of a large percentage of the words it is tested on.
  - Blow, grow, know, fly?, slay?
- It fails to generate any past tense form at all for certain words.
- It makes incorrect predictions about the reality of the distinction between regular rules and exceptions in children and in languages.

Concluding remarks

- MLPs are tuning equivalent
  - However tuning computation is not “human”
- “Progress in PDP modeling would undoubtedly force revisions in traditional models, because traditional assumptions about primitive mechanisms may be neurally implausible, and complex chains of symbol manipulations may be obviated by unanticipated primitive computational powers of PDP networks”
- If a connectionist appeals to a more powerful PDP model of unspecified design it claims as little attention as the hypothetical consequences of a non-existent machine.
- A Successful PDP model of more complexity might be nothing more than an implementation of a symbolic rule-based account

Questions??

Thank You