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personalized travel planning; personalization of public transport

Jörn SCHLINGENSIEPEN*
Technische Hochschule Ingolstadt
PO Box 21 04 54, 85019 Ingolstadt, Germany
Gudrun STOCKMANNS, Edwin NAROSKA, Oliver CHRISTEN, Tobias BOLTEN
Niederrhein University of Applied Sciences
Reinarzstr. 49, 47805 Krefeld, Germany
**Corresponding author*. E-mail: joern@schlingensiepen.com

PERSONAL SMART TRAVEL AGENT FOR EMPOWERING PERSONS WITH DISABILITIES USING PUBLIC TRANSPORT

Summary. Today's public transport is not easy to use by people having mental problems or those who are disabled. Traffic planning today is powered by online time tables calculating the optimal way to use public transport in terms of time and costs. Therefore usually a graph representing the public transport network is set up and algorithms taken from graph theory or operations research are used to find optimal routes. This is not suitable for a group of travellers having constraints in using vehicles, vehicle types or particular stations for health reasons. On the other hand, since most of those people are not able to drive a car on their own, making public transport available and moreover easily usable enable these people to improve their mobility and their quality of life in general. This paper shows an approach developed within the mobile project funded by The German Federal Ministry of economy and energy that allows supporting this group of users during a travel using public transport and undertaking personal constraints in route planning. This allows getting personalized advice during travel and while travel planning. This is implemented by generation of a second graph representing the public transport network not in dimension of time and costs but in preferences and dislike of a given traveller. The second graph is an overlay to the standard graph to get a personalized graph that allows finding a suitable route respecting the constraints of the user.

OSOBISTE INTELIGENTNE AGENCJE PODRÓŻY UMOŻLIWIAJĄCE OSOBOM NIEPEŁNOSPRAWNYM KORZYSTANIE Z TRANSPORTU PUBLICZNEGO

Streszczenie. Dzisiejszy transport publiczny nie jest łatwy w użyciu dla osób z chorobami umysłowymi czy niepełnosprawnych. Obecnie planowanie ruchu jest wspomagane przez narzędzia internetowe obliczania optymalnego sposobu korzystania z transportu publicznego pod względem czasu i kosztów. Dlatego też zazwyczaj wykres, przedstawiający sieć transportu publicznego, jest stworzony na podstawie algorytmów zaczerpniętych z teorii grafów i badań operacyjnych wykorzystywanych w celu znalezienia optymalnych tras. Takie postępowanie nie jest odpowiednie dla grup turystów, mających z powodów zdrowotnych ograniczenia związane z użyciem określonych typów pojazdów czy stacji. Ponieważ większość z tych osób nie jest w stanie prowadzić samochodu osobiście, udostępnienie transportu publicznego oraz ułatwienia w jego korzystaniu pozwoliłoby nie tylko na poprawę mobilności osób niepełnosprawnych, ale także podniesienie jakości ich życia. W artykule przedstawiono podejście wypracowane w ramach projektu, a mobilności finansowanego przez niemieckie Federalne Ministerstwo Gospodarki i Energetyki, który pozwala na wsparcie tej grupy użytkowników podczas podróży środkami transportu publicznego oraz uwzględnia ich osobiste ograniczenia podczas planowania trasy. Pozwala to na uzyskanie indywidualnych porad zarówno w czasie planowania, jak i samej podróży. Zostało to wprowadzone na podstawie drugiego wykresu reprezentującego sieć transportu publicznego nie w wymiarze czasu i kosztów, lecz w preferencji i niechęci danego podróżnika. Drugi wykres jest nakładką do standardowego wykresu, który pozwala uzyskać indywidualny wykres umożliwiający znalezienie odpowiedniej trasy, mając na celu ograniczenia danego użytkownika.

1. INTRODUCTION

About 28 million people use the public passenger transport in Germany daily, this shows the good acceptance of a well meshed traffic system. The Verkehrsverbund Rhein-Ruhr (VRR) is the public transport association covering the area of the Rhine-Ruhr conurbation in Germany. It was founded on 1 January 1980, and is Europe's largest body of such kind, covering an area of some 5,000 km² with more than seven million inhabitants, spanning as far as Dorsten in the north, Dortmund in the east, Langenfeld in the south, and Mönchengladbach and the Dutch border in the west [1].

