Some Remarks on Machine Reading from the Logic-Based Perspective

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Remarks on RTE.
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One brief remark demo re our (PF)LbR foray.
TE has gem-like beauty, but with all due respect is stunningly naive in its rejection of relevant discoveries from a number of other fields (e.g., psychometrics, formal logic, psychology of reasoning, psychology of decision making, etc.) — for example in what it takes as its gold standard.

These discoveries should be exploited to the benefit of AI’s push toward bona fide machine reading.
\[ t \Rightarrow h \]
\{t_1, t_2, \ldots, t_n\} \Rightarrow h
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iff the vast majority of humans regard \( h \)
to be entailed by the text in question.
(Or some such anti-logicist thing.)
Alas, untenable.

\[ \{ t_1, t_2, \ldots, t_n \} \Rightarrow h \]

iff the vast majority of humans regard \( h \) to be entailed by the text in question. (Or some such anti-logicist thing.)
A Pair

\[ t \quad \text{It’s not true that if there’s a cat on the mat, Elizabeth will be jinxed.} \]

\[ h \quad \text{There’s a cat on the mat.} \]
If there is a king in the hand, there is an ace in the hand; or if there is not a king in the hand, there is an ace in the hand; but not both if-then statements are true.

\[ t \]

There is an ace in the hand.

\[ h \]
Everyone loves anyone who loves someone, and Alvin loves Bill.

$h$ Everyone loves Bill.
For the Standard, Set the Logical System
For the Standard, Set the Logical System

Set the inferential machinery:

\[ \{ t_1, t_2, \ldots, t_n \} \vdash_{M_C} h \]
For the Standard, Set the Logical System

Set the inferential machinery:

\[
\{t_1, t_2, \ldots, t_n\} \vdash_{\mathcal{M}}^{\mathcal{C}} h
\]

Set the interpretative semantics:

\[
\{t_1, t_2, \ldots, t_n\} \models_{\text{Sem}}^{\text{RecDef}} h
\]
For the Standard, Set the Logical System

Set the inferential machinery:
\[ \{t_1, t_2, \ldots, t_n\} \vdash^M_C h \]

Set the interpretative semantics:
\[ \{t_1, t_2, \ldots, t_n\} \models^{Sem}_{RecDef} h \]

Set the inferential semantics:
\[ \beta \cup \{\psi_1 \land \psi_2\} \vdash (\text{left-and } \psi_1 \land \psi_2) \rightarrow \psi_1 \]
For the Standard, Set the Logical System

Set the inferential machinery:
\[ \{t_1, t_2, \ldots, t_n\} \vdash^M_C h \]


Set the inferential semantics:
\[ \beta \cup \{\psi_1 \land \psi_2\} \vdash (\text{left-and} \ \psi_1 \land \psi_2) \rightarrow \psi_1 \]
Better
Better

\[ \{t_1, t_2, \ldots, t_n\} \Rightarrow h \]
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\[ \{ t_1, t_2, \ldots, t_n \} \Rightarrow h \]

iff, given precise settings for inference, interpretive semantics, and inferential semantics, there is a formally verified argument establishing
iff, given precise settings for inference, interpretive semantics, and inferential semantics, there is a formally verified argument establishing

\[ \{t_1, t_2, \ldots, t_n\} \Rightarrow h \]

\[ \{t_1, t_2, \ldots, t_n\} \vdash^M_C h \]
Given such gold standards, do e.g. RTE3 development pairs provably check out, and what do the proofs look like?
To experiment with this for RTE pilots, we’ve used Slate.
Hughes loved his wife, Gracia, and was absolutely obsessed with his little daughter Elicia.

We can deduce from the premise that Hughes loved his wife, Gracia. (This is just one of the two conjuncts in the premise, after all.) We know that if $x$ loved $y$, where $y$ is the wife of $x$, then $y$ was the wife of $x$. We can therefore deduce that Gracia was the wife of Hughes.
British mountaineer Alison Hargreaves becomes the first woman to climb Mount Everest alone and without oxygen tanks.

Alison Hargreaves is a woman

Alison Hargreaves climbed Everest alone.

Alison Hargreaves climbed Everest solo.

A woman succeeds in climbing Everest solo.

Proof:

Alison Hargreaves (who we can denote by 'a') has a number of attributes, according to the given proposition. For example, we can immediately deduce that a is a woman, and that a climbed Mount Everest (which we can denote by 'e') alone. Given that if x climbed y alone, x climbed y solo, we can deduce that a climbed e solo. Given as well that if x climbed y solo, x succeeds in climbing y solo, we can deduce that a succeeds in climbing e solo. By generalization, we can now deduce that there exists an x such that x is a woman, and x succeeds in climbing e solo. QED
Italian film-maker, Fellini was awarded an honorary Oscar for lifetime achievement. He died on October 31, 1993.

