

# Supplemental Material for EMNLP 2018 Paper: Summarizing Opinions: Aspect Extraction Meets Sentiment Prediction and They Are Both Weakly Supervised

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## A OPOSUM Aspect Statistics

Table 7 shows product aspects and the number of segments that discuss these aspects in the human-annotated portion of the OPOSUM dataset.

## B Additional Results

**Aspect Clusters** For completeness, we also evaluated our aspect extraction system using two standard clustering measures that quantify the quality of the induced clusters. An *aspect cluster* contains segments whose most probable aspect, according to a system, is the same. *Purity* measures the extent to which a cluster contains segments primarily from one aspect. Larger purity values indicate better performance. The *entropy* measure considers how the various aspects are distributed within each predicted cluster of segments. Smaller values of entropy indicate better performance. For formal definitions, see (Zhao and Karypis, 2005). Table 8 presents the results.

**Per-domain Summarization Results** In the paper we present ROUGE scores averaged across domains. Table 9 shows how systems compare in each domain individually.

**Effect of Parameters** We illustrate the effect of the number of seeds per aspect for various system configurations. Figure 3 shows aspect extraction performance for  $ABAE_{init}$ , MATE without multi-tasking, and MATE with multitasking (two settings for  $\lambda$ ). Figure 4 compares the opinion salience rankings obtained by the same systems using Equation (12) in the paper. Figure 5 shows the quality of the systems’ summaries.

Figure 6 compares the variant of MATE presented in the paper, i.e., with fixed seed weights  $\mathbf{z}_i$  for the seeds of aspect  $a_i$ , against one that uses dynamic weights computed for every input segment

Laptop Bags	# EDUs	B/T Headsets	# EDUs
General	608	General	669
Size/Fit	196	Sound	209
Quality	170	Comfort	175
Looks	100	Ease of use	93
Compartments	69	Connectivity	81
Handles	65	Durability	65
Protection	51	Battery	58
Price	48	Price	39
Customer Serv.	24	Look	14

Boots	# EDUs	Keyboards	# EDUs
General	566	General	773
Comfort	234	Feel/Comfort	140
Size	129	Layout	124
Look	94	Build Quality	118
Materials	87	Extra function.	79
Durability	69	Connectivity	74
Weather Resist.	59	Price	54
Price	26	Noise	47
Color	25	Looks	36

Televisions	# EDUs	Vacuums	# EDUs
General	803	General	803
Image	187	Accessories	192
Sound	162	Ease of use	165
Connectivity	106	Suction Power	135
Customer Serv.	77	Build Quality	98
Ease of use	75	Noise	61
Price	63	Weight	49
Apps/Interface	48	Customer Serv.	46
Size/Look	45	Price	32

Table 7: Aspects and their segment frequency in OPOSUM’s human-annotated subset.

$s$  individually, based on its encoding cosine similarity with seed word embedding  $\mathbf{a}_{ij}$ :

$$z_{ij} = \frac{e^{\cos(\mathbf{v}_s, \mathbf{a}_{ij})}}{\sum_j e^{\cos(\mathbf{v}_s, \mathbf{a}_{ij})}}. \quad (13)$$

## C System Outputs

Tables 10–15 show summaries produced by a human annotator and 5 automatic summarizers; our best performing method, the *lead* baseline, *Sum-Basic*, *LexRank*, and *Opinosis*.

Aspect Extraction (Purity / Entropy)							
	L. Bags	B/T H/S	Boots	Keyb/s	TVs	Vac/s	AVG
Majority	45.7 / 78.1	47.7 / 75.6	43.9 / 78.6	53.5 / 73.4	51.3 / 74.9	50.8 / 74.3	48.8 / 75.8
ABAE	48.0 / 72.3	48.5 / 70.8	44.3 / 75.4	54.1 / 70.0	51.5 / 72.3	51.0 / 72.0	49.6 / 71.2
ABAE <sub>init</sub>	53.4 / 54.5	61.1 / 52.8	52.5 / 58.5	<b>56.9 / 55.2</b>	58.6 / 52.8	53.2 / 57.0	56.0 / 55.1
MATE	56.4 / 52.4	63.0 / 50.6	<b>54.5 / 57.0</b>	56.5 / <b>54.2</b>	60.6 / 50.8	54.7 / 56.3	<b>57.6 / 53.6</b>
MATE+MT	<b>56.5 / 52.2</b>	<b>63.1 / 50.2</b>	52.6 / 58.7	55.0 / 56.0	<b>60.9 / 50.7</b>	<b>54.9 / 55.5</b>	57.2 / 53.9

Table 8: Performance of aspect extraction systems according to clustering measures *Purity* and *Entropy*.