Since this infrastructure is already established it is a good investment to open this service for people which are not able to use it today. And the dense mesh provided by the companies running VRR is the perfect environment to do so.

2. PROJECT MOBILE

In order to reach the goals of the UN-Convention on the Rights of Persons with Disabilities [2] the German Federal Ministry of economy and energy (BMWi) has started the initiative from door to door, a mobility initiative for the public passenger transport of the future, for this group [3]. Within this initiative, a set of projects were started that address different aspects of public transportation.

The goal of the project mobile is to provide disabled people with means that support them during traveling in public transport systems [4, 5]. Especially, the local transportation system is addressed where a mixture of different transportation means (e.g., bus or tram) are used. As a result, a major problem is to support people while changing vehicles.

During the first assessments within the project, it appeared that a major problem of the people is lack of information and a proper handling of uncertainty. As a result, the goals of the project are to:

- provide the traveller with routes that meet their individual capabilities, restrictions, needs and preferences; this covers a wide range of issues like avoiding overcrowded buses, inability to use stairs, inabilities to use complex bus stations, etc.;
- provide travellers with timely information about their current schedule (what happens next, when to leave the vehicle, how much time is left until the connecting vehicle arrives, etc.);
- help people locating themselves, especially with respect to bus stations or other locations important for the current journey; this especially addresses identifying the right bus station on the appropriate side of the street or within a complex bus terminal station;
- identifying transportation vehicles in order to decide whether or not to enter a vehicle; this must be done in a way so that the traveller is sure that he enters the right bus or tram;
- inform people when to prepare and when to leave vehicle during a trip;
- identifying stressful situations to the traveller and calming down people when needed.

This findings lead to three problems to solve: (i) The actual advice generated by the system must be customizable to match the individual needs of the traveller and (ii) presentation and interaction with the system must be adaptable to user's capabilities. In order to provide the user with appropriate and timely advices and information the system needs (iii) to know very precisely where the user is. All problems are addressed in project mobile e.g. by indoor-navigation [9, 10] or personalized user interface design [11-13].

3. SUPPORT DURING TRAVEL

To support users during their travel, several systems that provide personalized advice to the user were developed.

3.1. Station and vehicle localization

Most navigation applications use GPS to locate the user. The disadvantage of GPS is that it is not suitable in many situations in the public transportation system, such as subway stops or stations. But even in a normal street environment the GPS signal is hampered through urban canyons and therefore it often happens that the user is not localized accurately enough.

In order to improve the GPS based localization, various approaches has been developed, like e.g. assisted GPS (AGPS) or combination of Wireless LAN with GPS as exploited by Android and discussed in several papers (e.g. [18]). While this improves the localization quality in many cases, our experiments showed still an insufficient performance. For example, in our tests with different smartphones GPS/AGPS based localization often located the user on the wrong side of a street. Unfortunately, to determine whether the user is at the right bus stop, at the right street side, is a very important localization task. Finally, GPS and WLAN based solutions [14, 15] are not sufficient to reliably help people navigating indoors as localization must work reliable within complex and highly dynamic environments.

To support the localization in such situations: stops, vehicles and optionally other important landmarks are equipped with Bluetooth beacons. These small battery-powered devices are continuously sending advertisement packets with a unique ID via Bluetooth low energy. The user end device receives the IDs and the signal strength of the beacons and can determine their own position.

The same approach is used to find the correct transportation vehicle by equipping buses and trams with these beacons. In addition, beacons are connected to the Integrated On-Board Information System and read the current line number and direction of the vehicle in order to generate a unique ID number. As a result, the ID can also encode the route and the current position of the vehicle. Moreover, this information can be exploited by the user while traveling with the bus in order to know when to leave the vehicle. As a result, a passenger can get an overview of current trip progress even if the vehicle is not equipped with displays or the user is in a bad sitting position to see them.

RFID technology has become a major innovation driver [16, 17] and many of the shelf modules are available and ready to be integrated into devices. Hence, stops and vehicles are also equipped with RFID tags to identify them. Due to the short distance interaction that is necessary here, there is a higher level of security particularly for uncertain passengers. To this end, a passive RFID tag is attached right next to the entrance door of a bus. The user can use a NFC equipped smartphone to read out the tag. The navigation system then checks whether the tag belongs to the right bus and informs the user whether or not to enter the bus. In addition, a special bracelet (see figure 1) can be used that is equipped with a RFID reader: by touching the special "localization plate" attached to the bus, the bracelet identifies the tag and informs the user how to proceed by green and red lighting. This scenario is shown in Figure 1. More information about the bracelet is provided in the next section.