Fellini was a film-maker.

Fellini is Italian.

Fellini was awarded an honorary Oscar.

Fellini is a director.

Fellini is an Italian director awarded an honorary Oscar.

An Italian director is awarded an honorary Oscar.
Our (PF)LbR Work

(PF)LbR of visual content.

Just as we avoid getting bogged down in informal natural language to tackle AI problems in mathematics, (for now, anyway) we don’t want to get bogged down in informal natural language in tackling LbR.

Hence we use logically-controlled natural language.
Parallel and Perpendicular Lines

**LEARN ABOUT IT**

Parallel and perpendicular lines lead to angle relationships which engineers and others who use applied mathematics often use in their work.

**EXPLORE Discover a Relationship**
- Draw 2 lines, one on either side of a ruler.
- Draw a line that intersects both of these lines.
- Measure $\angle 1$ through $\angle 8$ using a protractor.
  Record the measures in a table.

**TALK ABOUT IT**

1. How does $m\angle 2$ compare to $m\angle 6$?
2. How does $m\angle 4$ compare to $m\angle 8$?
3. How does $m\angle 1$ compare to $m\angle 2$? to $m\angle 3$?

Two lines that intersect to form four right angles are called **perpendicular** lines.

Lines $a$ and $b$ are perpendicular. We write: $a \perp b$.

A line that intersects two other lines is called a **transversal**. The angles formed by parallel lines and a transversal are related in the following ways.

$m\angle 1 = m\angle 4 = m\angle 5 = m\angle 8$
$m\angle 2 = m\angle 3 = m\angle 6 = m\angle 7$
$m\angle 1 + m\angle 2 = 180^\circ$

**TRY IT OUT**

1. Which angles measure $45^\circ$?
2. What is the measure of $\angle 2$ of $\angle 7$?
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   to $m\angle 3$?

Two lines that intersect to form four right angles are called **perpendicular** lines.

- $a \perp b$
- Lines $a$ and $b$ are perpendicular.
- We write: $a \perp b$

Two lines in the same plane that do not intersect are **parallel** lines.

- Line $p$ is parallel to line $q$.
- We write $p \parallel q$

A line that intersects two other lines is called a **transversal**. The angles formed by parallel lines and a transversal are related in the following ways.

- $m\angle 1 = m\angle 4 = m\angle 5 = m\angle 8$
- $m\angle 2 = m\angle 3 = m\angle 6 = m\angle 7$
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TALK ABOUT IT

1. How does $\angle 2$ compare to $\angle 6$?
2. How does $\angle 4$ compare to $\angle 8$?
3. How does $\angle 1$ compare to $\angle 2$ to $\angle 3$?

Two lines that intersect to form four right angles are called perpendicular lines.

$\perp \angle a \perp \angle b$

We write: $a \perp b$

A line that intersects two other lines is called a transversal. The angles formed by parallel lines and a transversal are related in the following ways.

$m\angle 1 = m\angle 4 = m\angle 5 = m\angle 8$
$m\angle 2 = m\angle 3 = m\angle 6 = m\angle 7$
$m\angle 1 + m\angle 2 = 180^\circ$

TRY IT OUT

1. Which angles measure $45^\circ$?
2. What is the measure of $\angle 2$ of $\angle 7$?
Math Example #5 ("Parallel Lines")

I = (Θ, Δ)

Parallel and Perpendicular Lines

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EXPLORE Discover a Relationship
- Draw 2 lines, 1 on either side of a ruler.
- Draw a line that intersects both of these lines.
- Measure ∠1 through ∠8 using a protractor.
  Record the measures in a table.

TALK ABOUT IT

1. How does m∠2 compare to m∠6?
2. How does m∠4 compare to m∠8?
3. How does m∠1 compare to m∠2? to m∠3?

Two lines that intersect to form four right angles are called perpendicular lines.

\[ \alpha \perp \beta \]

We write: \( a \perp b \)

A line that intersects two other lines is called a transversal. The angles formed by parallel lines and a transversal are related in the following ways.

\[
\begin{align*}
m\angle 1 &= m\angle 4 = m\angle 5 = m\angle 8 \\
m\angle 2 &= m\angle 3 = m\angle 6 = m\angle 7 \\
m\angle 1 + m\angle 2 &= 180°
\end{align*}
\]

TRY IT OUT

1. Which angles measure 45°?
2. What is the measure of ∠2 of ∠7?
**I = (Θ, Δ)**

(Gr 7 Textbook)

---

**Parallel and Perpendicular Lines**

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**EXPLORE Discover a Relationship**

- Draw 2 lines, 1 on either side of a ruler.
- Draw a line that intersects both of these lines.
- Measure ∠1 through ∠8 using a protractor.
  - Record the measures in a table.