Summarization (ROUGE-1 / ROUGE-2 / ROUGE-L)							
	L. Bags	B/T H/S	Boots	Keyb/s	TVs	Vac/s	
Random	34.5 / 10.4 / 33.8	36.6 / 13.0 / 35.7	37.7 / 13.3 / 36.9	34.1 / 10.4 / 33.4	32.0 / 09.5 / 31.2	35.6 / 11.4 / 34.9	
Lead	36.9 / 15.5 / 36.2	33.3 / 12.3 / 32.5	39.9 / 19.1 / 39.4	35.8 / 17.6 / 35.1	35.2 / 15.6 / 34.6	31.6 / 11.3 / 30.8	
SumBasic	37.1 / 14.3 / 35.8	34.4 / 12.2 / 33.5	34.9 / 11.3 / 33.2	31.6 / 08.2 / 30.0	30.9 / 10.3 / 29.4	35.3 / 10.6 / 33.6	
LexRank	34.9 / 12.0 / 34.1	40.3 / 16.3 / 39.3	39.3 / 16.0 / 38.5	33.9 / 09.9 / 32.7	37.2 / 13.9 / 35.7	40.3 / 16.6 / 39.0	
Opinosis	32.6 / 09.4 / 31.5	39.7 / 18.7 / 39.0	42.1 / 21.1 / 41.1	34.3 / 11.0 / 33.3	34.1 / 12.9 / 32.7	38.0 / 12.7 / 36.6	
Opinosis+MATE+MT	34.1 / 10.7 / 32.7	42.3 / 19.4 / 41.2	42.7 / 20.3 / 41.6	35.3 / 12.1 / 34.3	36.0 / 13.9 / 34.4	41.7 / 18.0 / 40.4	
MILNET+MATE+MT	44.0 / 23.0 / 43.2	47.1 / <b>26.1</b> / 46.6	43.5 / 21.1 / 42.6	40.9 / 19.1 / 40.0	38.5 / <b>15.9</b> / 37.5	47.3 / 25.0 / 46.8	
MILNET+MATE+MT+RD	<b>44.7 / 23.3 / 44.0</b>	<b>47.8 / 25.7 / 47.2</b>	<b>43.9 / 21.3 / 42.9</b>	<b>41.7 / 19.7 / 40.8</b>	<b>38.6 / 15.6 / 37.6</b>	<b>47.6 / 25.2 / 47.2</b>	

Table 9: Summarization results for different product domains.

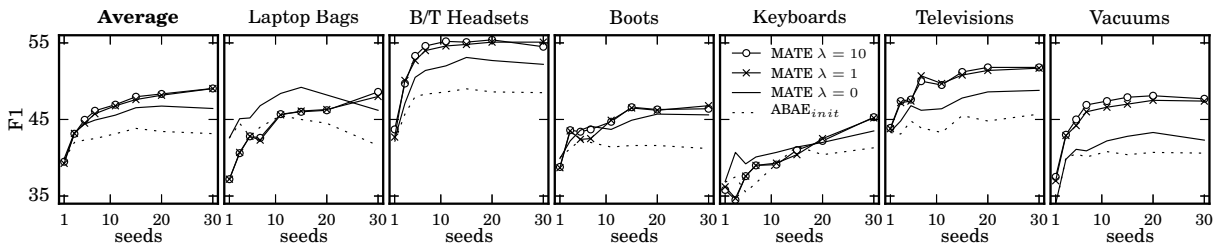


Figure 3: Aspect extraction F1 scores for ABAE<sub>init</sub> and MATE without ( $\lambda = 0$ ) and with multi-tasking ( $\lambda = 1, 10$ ).