In addition, bus stops are also equipped with these type of RFID tags so that the user can easily identify the right bus stop.

3.2. Wearable Gadget

In addition to the navigation application on a smartphone or tablet the user of the system can get the latest information for his trip (e.g. when to leave the vehicle) through a "wearable gadget" in form of a self-manufactured portable bracelet. The developed bracelet has a display and an LED array to display various information and also an RFID reader.

This own development has proved to be necessary for the target group of mentally limited users. For example, smart watches have been found as too complicated to use for the clientele. In addition, most displays of current smart watches are difficult or impossible to read under direct sunlight. The developed wearable gadget allows the display of simple signs and light signals, which are easy to read even in strong sunlight. In addition, the user can be alerted by a vibration. A first prototype of the bracelet we used to experiment with the signaling functionality is shown in figure 1. We used colored LED strips in order to test different signaling methods like using red, green or yellow colors in combination with animation or flashing sequences.

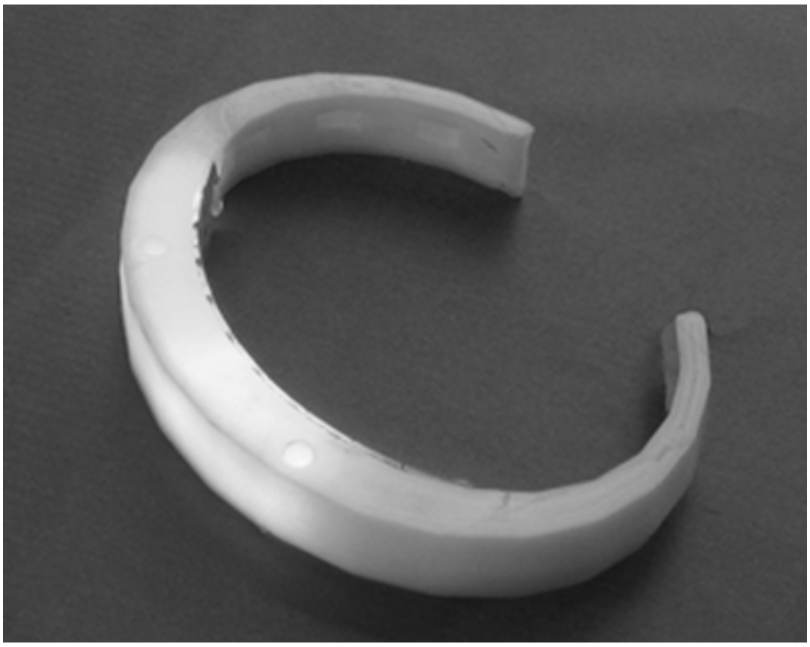

Fig. 1. Bracelet including RFID-Reader and Bluetooth connection to Smartphone
Rys. 1. Bransoletka wyposażona w czytnik RFID oraz Bluetooth w celu połączenia ze smartfonem

The integration of the RFID reader allows a contactless identification and validation of stops and transport vehicles over short distances. Currently, apart from our gadget, there is no other smart watch with an RFID function with the appropriate range available. The advantage of this technology is that stops and vehicles only have to be equipped with low-cost, low-maintenance passive tags.

Due to the high energy demand of the high-luminosity LED display and the RFID reader special attention was given to the energy-efficient use of these technologies in the development. For example, the RFID reader is only enabled when the system has already recognized that the user is close to a possible stop (e.g., by using Bluetooth beacons) and an appropriate hand gesture was detected by a position sensor.

The developed "wearable gadget" is coupled for data transfer via Bluetooth Low Energy using a smartphone or tablet.

3.3. Augmented Reality

As in a Mobile, a user friendly interface is needed that can be tailored to the specific needs of our target groups, including mentally handicapped people. Augmented reality based solution play a significant role here, because information can be visually connected with the appropriate object it is connected to. At the moment we are implementing a user interface that directly overlays a camera's view with relevant information as shown in the mock-up picture in figure 2.