**TALK ABOUT IT**

1. How does m∠2 compare to m∠6?
2. How does m∠4 compare to m∠8?
3. How does m∠1 compare to m∠2?
   - to m∠3?

Two lines that intersect to form four right angles are called **perpendicular** lines.

\[\begin{align*}
\text{If } a \perp b, \text{ then } m\angle 90^\circ.
\end{align*}\]

We write: \(a \perp b\)

A line that intersects two other lines is called a **transversal**. The angles formed by parallel lines and a transversal are related in the following ways.

- \(m\angle 1 = m\angle 4 = m\angle 5 = m\angle 8\)
- \(m\angle 2 = m\angle 3 = m\angle 6 = m\angle 7\)
- \(m\angle 1 + m\angle 2 = 180^\circ\)

**TRY IT OUT**

1. Which angles measure 45°?
2. What is the measure of \(\angle 2\) of \(\angle 7\)?

---

**Q1**

**Q2**
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3. How does $m\angle 1$ compare to $m\angle 2$ to $m\angle 3$?

Two lines that intersect to form four right angles are called **perpendicular** lines.

\[ \begin{align*}
\alpha & \quad \text{Lines } a \text{ and } b \text{ are perpendicular.} \\
\angle 1 = \angle 2 = \angle 3 = \angle 4 & \quad \text{We write: } a \perp b \\
\angle 5 = \angle 6 = \angle 7 = \angle 8 & \quad \end{align*} \]

A line that intersects two other lines is called a **transversal**. The angles formed by parallel lines and a transversal are related in the following ways.

\[ \begin{align*}
m\angle 1 = m\angle 4 = m\angle 3 = m\angle 5 \\
m\angle 2 = m\angle 3 = m\angle 6 = m\angle 7 \\
m\angle 1 + m\angle 2 = 180^\circ \]

**TRY IT OUT**

1. Which angles measure $45^\circ$?
2. What is the measure of $\angle 2$ of $\angle 7$?
Math Example #5 ("Parallel Lines")

I = (Θ, Δ)
(Gr 7 Textbook)

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TALK ABOUT IT

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3. How does m∠1 compare to m∠2?
   to m∠3?

Two lines that intersect to form four right angles are called perpendicular lines.

\[ \begin{align*}
\angle a & \perp \angle b \\
\text{We write: } & \quad a \perp b
\end{align*} \]

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- m∠1 = m∠4 = m∠5 = m∠8
- m∠2 = m∠3 = m∠6 = m∠7
- m∠1 + m∠2 = 180°

TRY IT OUT

1. Which angles measure 45°?
2. What is the measure of ∠2° of ∠7°?
Math Example #5 ("Parallel Lines")

$I = (\Theta, \Delta)$

(Gr 7 Textbook)

Parallel and Perpendicular Lines

**LEARN ABOUT IT**

Parallel and perpendicular lines lead to angle relationships which engineers and others who use applied mathematics often use in their work.

**EXPLORE** Discover a Relationship

- Draw 2 lines, 1 on either side of a ruler.
- Draw a line that intersects both of these lines.
- Measure \( \angle 1 \) through \( \angle 8 \) using a protractor. Record the measures in a table.

**TALK ABOUT IT**

1. How does \( m\angle 2 \) compare to \( m\angle 6 \)?
2. How does \( m\angle 4 \) compare to \( m\angle 8 \)?
3. How does \( m\angle 1 \) compare to \( m\angle 2 \) to \( m\angle 3 \)?

Two lines that intersect to form four right angles are called *perpendicular* lines.

- Lines \( a \) and \( b \) are perpendicular.
- We write: \( a \perp b \)

\[
\begin{align*}
\angle 1 &= 90^\circ \\
\angle 2 &= 90^\circ \\
\angle 3 &= 90^\circ \\
\angle 4 &= 90^\circ \\
\angle 5 &= 90^\circ \\
\angle 6 &= 90^\circ \\
\angle 7 &= 90^\circ \\
\angle 8 &= 90^\circ 
\end{align*}
\]

A line that intersects two other lines is called a *transversal*. The angles formed by parallel lines and a transversal are related in the following ways.

- \( m\angle 1 = m\angle 4 = m\angle 5 = m\angle 8 \)
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- \( m\angle 1 + m\angle 2 = 180^\circ \)

**TRY IT OUT**

1. Which angles measure \( 45^\circ \)?
2. What is the measure of \( \angle 2 \) of \( \angle 7 \)?
Math Example #5 ("Parallel Lines")

**I = (Θ, Δ)**

(Gr 7 Textbook)

**Parallel and Perpendicular Lines**

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**EXPLORE Discover a Relationship**

- Draw 2 lines, 1 on either side of a ruler.
- Draw a line that intersects both of these lines.
- Measure 1 through 8 using a protractor. Record the measures in a table.