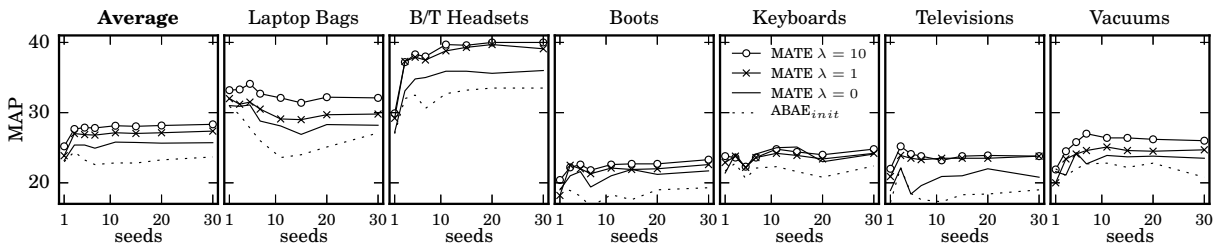


Figure 4: Saliency ranking MAP scores for ABAE<sub>init</sub> and MATE without ( $\lambda = 0$ ) and with multi-tasking ( $\lambda = 1, 10$ ).

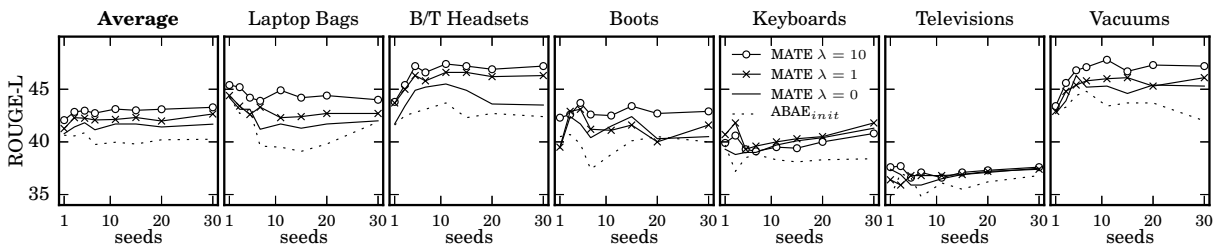


Figure 5: Summarization ROUGE-L scores for ABAE<sub>init</sub> and MATE without ( $\lambda = 0$ ) and with multi-tasking ( $\lambda = 1, 10$ ).

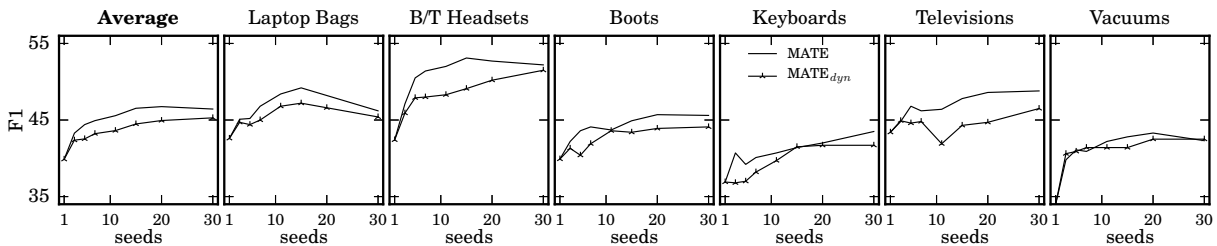


Figure 6: Aspect extraction F1 scores for MATE with fixed seed weights and with dynamic cosine-based weights (*dyn*).