Fig. 2. Augmented Reality mock up highlighting proper bus station in the city of Krefeld
Rys. 2. Rozwiązanie mobilne podkreślające właściwy dworzec autobusowy w mieście Krefeld

As can be seen on figure 2, when pointing with the smartphone camera to the bus stop sign, information about the bus stop (right or wrong one) as well as data, such as estimated arrival time is shown on the camera preview. As a result, the traveller can easily use the smartphone to search the environment for relevant objects like e.g. transport vehicles or bus stops.

While this approach is suitable for many people, a physically impaired traveller may not be capable of using a smartphone as an “environmental browser”. Some people from our target group do not have the ability to hold a smartphone in an arbitrary angle or even do not have one or two free hands to hold a smartphone at all. Hence, we are also integrating smart glasses into our solution, where the information is directly displayed into the traveller’s field of view.

Our first tests with mock-ups of the AR based user interfaces show a good acceptance of this technology by our target group. Many of the people from our test group are young and hence are willing and curious to use devices such as smart glasses or smart phones.

4. PERSONALIZED ADVICES AND TRAVEL PLANNING

An important component in the mobile infrastructure is the back-end system that generates personalized advices based on the current traffic situation and road maps.

The people within the target groups that are addressed in this projects differ significantly with respect to their capabilities and needs. In general two major groups are addressed: people with mental problems and people with physical disabilities.

The group of mentally restricted people suffer from a wide range of problems that start from intellectual restrictions like illiteracy or in-capabilities of dealing with concepts of time. These people need a strong support and a user interface that especially addresses their deficiencies. For example, speech output or simple graphical symbols must be used if the traveller cannot read. On the other hand, there are also people that e.g. are capable of using a smart-phone without any problems but may be easily distracted. As a result, special means are needed to draw their attention towards the current travel related issues.

For the group of physically disabled people, we especially address temporary restrictions (e.g. caused by the surgery). For these cases, people that usually travel by their own car are temporarily forced to use public transport and often suffer from a lack of knowledge and training how to use public transportation. As a result, information about where to reach the next bus station, which vehicle to enter and when to leave are the major aspects that are to be addressed.

4.1. Characteristics

To allow describing the characteristics of infrastructure and users an attribution system was developed. There are five types of entities that can be described by attributes, while the attribute value may vary depending on the time of day, the day of week or holidays:

- **Users** have different needs and preferences that can be expressed by attributes assigned to this user. We call this image of a user inside the system personal avatar. Users have Tolerance settings describing the user's tolerance to route changes, idle time along the trip, crowded areas, noisy surroundings and visual contact with other people. Movement settings describing the user's motoric capabilities, which includes the walking speed and endurance as well as the ability to take steps, use escalators or elevators. This includes also the demand of the user to get a free seat or special places at stations or within transport vehicles.
- **Vehicle types** have different attributes describing the way a special type of vehicle can be used, e.g. a low floor bus can be used by wheelchair users, while a common bus cannot be used. So the most important attribute of vehicle type are height, width, steps and existence of special places.
- **Vehicles** have different attributes describing the way a particular vehicle can be used. Some buses may have identification support, while others do not. In this case users that are reliant on a vehicle identification support are not able to use this vehicle.
- **Stations** are the nodes in the network having different attributes describing the way they can be used for start and end of travel or during changing vehicles. In terms of personalized route planning the most important attributes describing a station are steps, daylight, security and load. The existence of steps without an elevator makes a station unusable for wheel chair users. Daylight and load has to be added to cover needs of users having mental problems and may panic in crowded stations or vehicles or on using an under-bridge. Load attribute dependents on time of use. Since most of the users in our target group are defenceless the attribute security became very important during travel planning.
- **Links** between the nodes are the traffic lines used by the user during traveling a calculated route. In terms of personalized route planning the most important attributes describing a link are the load, security, costs and speed. While costs and speed are usual attributes in route planning, the load and security has to be added to meet user's requirements (see above).