**TALK ABOUT IT**

1. How does m∠2 compare to m∠6?
2. How does m∠4 compare to m∠8?
3. How does m∠1 compare to m∠7?
   to m∠3?

Two lines that intersect to form four right angles are called **perpendicular** lines.

\[ \theta = 90° \]

We write: \( a \perp b \)

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\[
\begin{align*}
m∠1 &= m∠4 = m∠5 = m∠8 \\
m∠2 &= m∠3 = m∠6 = m∠7 \\
m∠1 + m∠2 &= 180°
\end{align*}
\]

**TRY IT OUT**

1. Which angles measure 45°?
2. What is the measure of \( \angle 2 \) of \( \angle 7 \)?

---

**Query Q (TIMSS M8 2003)**

In this figure, \( PQ \) and \( RS \) are parallel.

Of the following, which pair of angles has the sum of 180°?

- (A) \( \angle 3 \) and \( \angle 7 \)
- (B) \( \angle 3 \) and \( \angle 8 \)
- (C) \( \angle 1 \) and \( \angle 5 \)
- (D) \( \angle 1 \) and \( \angle 7 \)
- (E) \( \angle 2 \) and \( \angle 8 \)
Math Example #5 ("Parallel Lines")

\[ I = (\Theta, \Delta) \]

(Gr 7 Textbook)

Parallel and Perpendicular Lines

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**EXPLORE** Discover a Relationship

- Draw 2 lines, 1 on either side of a ruler.
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\[
\begin{align*}
\angle a & \quad \text{Lines } a \text{ and } b \text{ are perpendicular.} \\
90^\circ & \\
\angle b & \quad \text{We write: } a \perp b
\end{align*}
\]

A line that intersects two other lines is called a **transversal**. The angles formed by parallel lines and a transversal are related in the following ways.

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\begin{align*}
\angle 1 &= \angle 4 = \angle 5 = \angle 8 \\
\angle 2 &= \angle 3 = \angle 6 = \angle 7 \\
\angle 1 + \angle 2 &= 180^\circ
\end{align*}
\]

**TRY IT OUT**

1. Which angles measure \( 45^\circ \)?
2. What is the measure of \( \angle 2 \) of \( \angle 7 \)?

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**Query Q**

(TIMSS M8 2003)

In this figure, \( PQ \) and \( RS \) are parallel.

Of the following, which pair of angles has the sum of \( 180^\circ \)?

- (A) \( \angle 3 \) and \( \angle 7 \)
- (B) \( \angle 3 \) and \( \angle 6 \)
- (C) \( \angle 1 \) and \( \angle 5 \)
- (D) \( \angle 3 \) and \( \angle 7 \)
- (E) \( \angle 3 \) and \( \angle 8 \)
**Math Example #5 ("Parallel Lines")**

\[ I = (\Theta, \Delta) \]

**(Gr 7 Textbook)**

**Parallel and Perpendicular Lines**

**LEARN ABOUT IT**

Parallel and perpendicular lines lead to angle relationships which engineers and others who use applied mathematics often use in their work.

**EXPLORE: Discover a Relationship**

- Draw 2 lines, one on either side of a ruler.
- Draw a line that intersects both of these lines.
- Measure \( \angle 1 \) through \( \angle 8 \) using a protractor. Record the measures in a table.

**TALK ABOUT IT**

1. How does \( m\angle 2 \) compare to \( m\angle 6 \)?
2. How does \( m\angle 4 \) compare to \( m\angle 8 \)?
3. How does \( m\angle 1 \) compare to \( m\angle 2 \) to \( m\angle 3 \)?

Two lines that intersect to form four right angles are called **perpendicular** lines.

\[
\begin{align*}
\angle a & = \angle b \\
90^\circ & = 90^\circ \\
\angle c & = \angle d
\end{align*}
\]

We write: \( a \perp b \)

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**Query Q**

(TIMSS M8 2003)

In this figure, \( PQ \) and \( RS \) are parallel.

**Options**

- (A) \( \angle 3 \) and \( \angle 7 \)
- (B) \( \angle 3 \) and \( \angle 6 \)
- (C) \( \angle 1 \) and \( \angle 5 \)
- (D) \( \angle 1 \) and \( \angle 7 \)
- (E) \( \angle 2 \) and \( \angle 8 \)

**Answer**

\( O = (J, A) \)
A TIMSS Problem in Slate

Slate leverages the power of Solomon to read both text and diagrams allowing for integrated problem solving.

Selmer Bringsjord
Micah Clark
Andrew Shilliday
Joshua Taylor

03.26.2007
Bringing Text into Slate

The Dreadsbury Mansion Mystery, described in Attepto Controled English (ACE) is automatically parsed into Slate, where it is then solved.

Selmer Bringsjord
Micah Clark
Andrew Shilliday
Joshua Taylor

March 7, 2007