<b>Product domain:</b> Laptop Bags <b>Product name:</b> 14.1 inch Purple Diamond Quilted Pattern Notebook Sleeve	
Human	<p>This bag might look nice,  Has good protection on the inside for the lap top  It is very well built,  The price was good,  It is lightweight.  Love the color.  Poor quality.  Then there was the overpowering chemical smell  Materials are cheap, stitches along the borders are not very secure. barely fit a 14 inch hp sleek notebook.  Does not worth 25 \$.</p>
This work	<p>Has good protection on the inside for the lap top  Very fast shipping.  It has two pockets, one for the laptop itself and then one for other things such as folders or a planner.  It is wonderful.  It looks great  the material has good quality  Also it has cellphone and pens compartments  and it fits my 14 inch Toshiba perfectly.  and holds the cords, my mouse and a mouse pad.  Love the color.  Poor quality.  The strap broke after only 3 months,  This bag does not fit my laptop.</p>
Lead	<p>Poor quality.  This bag might look nice,  My handle has already started to rip.  Very fast shipping.  Looks very good, very professional, fashionable.  This bag does not fit my laptop.  I recently purchased my first mac for college  I purchased this for work,  Love the bag, protects my lap top perfectly!  The price was good,  The " quilted  but it is of terrible quality.  It looks similar to a lap top bag not a purse  Materials are cheap, stitches along the borders are not very secure. barely fit a 14 inch hp sleek notebook.  Material is way to cheap</p>
SumBasic	<p>! The price was good,  and it fits my 14 inch Toshiba perfectly. It looks good  and holds the cords, my mouse and a mouse pad.  It is lightweight. It does come with a shoulder strap. I picked this bag  because it had cushioning on the inside for extra protection. The only thing  I would have liked  is an outside pocket.  But that is minor.  Love the color.  This would be more of a personal laptop bag Love the bag, protects my lap top perfectly!</p>
LexRank	<p>When I saw this bag  that comes with this bag.  I can fit in the bag.  This bag does not fit my laptop.  I definitely recommend this bag!!!  I would not recommend this bag.  This bag might look nice,  and the little bag for the laptop cables is big enough  Who wants a laptop case  this bag is big enough to carry it as well.  This would be more of a personal laptop bag  that I put too much weight in the bag.  Love the bag, protects my lap top perfectly!</p>
Opinosis	<p>for the laptop itself and then one for other things such as folders or a planner and a planner.  case, glasses case, the little white bag, my speakers, and my wallet.  the laptop, and a few folders, the bag looks and closes nice.  i won't recommend it if you will use it everyday or for traveling.  this bag is big enough to carry it as well.  the bag is lovely and true to the pic.  my laptop's pink case, pink speakers and pink keyboard cover (3.  materials are cheap, stitches along the borders are not very secure.</p>

Table 10: System outputs for a product in the *Laptop Bags* domain.

<b>Product domain:</b> Bluetooth Headsets <b>Product name:</b> Samsung HM1300 Bluetooth Headset	
Human	<p>The fit is excellent.  easy pairing and good clear sound.  The battery is pretty good as well.  Controls are simple and easy to learn,  and the price is very reasonable.  The calls were not all that clear and callers complained of hearing feedback  and not being able to hear me well on the call.  hurt my ear  However, the ear piece hook broke very easily after about a week wearing.</p>
This work	<p>This model had the most vibrant color  The fit is excellent.  Feels great in my ear.  The controls are simple and easy to manipulate  The battery is pretty good as well.  It connects quickly to any device  It is easy to connect with my phone  and has sufficient volume  and the price is very reasonable.  It doesn't have crystal clear sound,  and there are no instructions on how to install them.  I'm going back to the Plantronics M50  but the sound is horrible.  No matter how high you turn it up, you can barely hear anything</p>
Lead	<p>I gave this headset a try  I really liked the color of this bluetooth.  No matter how high you turn it up, you can barely hear anything  Let's be honest,  The price is right for sure.  In terms of function it works  I have to say  I bought this product as a gift  I have been very pleased with this headset.  Works AMAZINGLY.  because it's made by Samsung.  I bought all three models, HM1900, HM1700 and the HM1300.  being said,  it's cheap,  The call recipients on the other hand can hear me fine,  just as promised -</p>
SumBasic	<p>I would buy it again I have to say  that am very happy with this bluetooth.  For the price of this device, is pretty good. It doesn't have crystal clear sound,  but it's pretty decent for the price  and what I use it for. The battery is pretty good as well. I would recommend this device to any one  who is just looking for a basic bluetooth. I bought this product as a gift  and they say  they love it! It connects quickly to any device  and it is recognized very quickly.</p>
LexRank	<p>that goes around the ear  For the price of this device, is pretty good.  It seems hard to get a good fit in the ear.  hard to hear,  The calls from him are clear and not as much background noise  The ear piece  Anyway, the device is small  easy pairing and good clear sound.  as I expected and has volume control on the actual device  It connects quickly to any device  I would recommend this device to any one  but it's pretty decent for the price</p>
Opinosis	<p>callers complained of hearing feedback and not being able to hear me well on the call.  the ear piece hook broke very easily after about a week wearing.  it has been 2 weeks since using the spare and so far so good.  also, it does not seem to automatically link up with my samsung galaxy s4.  controls are simple and easy to learn.  for the price of this device, is pretty good.  no matter how high you turn it up, you can barely hear anything.  the call recipients on the other hand can hear me fine.</p>