To allow easier management of attribution of entities a class system was developed. The system consists of:

- **Persona** describing a stereotypical user which is similar to real passengers [6] and are constructed with different behaviours, profiles and objectives. A persona does not correspond to a real person, but represents a typical user, which is composed of different features and behaviour. Inside the system every user is composed of the different behaviours of persona, where specific needs overwrite the attributes of the assigned persona.
- **Infrastructure Elements** are all elements in the public transport system, like Vehicles, Vehicle Type, Lines, Links, Stations, etc. Those elements provide facility for given needs, therefore the Infrastructure Elements are designed as a complement to Persona.
- **Classes** of Persona or Infrastructure Elements incorporate entities with similar attributes, this allows easy management of descriptions by implementing classes of stations (main station, hub, terminal, etc.) or disease patterns.

4.2. Dimensions and Penalty

To allow a comparison of routes and finding a suitable route for a user a penalty system was developed to overlay the speed and cost optimal routes with the needs of the user. To calculate this weighted route efforts each infrastructure element used in a route is loaded by a user specific penalty summand (e.g. stations) or a user specific penalty factor (e.g. links, vehicle use). In reality not all attributes for stations and users are available at run time since the data quality is very poor. Therefore we developed a system that allows flexible calculation based on the available information, therefore all attributes are normalized and ordered in dimensions. E.g. the need of a user for an elevator instead of stairs and the existence of an elevator in a station are the same dimension. Inside a dimension the attribute values are normalized, like shown in table 1.

The system to calculate this weights works in four steps:

- Determine the specific descriptions of user’s needs from Persona, Class of Persona and personal settings.
- Determine the specific description of possibly used infrastructure element.
- Calculate a penalty factors and summands on usage of each possibly used infrastructure element.
- Calculate the route efforts while using weighted speed and costs.

Table 1

Normalized values for attributes

Value	**User**	**Infrastructure Element**
-8	Try to avoid	Very hard to use
-4	Strong do not like	Hard to use
-2	Do not like	Inconvenient to use
0	No special need	No special service
2	Nice to have	Provide service
4	Recommended	Special facilities to provide
8	Strongly recommended	Perfect
1000	Hard need	-/-

Determination of the specific attributes and values for a user is done by collecting values for each dimension from the class system, by the following algorithm: Starting with personal record, if dimension attribute is set take it, go to next dimension, if attribute is not set go on with the record of the class this record is based on. Reaching the root class without getting an attribute means this dimension is not described for this user. Figure 3 show determination of attribute values.

Determination of the specific description of an infrastructure element follows the same algorithm using the records of infrastructure description.