Table 11: System outputs for a product in the *Bluetooth Headsets* domain.

<b>Product domain:</b> Boots	
<b>Product name:</b> Minnetonka Women's Double Fringe Side Zip Boot	
Human	<p>They are awesome looking Well made and just something different to wear. The colour is beautiful the attention to detail is great! So well made so very comfortable! They do not fit well, are horribly uncomfortable and make a squeaky noise no matter what type of floor you are walking on. The seam on the top of the foot sits too low and rubs against the top of the foot. These were very narrow. They are too big even with heavy socks,</p>
This work	<p>They are awesome looking I'd recommend these any day Love the style and taupe color is perfect. I love wearing them with skinny jeans or with tights and a dress. the attention to detail is great! So well made so very comfortable! I love the colour plum as other reviewers have pointed out : Narrow. They have stretched a little, but maybe get a size or half size up They do not fit well, are horribly uncomfortable Not worth it to me. but not good for an every day use. dont waste your money on these,</p>
Lead	<p>I hate these. The seam on the top of the foot sits too low and rubs against the top of the foot. These were very narrow. I was super excited to get these I ordered these in a 7?1/2 I wanted a true purple boot, Love the style and taupe color is perfect. I was looking for something comfy These boots are really cute and great quality. Minnetonka makes the best moccasins They do not fit well, are horribly uncomfortable Tried multiple sizes and they all had the same seam issue. Will have to return them.</p>
SumBasic	<p>These were very narrow. Will have to return them. Was sad that my 10 year old granddaughter's Christmas gift was a bust. Such a beautiful moccasin but a shame they didn't seem true to size. I was super excited to get these but after on the second day of use one of the metal buttons above the fringe broke off AND the zipper's leather tassel came undone, when I tried to tie it back it would stay tied as well. The shoe its self is stylish, but not good for an every day use.</p>
LexRank	<p>I used to be a big fan of Minnetonka They are too big even with heavy socks, but sent them back because too big. and I do love them. I really love Great buy - love Minnetonka! these boots are very nice, well made, the bottom tread is cut to this narrow width. They are a comfortable fit on width, but a little long in length. the sizing issue doesn't give me any problems Tried multiple sizes and they all had the same seam issue. even though they are too big though - but they are still too big.</p>
Opinosis	<p>the top of the foot sits too low and rubs against the top of the foot. i didn't want to send back and wait more time to get them again. and make a squeaky noise no matter what type of floor you are walking on. they are a comfortable fit on width and too big even with heavy socks. a beautiful moccasin but a shame they didn't seem true to size. and rested some heavy books on top of them for a few days. the fringe was all crazy and going in every which direction.</p>

Table 12: System outputs for a product in the *Boots* domain.