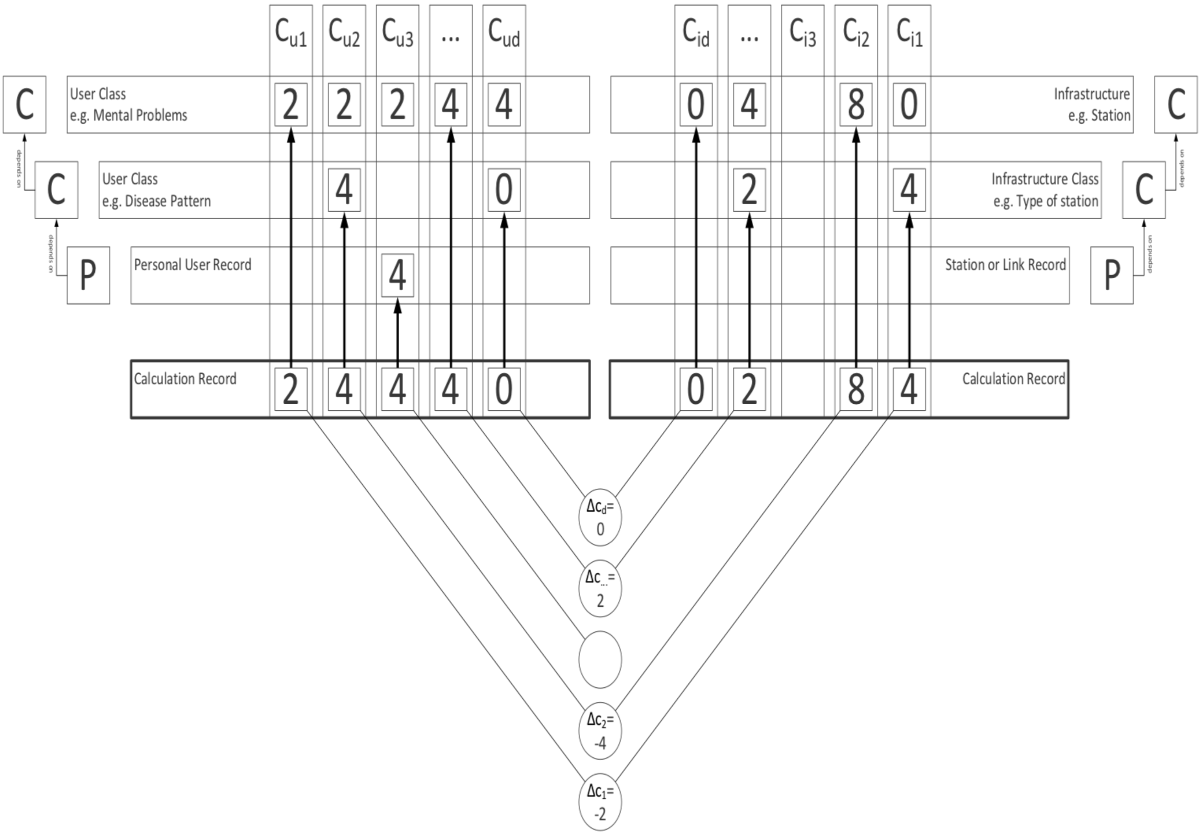

Fig. 3. Using class system to determine user and infrastructure element specific attributes

Rys. 3. Korzystanie z systemu klasy, w celu określenia konkretne atrybutów użytkownika oraz elementów infrastruktury

Calculation of penalty factor p_{ui} (User u uses infrastructure element i) for n determined dimensions is done by calculation of the normalized distance in R^n, as shown in eq. 1 the distance in dimension d (Δcd) is calculated by the difference of the user attribute in dimension d c_{ud} and the infrastructure attribute in this dimension c_{id}. The normalized weight factor is calculated by Pythagoras and normalized by division by maximal distance in the given dimension (see eq. 2).

$$\Delta c_d = c_{ud} - c_{id} \tag{1}$$

$$p_{ui} = \frac{|\Delta\vec{c}|}{|\Delta c_{\max}|} = \frac{\sqrt{\sum_{d=1}^{n} \Delta c_d^2}}{4\sqrt{n}} \tag{2}$$

Calculation of the route efforts is usually done by minimizing two aspects of speed (time consumption) and costs, where most route planers use travel time as a target dimension and add the cost as an informational aspect. In our use case we decided to use travel time as a target dimension as well.

This lead to the need to convert the penalty in time to get a value to minimize. Since we get penalty factors from the steps above, we can calculate a weighted travel time. Therefore, all time consuming usages of transport vehicles are multiplied with the specific penalty factor for this user and vehicle and the usage of static infrastructure elements like stations is considered by adding a summand that is calculated by multiplying the penalty factor with a user specific constant.

$$t_R = \sum_{x=1}^{m} t_{vx} + \sum_{x=1}^{0} t_{sx} \tag{3}$$

$$t_{uR} = \sum_{x=1}^{m} p_{ux} t_{vx} + \sum_{x=1}^{0} (t_{sx} + p_{ux} w_u) \tag{4}$$

Eq. 3 shows the calculation of time consumption for a route (t_R) as a sum of time using m vehicles (t_{vx}) and waiting/change vehicles at o stations (t_{sx}). Eq. 4 shows the calculation of user specific weighted time consumptions (t_{uR}) using calculated penalties (p_{ux}) and personal (user specific) weight factor (w_u). During route planning both has to be used since the planning of change vehicles has to be done with real travel time and not the weighted travel time.

5. CONCLUSIONS AND NEXT STEPS

By adding additional scales to route planning we can generate a user specific graph that can be used to generate user specific advice. By implementing mechanisms and technology to provide personalized support to the user during travel and travel planning we help to utilize public transport for disabled people allowing them to get more self-determination.

This approach may also help supporting elder people, which will become important considering the demographic change, and may be the next step toward to so called Smart Cities that provide smart and personalized services to inhabitants [7, 8]. The current approach needs one overlayed graph per user, which is not feasible, since the amount of data for the time table is very large. Our next step is optimizing the algorithm to allow separation of route planning and route evaluation to allow implementation for a wider user group. The test of the shown gadgets and user interfaces were promising so in the next step we plan to equip a wider range of vehicles to enhance the test bed.

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