<b>Product domain:</b> Keyboards	
<b>Product name:</b> Anyware Computers Full Size Multimedia USB Lighted Keyboard	
Human	<p>This keyboard looks very sleek  This is a pretty good keyboard for the price.  The illumination of the keys is perfect.  They're not too bright or too dim.  This keyboard is nice and bright, plug and play and easy to use.  It has a variety of other useful function buttons including volume buttons for the sound.  Also the location of some of the important keys are in odd places.  Even the space bar is tiny.  The keyboard also feels flimsy when typing on it.  This is NOT a " full sized " standard keyboard.</p>
This work	<p>This keyboard looks very sleek  The illumination of the keys is perfect.  This keyboard is nice and bright, plug and play and easy to use.  It has a variety of other useful function buttons including volume buttons for the sound.  because I like to surf the web right before go to sleep  Even though I can type  I like the blue LED color.  You can also turn the lights on and off.  Great product at a good price.  The blue lit keyboard is the best looking  the backspace button was a little larger...  What a waste of time and money.</p>
Lead	<p>A full size keyboard should not cause even the biggest guy  I bought this for a customer,  Dad wanted a keyboard  This keyboard looks very sleek  This is a pretty good keyboard for the price.  The illumination of the keys is perfect.  This keyboard is nice and bright, plug and play and easy to use.  The keys are a little clackety for my taste  I purchased this keyboard  Great product at a good price.  to feel ' fat fingered '.  and  he could see at night  and I love the lit keys.  The backlit keys look great</p>
SumBasic	<p>Haha. But for the price you are getting a great product  and I would recommend it to anyone  looking for a backlit keyboard. Great product at a good price. I'm always  missing it! Works as described. I would recommend it to anyone  looking for a product such as this. The blue lit keyboard is the best looking  that I have seen. I guess  I just wish  the backspace button was a little larger...  I mean what good is a keyboard  if some of the keys don't work????</p>
LexRank	<p>but it feels a little smaller than a full size.  I definitely would not recommend this for gaming or a lot of typing.  it's smaller size  and the backspace key is very small, the same size as the letter keys.  A full size keyboard should not cause even the biggest guy  like the size is between a full size keyboard and a laptop computer.  it's a full size keyboard,  and cut the size of the back/delete key.  Great product at a good price.  This is NOT a "" full sized "" standard keyboard.</p>
Opinosis	<p>the keys are noisy and a little clackety for my taste.  the key is very small, the same size as the letter keys and the keys.  the half-sized delete key with the home button right next to it is particularly egregious.  a little smaller than other keyboards but not significantly so, a full size and on most boards.  i definitely would not recommend this for gaming or a lot of and typing.  this keyboard and bright, plug and play and easy to use.  like the size is between a full size keyboard and a laptop computer.</p>

Table 13: System outputs for a product in the *Keyboards* domain.

<b>Product domain:</b> Televisions	
<b>Product name:</b> Sony BRAVIA KDL46EX523 46-Inch Integrated WiFi 1080p LED HDTV	
Human	<p>Plenty of ports and settings            Easy hookups to audio and satellite sources.            The sound is good and strong.            This TV looks very good            and the price is even better.            The on-screen menu/options is quite nice            and the internet apps work as expected.            The picture is clear and sharp.            the wireless connectivity is 802. 11b...            which is TOO SLOW to stream HD video...            The software and apps built into this TV            are difficult to use and setup            Their service is handled off shore making communication a bit difficult. : (</p>
This work	<p>Plenty of ports and settings            and have been extremely happy with it.            What I like best are the many ports - 4 hdmi, 1 component, 1 composite and 1 USB.            The sound is good and strong.            The picture is beautiful.            Also you can play movies from your computer thru the DLNA,            and the price is even better.            Unbelievable picture and the setup is so easy.            wow look at the color, look at the sharpness of the picture, amazing.            The picture is clear and sharp.            the Yahoo! widgets do not work,            and avoid the Sony apps at all costs.</p>
Lead	<p>I am very disappointed with this TV for two reasons : picture brightness and channel menu.            DO NOT BUY! this SONY Bravia ' Smart ' TV..            Unit developed a high pitch whine            Picture quality great,            Picture is crisp and clear with lots of options            A nice quality TV in the usual Sony tradition.            I have owned this television for almost a year            This TV looks very good            Unbelievable picture and the setup is so easy.            The TV in my office finally died            The picture looked dull and not bright at all even compared to my 6-year old Sony LCD TV.</p>
SumBasic	<p>DO NOT BUY! The picture is clear and sharp. The sound is clear as well. It is WiFi enabled            which was a            must have for me            but boy did I under estimate            what I was getting with that. Let's just say            there is a dedicated button on the remote            for accessing Netflix,            how cool is that. I just do not have enough time            to list all of the amazing features in this review.            But the numbers of options available in the on-line area of the Tv are numerous and extremely useful!</p>
LexRank	<p>Get a Roku or Netflix box            I watch cable, Netflix, Hulu Plus, YouTube videos and computer movie files on it.            Sound is good much better            DO NOT BUY! this SONY Bravia ' Smart ' TV..            and avoid the Sony apps at all costs.            Because of these two issues, I returned the Sony TV            Also you can change the display and sound settings on each port.            However, the streaming speed for netflix is just down right terrible. most of the time I just quit            since I do not own the cable box,            So, I have the cable</p>
Opinosis	<p>the picture and not bright at all even compared to my 6-year old sony lcd tv.            it will not work with an hdmi connection because of a conflict with comcast's dhcp.            being generous because i usually like the design and attention to detail of sony products).            i am very disappointed with this tv for two reasons : picture brightness and channel menu.            numbers of options available in the on-line area of the tv are numerous and extremely useful.            wow look at the color, look at the sharpness of the picture, amazing and the amazing.</p>

Table 14: System outputs for a product in the *Televisions* domain.

<b>Product domain:</b> Vacuums	
<b>Product name:</b> Hoover WindTunnel Air Steerable Upright Vacuum	
Human	<p>and the vacuum is lightweight and maneuvers nicely.  It has good suction  The way the attachments work is very clever and efficient.  Cleans great  Its well built,  It is an exceptional value for the price.  The filtration system is wonderful,  it doesn't suck well on carpets  The brush needs to be cleaned out almost every time  The vacuum recently overheated and the motor stopped working.  However, it's very heavy.  And it's not very steerable.  The cord is very short.  the hose is messy  It only comes with a single narrow attachment.</p>
This work	<p>The way the attachments work is very clever and efficient.  I also like the way you can easily turn on or off the brush roller  Cleans great  We have two small dogs  The suction on this vacuum is very strong.  It is light weight and easy to maneuver.  It is an exceptional value for the price.  Effortless maneuvering with the twist of a wrist.  Extremely powerful suction picked up anything in it's way.  the brush roller would not turn on anymore.  except that hair never gets in the dust bin</p>
Lead	<p>I bought this vacuum cleaner from Best Buy in December  This vacuum was good for the first few months  I'm very disappointed.  I was happy with this vacuum for the most part  Cleans great  I did a lot of research  Very good vacuum for the price.  I have had this vacuum for 3 months now.  This vacuum is amazing!  Excellent vacuum and good price.  after ordering and returning a \$ 519 Dyson Animal vacuum cleaner  except that hair never gets in the dust bin  This vacuum cleaner seemed so great at first.  until it quit working.</p>
SumBasic	<p>Uggh. Cleans great  but it's heavy and hard to push, especially on large area rugs  that have a solid backing. It seems to suck down  and be difficult to move. EVER! I have not yet tried the company for help so  but plan to try soon.  I'm very disappointed.  This vacuum cleaner seemed so great at first.  It's very light and compact.  It has good suction  for cleaning hard floors,  which is mostly  what I'm interested in. The way the attachments work is very clever and efficient.</p>
LexRank	<p>NOW only seven months after I bought it the brush doesn't turn anymore  so is no longer any good for the carpet.  I tried cleaning the brush,  However, one day recently the brush roll button wouldn't turn on the brush roll.  The brush needs to be cleaned out almost every time  It has good suction  I also like the way you can easily turn on or off the brush roller  but it's heavy and hard to push, especially on large area rugs  the brush roller would not turn on anymore.  for cleaning hard floors,</p>
Opinosis	<p>however, one day recently the brush roll button wouldn't turn on the brush roll.  i bought it doesn't turn anymore so is no longer any good for the carpet.  we registered it late and still haven't gotten a warranty card in and the mail.  this vacuum cleaner seemed so great at first.  however, it can't spin anything after second use.  the hosehandle attachment is great for getting to hard to reach places.  i haven't been able to vacuum for two weeks.  the dust bin spins dirt around for my first use.</p>

Table 15: System outputs for a product in the *Vacuums* domain.